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**Beyond survival: farming chronicles, outlook and strategies for Ukrainian agriculture following the
2022 Russian Invasion**

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Beyond survival: farming chronicles, outlook and strategies for Ukrainian agriculture following the 2022 Russian Invasion

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Throughout its history, Ukraine served as a “breadbasket” for the neighbour and more distant regions. In 1940-50s, after the devastating famine of 1932-33 and despite difficult relationship with the Soviet Government, it produced over 25% of the Soviet Union’s grains (Panchenko et al. 1996). In 1992, a year after Ukraine gained its state back, total production of wheat, corn, barley and rye amounted for 35.6 million (further, mil) tons and export for 1.2 mil tons. By 2020 the production doubled, and export increased 42.3 times (State Statistics Service of Ukraine, further, SSSU, 2022) – Ukraine has become one of the major players on the world agricultural market. In the last years, 10% of world wheat, 15% of corn and barley, and 50% of sunflower oil in global exports were from Ukraine (FAOSTAT 2022).

Abundance of black soils (27.8 mil hectares) and landscape characteristics that allow for higher yields and larger fields, play one of the key roles in the development of agricultural production. Around 80% of the total utilized agricultural area (further, UAA) in Ukraine are used for cultivation of cereals, oilseeds, vegetables and other annual crops (WBD 2021, SSSU 2020a). In 2021, agriculture contributed almost 10% to the country’s GDP, around 18% to employment, and 44% to its export value.

On February 24, 2022, only four days after the Winter Olympics in Beijing, where 91 countries including RF and Belarus celebrated peace and human dignity, Ukraine was covered with missile attacks from the territories of these two countries. Today, more than 5 months past the RF’s invasion, dozens of Ukrainian cities, towns and villages, hundreds of cultural heritage and infrastructure objects are destroyed. The offense puts Ukrainian agriculture at risk. Airstrikes, occupation and active military battles are serious threats to the sowing and harvesting campaigns; severe input supply and logistics complications threaten to tremendously curb the agricultural production.

The current study aims at highlighting economic and developmental losses of agricultural sector of Ukraine from the war, analyzing the scenarios for agricultural markets development, and providing the potential options for tackling the consequences of the crisis.

1. Agricultural production and policy chronicles: rocky road from planned to market economy

1991-1994

Soviet Union left Ukraine the heritage of state monopoly on land and state regulation of the economy. One of the milestones in development of the agricultural sector was land reform. The Land Code of Ukraine of March 13, 1992, allowed transferring property rights on agricultural land (except some land in a state land reserve) from the state and collective enterprises, i.e., “kolhospy” and “radhospy”, to the collective ownership of their transformed peers – collective agricultural enterprises (CAEs). To strengthen the status of CAE members as co-owners of the collective property, the privatization of the CAEs’ agricultural land began in 1994. Each CAE member was given the right to manage and own an allotment of land of 3.6 hectares (further, ha) on average. As a result, 6.9 mil rural residents (about 16% of total population) — members of about 11 thousand (further, thsd) CAEs — received more than 27 mil ha of agricultural land (about 45% of the total territory of Ukraine) in private ownership. By 1994 more than 32 thsd of private farming entrepreneurs emerged.

State regulation of the economy, and of the agricultural sector continued until 1995. The Government controlled the supply channels, performed stock interventions, and capped the prices for agri-food commodities at around 10% of the respective world market prices. Export quotas disincentivized exporting. With the break of 1993

macroeconomic crisis, when the inflation reached 4700% and production factor prices sky-rocketed, production of agri-food commodities, especially of livestock, severely dropped (see Agricultural production 1991-2021 section). As the rest of the sectors stagnated as well, more people were attracted to engage into agricultural production activities within their own rural households. Consequently, the latter became the taskforce of agricultural production (KSE 2021, Kvasha et al. 2021).

1995-1998

Since 1995, the Ukrainian government worked on reducing fiscal deficit, financing the reforms with monetary expansion, cancelation of export quotas and privatization of public food processing plants. Neither the cancellation of the quotas nor the privatization of plants provided with the desired levels of liberalization and efficiency. Instead of the quotas, minimum export prices were introduced, and major food production enterprises were excluded from the privatization. These left Ukrainian grains and oilseeds producers with around 40% of export FOB price and inability to pay for the production factors. Consequently, by 1999 production by the agricultural enterprises dropped to 50% of the pre-independence level. Rural households continued providing the population with most of the food items.

In 1998, the crisis which originated in South-East Asia, RF and Latin America, uncovered major disbalances in the Ukrainian economy which led to the financial distress in the country: Ukrainian national currency (further, UAH) fell by 100% against the US dollar (further, USD). This, however, produced one positive effect: urge for more efficient reforms (Kvasha et al. 2021).

1999-2000

In 1999, after the end of the crisis, land ownership and the scheme of agricultural production factors purchase were changed, and tax benefits for agricultural producers provided. CAEs turned into private individual farms, corporate enterprises, limited liability companies and private enterprises. Consequently, agricultural land became predominantly private. Out of 42.7 mil ha of it (or about 71% of Ukraine's territory), 32 mil ha comprised private ownership, 10.5 mil ha state ownership and only about 30 thsd ha were in communal ownership. Further, from now on, agricultural production factors were delivered upon immediate payment, which resolved the issue of producers' debts to the suppliers.

An important role in boosting agricultural production played tax benefits. They were accumulated from the so-called single tax of the simplified taxation system (further, STS) and a special value-added tax (further, VAT) regime. Until 2013, STS replaced about twelve other taxes and fees. Special VAT regime implied the right to withhold VAT received and reimburse it onto the production factors. These tax benefits left agriculture essentially tax-free. They implicitly provided more support to more productive and often larger agricultural producers, and thus supported large-scale agriculture.

Such decisions caused considerable optimism in Ukrainian agriculture. In 2000, as compared to the previous years, a lot more investments into the sector were made. In 2000 and 2001, for the first time since 1995, net profits of agricultural enterprises were positive, and agricultural exports doubled. Both in agriculture and food industry, employment began to fall, and wages to rise (Kvasha et al. 2021).

2001-2013

Bad harvests of 2000 and 2003, and at times occurring unfavorable conditions at the world and domestic markets, motivated the Ukrainian Government to take a few steps away from liberalization. The new policy measures included certification of grains exported, mandatory crop insurance, capping of consumer prices for bread, minimum prices for sugar, wheat-price pledging, 23% (later 17%) export tax on sunflower seeds and abolishment of VAT compensation for commodities exported. Although agricultural land could now be private, only managing and owning it applied. Selling the land was strictly prohibited, and the only legal way to assemble a larger plot was

renting. In response to the tightening control, in 2011, the agricultural producers reached an agreement with the Government that each year their total exports of grains and oilseeds would not exceed 80% of the expected harvest (Kvasha et al. 2021).

Despite fluctuations in market and export controls, Ukraine has signed bi- and multilateral trade agreements since 1995. The first free trade agreements (further, FTAs) were with Turkmenistan (1995)¹, Georgia (1996)² and Azerbaijan (1996)³. FTA with the Republic of Northern Macedonia entered into force on July 5, 2001⁴.

Following the Orange Revolution of 2004, which was caused by the brutal faking of Presidential elections results, Ukraine fulfilled the World Trade Organization's (further, WTO) membership conditions, and in 2005 became its member. Import tariffs on non-sensitive foodstuffs and agricultural products as well as many specific tariffs were reduced, and Most-Favored Nations (further, MFN) tariff regime and many other tariffs unified. The country continued concluding the FTAs, and in 2012-2013 signed with the EFTA states (Iceland, Liechtenstein, Norway and Switzerland)⁵ and with Montenegro⁶. The CIS FTA among Armenia, Belarus, Kazakhstan, Kyrgyz Republic, Tajikistan, Uzbekistan, Moldova, and the RF became effective in 2012 as well⁷. However, as of January 1, 2016, RF and Ukraine suspended the FTA with respect to each other.

2014-2021

Starting from 2014, the reforms in agriculture of Ukraine were driven by the agenda of Association Agreement (further, AA) with European Union (further, EU). The AA entails a comprehensive program of market and institutional reforms, whereas its trade component, Deep and Comprehensive Free Trade Area (further, DCFTA), defines the stages of trade liberalization and institutional convergence between EU and Ukraine. The AA was initiated in March 2012, and it had to be concluded at the EU summit in Vilnius in November 2013. Contrary to the expectations, the former (currently, in exile) President of Ukraine, Viktor Yanukovich, refused to sign the AA at the very day of the summit. This caused the uprising of the Revolution of Dignity and fleeing of Mr. Yanukovich and his peers to RF. Shortly after, RF annexed the Crimean Peninsula and started a hybrid war in the east of Donbas region. Overcoming various obstacles, the AA was signed by the new Government, and entered into force on September 1, 2017.

Following the DCFTA, Ukraine began the introduction of the EU's technical requirements for food production, standardization, compliance assessment, surveillance, sanitary and phytosanitary measures. Tariff-free import quotas allowed the sector to benefit from increased exports to the EU. The reforming process has as well been enhanced by cooperation with the International Monetary Fund (further, IMF). Adoption of flexible exchange rate policy, inflation targeting policy, reforms in the banking sector and abolishing of special VAT regime played

¹ Agreement on Free Trade between the Government of Ukraine and the Government of Turkmenistan (1995), https://www.wto.org/english/thewto_e/acc_e/ukr_e/wtaccukr52_leg_22.pdf

² Agreement on Free Trade between the Government of the Republic of Georgia and the Government of Ukraine (1996), <https://www.worldtradelaw.net/document.php?id=fta/agreements/geoukrfta.pdf>

³ Agreement on Free Trade between the Government of Ukraine and the Government of the Republic of Azerbaijan (1996), <https://wits.worldbank.org/GPTAD/PDF/archive/Azerbaijan-Ukraine.pdf>

⁴ Agreement on Free Trade between the Republic of Macedonia and Ukraine (2001), <https://wits.worldbank.org/GPTAD/PDF/archive/FYROM%20-%20Ukraine.pdf>

⁵ Free Trade Agreement between the EFTA States and Ukraine (2012), <https://www.efta.int/sites/default/files/documents/legal-texts/free-trade-relations/ukraine/EFTA-Ukraine%20Free%20Trade%20Agreement.pdf>

⁶ The Agreement on free trade between the Government of Ukraine and the Government of Montenegro (2013), <https://mfa.gov.ua/en/about-ukraine/economic-cooperation/free-trade-agreements-fta>

⁷ CIS Free trade Agreement (2012), <https://mfa.gov.ua/en/about-ukraine/economic-cooperation/free-trade-agreements-fta>

significant role in the development of the agricultural sector (Kvasha et al. 2021 and Nykolyuk et al. 2021). In 2017 and 2019, Ukraine as well signed FTAs with Canada⁸ and State of Israel⁹.

The period after the Revolution of Dignity could be marked as very modest in terms of the land reform. With a launch of the national decentralization reform in 2014, about 1.68 mil ha of agricultural land were transferred from the state into a communal ownership. To increase the efficiency of land use, auctions for selling rental rights for state and communal land were introduced. Their mandatory character led to a significant increase in the land rental prices and local budget revenues. Furthermore, a minimum duration of seven years on lease contracts was introduced, thus dragging shorter term leases into informal arrangements. Transparency and access to information on land and related rights was somewhat improved by adopting the relevant normative base and infrastructure (KSE 2021).

The most common agricultural land transactions of that period included inheritance and emphyteusis (around 18% of the transactions), and long and short-term lease (around 76% of the transactions) (Nizalov et al. 2018). According to the statistical records, in 2018 the average rental price for a ha of agricultural land in Ukraine was around 50.2 EUR per year (USSGCC 2019, in current prices).

In 2019, after the presidential and parliamentary elections, the land reform got a new momentum. The land turnover law of March 31, 2020 established a design for the land sales market. The latter came in on July 1, 2021. Despite being a huge step towards market economy, some temporary exemptions were still in place. In particular, agricultural land of public property, foreign legal entities and individuals, as well as until July 2023, domestic legal entities, cannot participate in the land market. As of the time of writing this article, agricultural land may only be purchased by the citizens of Ukraine and up to the total acreage of 100 ha. From 2024 onwards, the possibility of land purchase will extend to 10 thsd ha for legal entities (as long as the beneficiaries are Ukrainian citizens that have no business abroad or offshore companies).

By the end of 2021, the total acreage of land in circulation amounted to 0.4% of the total agricultural land area. More than 60% of this land was purchased for commercial agricultural production and around 35% for individual peasant farming. The average sale price was 1100 USD, the average number of sales transactions per day 459, and the average size of the land parcel sold 2.4 ha (KSE 2022).

In the last decade, five main types of agricultural producers emerged in Ukraine: rural households, family farms, private and public agricultural enterprises and, the so-called, agricultural holdings (further, agroholdings). Rural households currently cultivate land parcels of around 1.3 ha. In 2019 their input to the total value (in current prices) of crop commodities was 30.1%, and of livestock commodities 48.7%. Family farms, public and private enterprises differ from each other by the type of ownership. Family farms are privately owned and run mainly by the family members (LoU 2003). The average size of a family farm is around 134 ha. Private agricultural enterprises are defined as enterprises whose main economic activity is agricultural production. Average acreage of land cultivated by such enterprises is around 1.2 thsd ha. Public enterprises are owned by the state. Along with rural households, private enterprises are the main contributors to gross agricultural output in Ukraine (Bogonos and Stepaniuk 2017, SSSU 2020b).

Agroholdings belong to a rather unique type of agricultural enterprises. They are organized around parent companies which control and manage dozens of subsidiary agricultural enterprises. Because such parent companies do not always own the subsidiary enterprises or their majority stocks, the term “holding” may be somewhat

⁸ Canada-Ukraine Free Trade Agreement (CUFTA) (2017), <https://www.international.gc.ca/trade-commerce/trade-agreements-accords-commerciaux/agr-acc/ukraine/index.aspx?lang=eng>

⁹ Free Trade Agreement between the Government of the State of Israel and the Cabinet of Ministers of Ukraine (2019), https://www.gov.il/BlobFolder/policy/isr-ukraine-fta/he/sahar-hutz_agreements_israel-ukraine-fta-en.pdf

misleading (Hermans et al., 2017). Agricultural land area cultivated by one such agroholding may range from around ten to more than 600 thsd ha (Horovetska et al., 2017).

Crops and livestock production 1991-2021

Since 1992, crops production has dominated Ukrainian agriculture. Although in 1991-2000, grains harvest and export fell, starting from 2001 they followed steadily increasing trends. Oilseeds production was on the move upwards since 1991. Production of wheat, barley, rye and oats demonstrate tremendous volatility which mainly results from their dependence on the weather. Starting from 2014, however, this volatility seems to decrease. One of the possible reasons – improvement of production technologies, i.e., improved access to fertilizers and use of more efficient machinery. Whereas production of wheat and maize continue growing, barley quantities seem to remain steady in the last ten years. Oats and rye production, supplied to the domestic market, decrease. Growth of maize production from 3.8 mil tons to 41.9 mil tons in 2000-2020 demonstrated the responsiveness of Ukrainian agricultural sector to export demand, quickly developing poultry sector and favorable for this crop climatic conditions.

Sunflower is the traditional oil crop for Ukraine. Its production has been increasing at high rate and steadily throughout the years. Starting from 2000, sunflower oil production and export stood on the way of rapid development as well. Rapeseed and soya beans, although currently occupy much smaller areas of agricultural land, follow rapid growth as well (Figure 1).

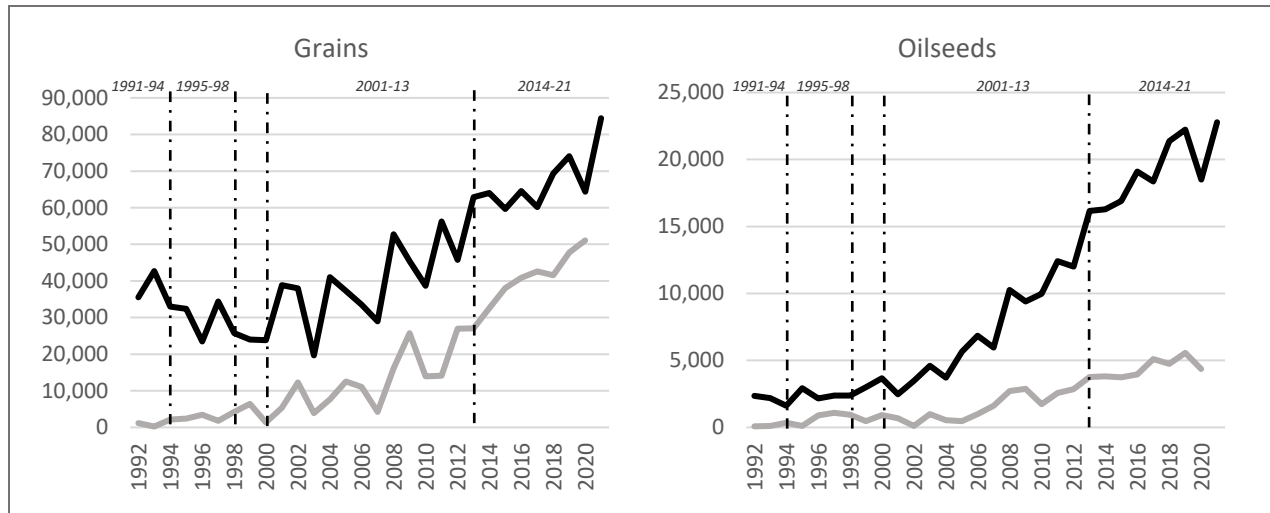


Figure 1 Production and export of grains, oilseeds and oils in Ukraine in 1992-2021, thsd tons

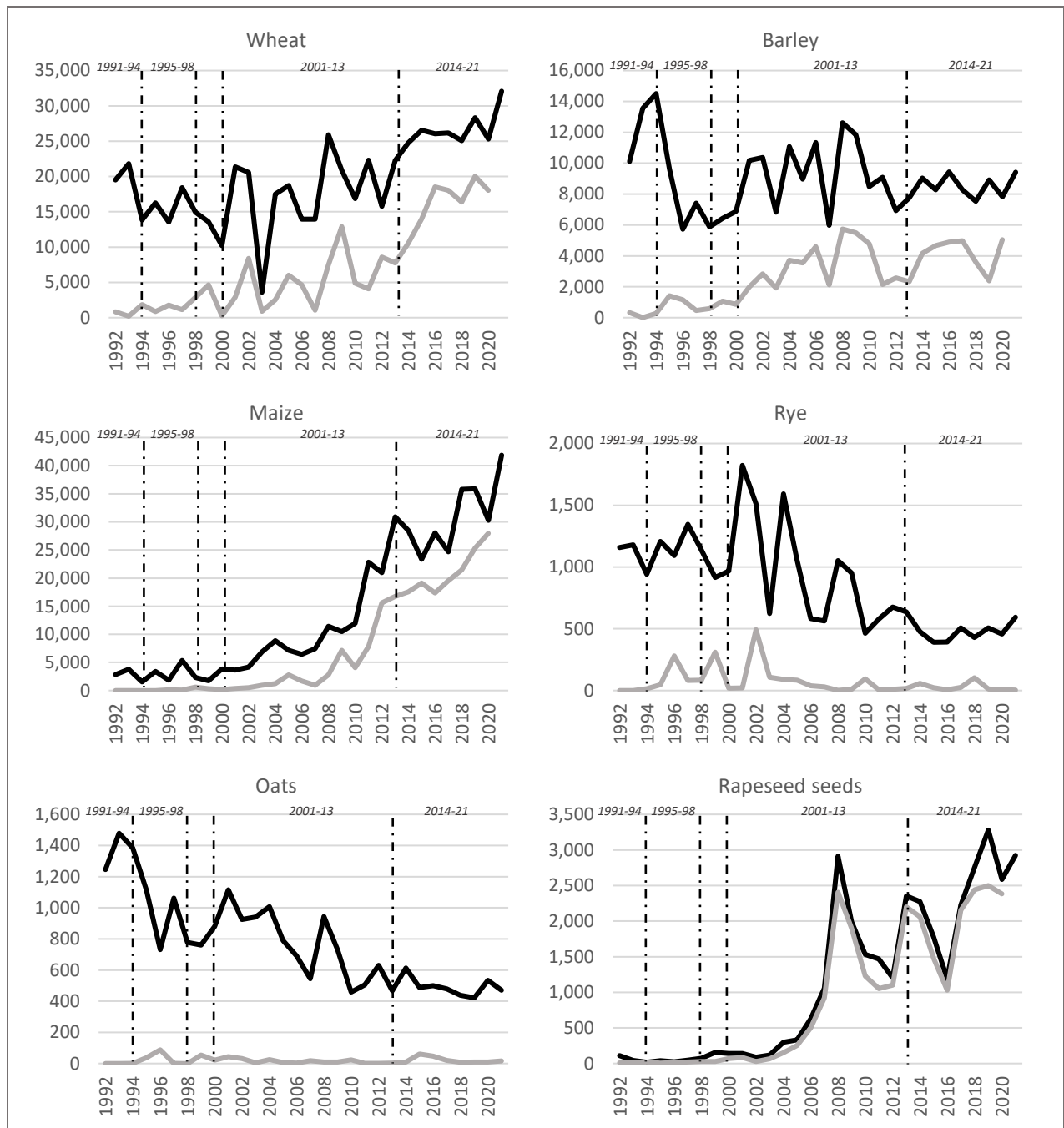


Figure 1 (cont.) Production and export of grains, oilseeds and oils in Ukraine in 1992-2021, thsd tons

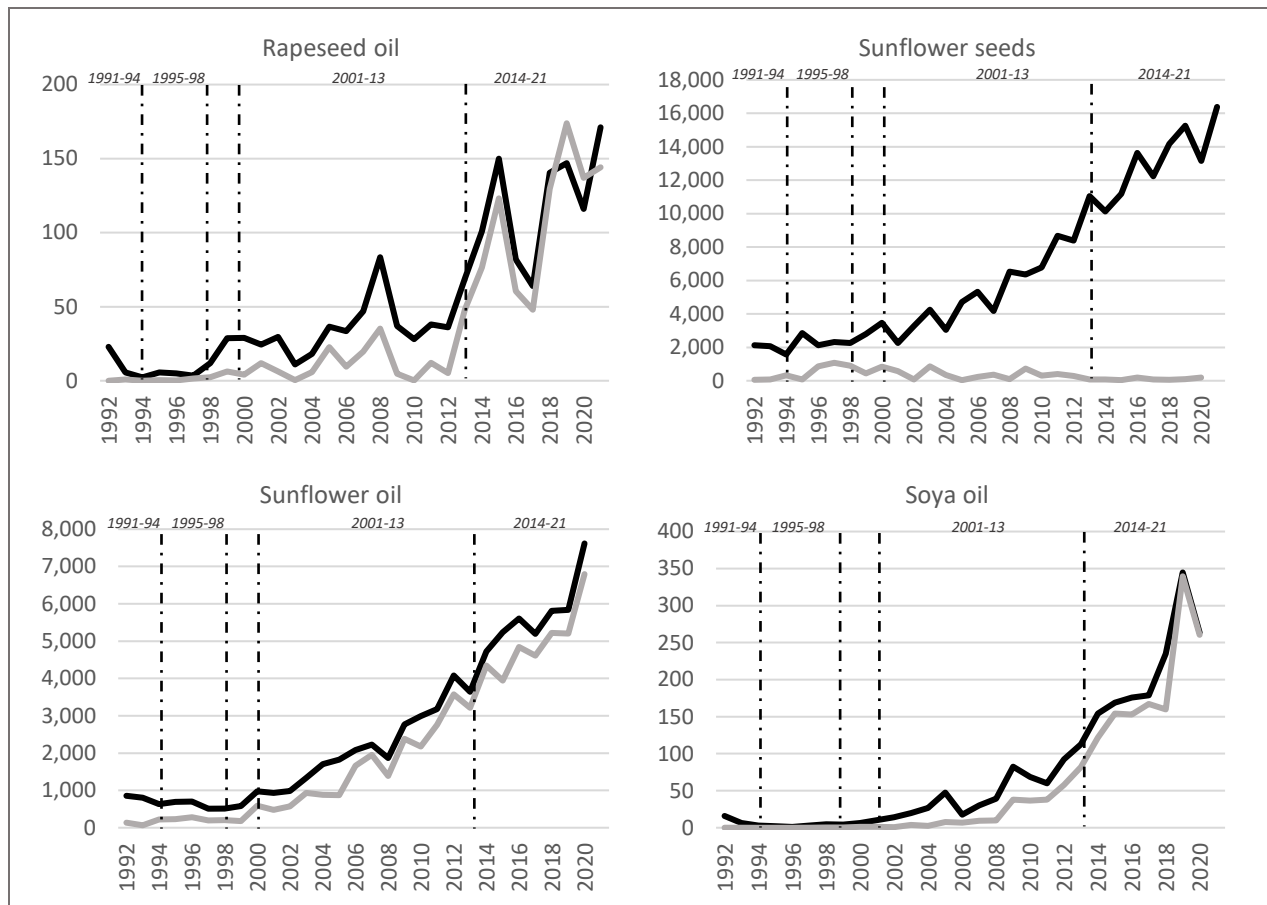


Figure 1 (cont.) Production and export of grains, oilseeds and oils in Ukraine in 1992-2021, thsd tons

Source SSSU 2021

In contrast to crops production, production of livestock commodities does not follow a positive trend. Steady reduction in cattle heads since 1992 led to the decrease in beef and veal and milk production. Most of the herd decline took place at the rural households. Although in 2010-2019 cattle slaughter weight increased from 203 to 229 kilograms (further, kg), the impact of herd decline was greater (SSSU 2020b, SSSU 2020c, SSSU 2011). Similarly, milk yield at the agricultural enterprises improved from 4.1 to 6.1 thsd kg per cow and year, and at the rural households from 3.9 to 4.6 thsd kg. Nevertheless, the decline in dairy cows had considerably stronger effect on the negative trend of milk production.

Swine sector in Ukraine is represented by two large groups of producers as well: rural households and agricultural enterprises. In 2019, the respective shares of swine reared by these producer groups were 43.5% and 56.5%. In 1991-2005 the herd decreased tremendously. Starting from 2006, however, the fall slowed down, and by 2021 reached 5.9 thsd heads. Increases in swine slaughter weight allowed to increase and, consequently, stabilize pig meat production at around 700 thsd tons (SSSU 2020b, SSSU 2020c, SSSU 2011). Numbers of sheep and goats as well as their total output (i.e., wool and milk) were declining steadily (SSSU 2020b, SSSU 2020c, SSSU 2011).

In 1991-1996, as the rest of livestock commodities, chicken meat and eggs production experienced major decline. Starting from 2000, however, production of both products resumed. Chicken meat production changed from 193 thsd tons in 2000 to 1596 thsd tons in 2021. Chicken eggs production experienced 123.9% growth in 2000-2013, and after the start of the war on the east of Ukraine in 2014, dropped by 28.2%. Agricultural enterprises take the lead in this sector. They produce around 89% of chicken meat and 56.1% of eggs. The remaining 11% and 44%, respectively, are produced by rural households (SSSU 2020c, Tarasevych 2020, SSSU 2020d).

Quantities of livestock commodities exported from and imported to Ukraine vary. 42.7 thsd tons of cattle meat were exported from, and 1.4 thousand tons imported to Ukraine in 2018. The changes in 2018 as compared to 2010 were, respectively, 221.1% and -43.13%. Quantities of pig meat exported and imported in 2018 were, respectively, 2.2 and 30 thsd tons. The growth rates from 2010 were, respectively, 584.7% and -67.7%. Meat production in Ukraine, despite decreasing and orienting mostly towards the domestic market, nevertheless has positive trade balance in terms of trade volume. Export of butter in 2018 was 28.7% of its total production, and import less than 1%, whereas export of cheese was 6.6% of its total production and import 10.9%.

Net trade of chicken meat and eggs grew rather considerably in 2010-2018. For chicken meat it turned from -96.8 to 213.4 thsd tons, and for eggs from 15.7 to 111.9 thsd tons (FAOSTAT, SSSU 2020b, SSSU 2020c, SSSU 2011).

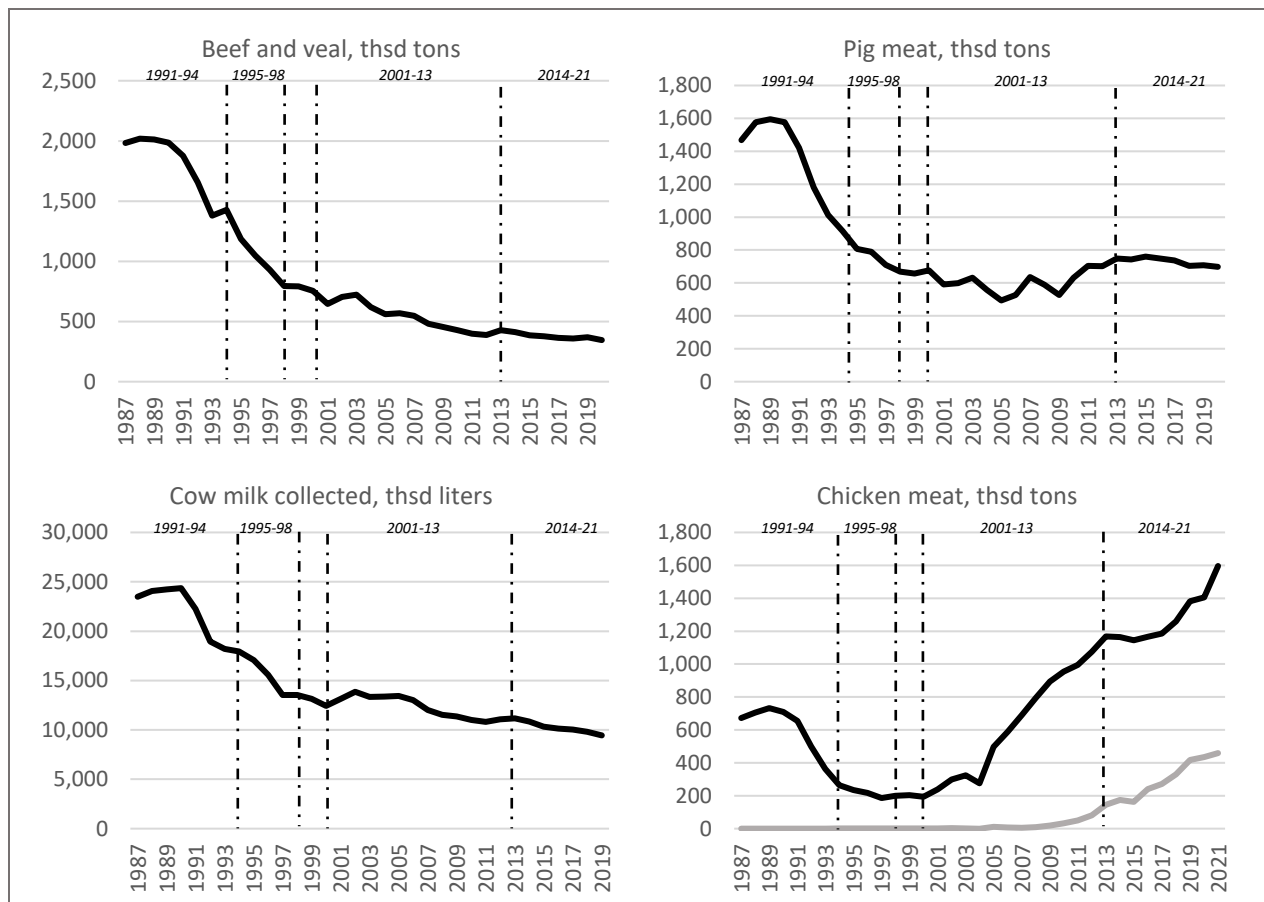


Figure 2 Production and export of livestock products in Ukraine until 2021

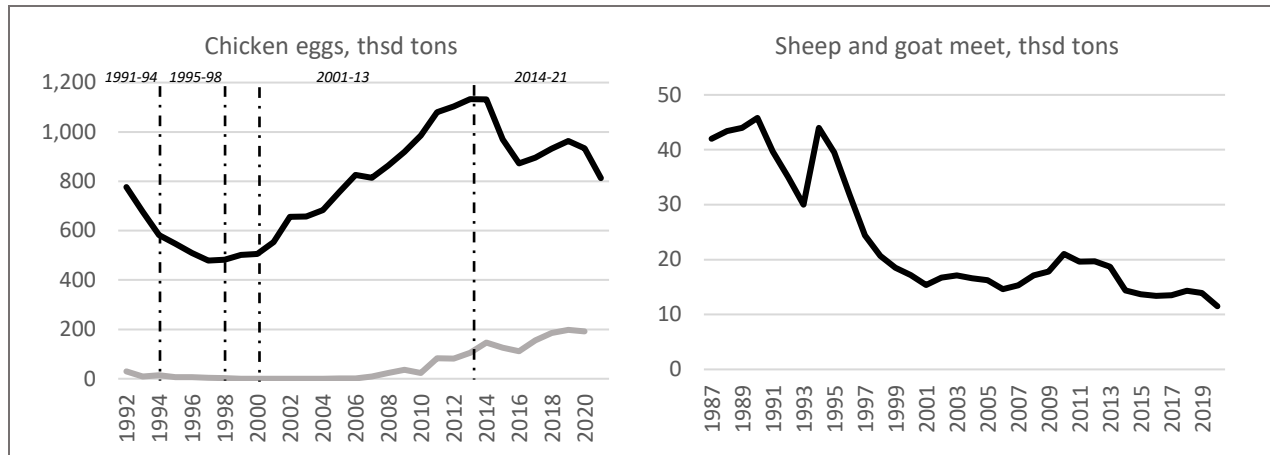


Figure 2 (cont.) Production and export of livestock products in Ukraine until 2021

Source SSSU 2021

2. Agricultural sector in the time of war

Damages and losses – data and methods

Full scale military assault by RF brought substantial damages and losses to Ukraine’s economy and its agricultural sector. To estimate the impacts on agriculture, the rapid damage assessment methodology of the World Bank and FAO is used. In the core of this approach lies comparison of the pre-disaster and post-disaster conditions, and distinction between damages and losses. Damages are defined as partial or total destruction of infrastructure and physical assets in terms of number of units and their monetary value. Losses are an estimate of the changes in economic flows arising from (i) the disruption of service delivery and availability/access to goods and services, (ii) disruption of governance and social processes and (iii) increased risks and vulnerabilities (WB 2017).

For assessing the damages, the agricultural sector’s assets and infrastructure are categorized in seven groups: machinery, storage facilities, livestock, perennial crops, fertilizers and fuel, stored harvest, farmland and unharvested winter crops. Their baseline quantities (number) and monetary values are calculated based on the 2020 data from SSSU, State Water Resources Agency of Ukraine and Ministry of Agrarian Policy and Food of Ukraine.

The degree of damage is estimated with regional coefficients (Table 1) which vary among the assets and infrastructure groups, are regional and rely on expert opinion. For damaged machinery, excluding tractors and trucks, storage facilities, livestock, and perennial crops, the coefficients depend on the severity of battles and occupation and increase linearly with time. One year of active fire is assumed to result in 100% damage. Therefore, daily increase of the damage corresponds to 0.274% from the baseline quantity (number). Since the coefficient is regional, if active fire take place on half of the region’s territory, the damage rate is halved as well. If the region is under occupation, the pace of increase in the damage is slower by 50%, i.e., 0.137%. The coefficients for tractors and trucks are 1.2 higher than for the rest of the machinery. These assets can potentially be used for military transportation and repair, and thus pose increased interest for being stolen by the occupants. For translating the damages into monetary values, the principle "build back better" is applied. It means that if the destruction covered more than 40% of an item, the latter cannot be repaired and must be replaced with the equivalent and cost-efficient option available on the market.

To estimate the coefficient for damaged and stolen fuel, assumption that the RF’s army uses all the fuel available in the regions they have control of is used. Assuming equal distribution of fuel in a region, the share of damaged

and stolen fuel is thus proportionate to the approximate percentage of the region occupied or at the peak of the fighting.

The coefficients for the shares of stolen grains, sunflower seeds, crop protection products and fertilizers follow the assumption that RF's army and RF's Government representatives benefit from selling and, where appropriate, using the stolen goods. However, it is further assumed that such activity starts only after at least one month of control of the territory.

The coefficients for damages related to unharvested winter crops and mining and destruction of agricultural land are defined as follows. In the previously occupied but then liberated regions of Kyiv, Sumy, Chernihiv, and Mykolaiv, the damages occurred at around 15% of the baseline sown area. In the regions which were occupied or suffered heavy fighting during the sowing season, i.e., the regions of Kharkiv and Zaporizhzhya, the damage affected 50% of areas sown with winter crops. And in Kherson, Donetsk, and Luhansk regions, the farmlands are assumed to be entirely inoperable. Furthermore, 10% of these lands need active demining, 33% need some recultivation and 3% substantial recultivation.

In the regions with little military activities and no prior occupation, the damages are assumed to be zero. Monetary values of the damages are estimated with 2021 market prices.

Table 1 Coefficients for estimation of damages in the affected regions of Ukraine by June 1 according to the assets and infrastructure groups, % of damage from the baseline quantity (number)

	Donetsk	Zaporizhzhya	Kyiv	Luhansk	Mykolayiv	Sumy	Kharkiv	Kherson	Chernihiv
Mining pollution of agricultural land	100	50	15	100	15	15	50	100	15
Recultivation of agricultural land	33.3	16.7	5	33.3	5	5	13.3	33.3	5
Unharvested winter crops	100	50	15	100	15	15	50	100	15
Agricultural machinery and equipment	26.6	13.3	10	26.6	5	10	13.3	13.3	10
Agricultural machinery – trucks and tractors	31.9	16	12	31.9	6	12	16	16	12
Storage facilities	26.6	13.3	5	26.6	5	5	13.3	13.3	5
Livestock	26.6	13.3	10	26.6	15	10	13.3	13.3	10
Perennial crops	100	50	15	100	15	15	50	100	15
Crop protection products and fertilizers	26.6	13.3	5	26.6	5	5	13.3	13.3	5
Fuel	100	66	40	100	33	80	50	100	80
Stored agricultural produce	26.6	21.5	0	26.6	0	0	13.3	26.6	0

Source Own estimation

For estimation of losses in agriculture the baseline quantities of crops and livestock production were set at the levels of 2021. Area-specific losses coefficients which were based on the expected severity of production decrease (according to data and experts' opinion) are then applied to these baseline quantities. Monetary values of the losses are estimated with 2021 market prices. For territories previously occupied/attacked and then liberated from the RF's army, i.e., Kyiv, Sumy, Chernihiv, and Mykolaiv regions, 15% decrease in annual crops and livestock production is used. It is based on the share of agricultural land under mining pollution. For regions that were occupied or under heavy fighting during the sowing season, we impose a loss coefficient that reflects the share of the occupied territories or share of the region with active fighting, i.e., 50% for Zaporizhzhya and Kharkiv regions and 100% for Kherson, Donetsk, and Luhansk regions. The loss coefficient for perennial crops reflects the damage coefficient for this category. We also assume that the yields would be 10% lower than in the baseline scenario. The productivity

decrease is expected primarily due to the logistics disruptions. Such disruptions are caused by fuel shortages and the inability to get the required spare parts for the machinery and other agricultural inputs in time. They result in suboptimal course of the sowing campaign, fertilization, and crop protection products application.

Damages and losses – results

According to the estimates, as of June 1, Ukrainian agriculture lost 4.3 billion (further, bil) USD of its assets and infrastructure – 15% of the total capital stock of the sector. The categories with the highest values of damages include unharvested winter crops (1.4 bil USD), machinery and equipment (926 mil USD), and stored agricultural produce (613 mil USD). Furthermore, the estimated 3.9 out of 60 mil tons of storage capacity could be at least partially damaged because of the war that translates into 272.4 mil USD. The estimated number of animals that died because of the RF's aggression is 42 thsd heads of sheep and goats, 92 thsd heads of cattle, 258 thsd pigs, and over 5,700 thsd heads of poultry. The value of this damage is 136.4 mil USD. More than 7.8 thsd ha of perennial crops located in the affected areas are partially or completely destroyed – 89.1 mil USD. Fertilizers and crop protection products are assumed not to be an element of high interest to the RF military and are mostly being lost due to physical damage. Fuel, however, is one of the primary subjects for looting. The expected rate of fuel stock being lost on the territories controlled by the RF's army is 100%. The value of fuel, plant protection products and fertilizers lost is around 119.6 mil USD.

Apart from the damages, Ukrainian agricultural producers suffered substantial losses (Table 2). Under the assumption that Ukrainian sea ports continue to be blocked by the RF's forces, the total economic losses are estimated at 23.3 bil USD. The most significant source of losses is not the decrease in production but the increased logistics costs and lower domestic market prices for export-oriented commodities that totals to 11.9 bil USD.

Before the RF's invasion, around 5-6 mil tons of agricultural commodities a month were exported by sea. This corresponded to at least 90% of agricultural exports. The naval blockade imposed by the RF halted maritime export. In the first three months of war Ukraine exported only 3.7 mil tons of agricultural products. As a result, Ukraine faced oversupply of agricultural commodities on the domestic market and drop of the respective producer prices by 33.7% (weighted average prices for key agricultural commodities in May 2022 compared to February 2022). If maritime export were restored, the domestic market prices would increase, and the losses be smaller.

Ukraine's production of the key export-commodities is expected to be lower as well. According to the NASA Harvest, Ukraine lost control over 22% of its agricultural land. The losses from decreased production due to smaller area and lower productivity are estimated at 9.6 bil USD.

Table 2 Losses in agriculture by June 1, mil USD

Item	Value of losses
<i>... due to production decrease</i>	
Wheat	2,027.6
Corn	1,296.2
Barley	564.3
Sunflower	2,427.3
Pome fruits	35.1
Stone fruits	98.1
Berries	89.2
Other crops	3,314.5
Cattle	63.7
Pigs	327.1
Sheep and goats	2.2
Poultry	41.3
Milk	0.3
Eggs (mil. pcs)	247.3
<i>... due to logistics disruption and lower prices for export-oriented commodities</i>	
Wheat	2,957.9

Corn	4,126.8
Barley	670.1
Sunflower	4,180.1
<i>... due to higher production prices</i>	
Fertilizer	378.9
Fuel	480.4
Total	23.3

Source Own estimation

Domestic food security – data and method

Another consequence of the war is that food security in Ukraine is challenged. The respective changes are estimated with Food affordability index (FAI). FAI is the ratio of average consumer income to the regional daily consumer prices for 21 critical food products in Ukraine weighted by the standard consumption pattern of each of these products. The food items are wheat bread, rye and rye-wheat bread, wheat flour, pasta of soft wheat, millet, buckwheat, oats, beef, pork, chicken meat, chicken eggs C1 category, milk pasteurized <2.6% fat, sour cream <15% fat, butter <72- 82.5% fat, sunflower oil, white sugar, cabbage, onion, beetroot, potato and carrot. The food consumption pattern is the recognized by the Government of Ukraine standard average consumption quantities of these food products. Price data are collected from SSSU. If for some observations price information is not available, weekly average price of food products using only the days for which food price information is available is applied. In case prices are missing for the entire region, the national average price for a given period is used. A region with no price information for at least one basic food item for at least one day in a week is considered having unstable physical food access.

A proxy for consumer income is salaries. In March-April 2022, Gradus and Kyiv School of Economics conducted a survey on changes in salaries as compared to the pre-war period. According to this study, average earnings of people who were employed before the invasion decreased to 10,155 UAH per month, or by over a third (34% decrease in average nominal earnings, including the unemployment benefits for those who lost their jobs) (Gradus 2022).

Domestic food security – results

Severe drop in nominal wages, weakened national currency and increased food prices reduced the affordability of basic food commodities in May 2022 by 38%. In other words, before the RF's war, FAI score was 12.4, implying that the person with an average salary could buy 12.4 months' worth of food products, and after the invasion the index dropped to 7.7. In June, FAI dropped further to -47.6% (Table 3). Dramatic increase in consumer prices is the main reason. Vegetables of the fresh harvest, such as onions, potatoes, beetroots and carrots, replace the last year's harvest and are considerably more expensive. In general, prices continue to grow due to UAH devaluation, increasing production costs and occupation of the agricultural commodities producing regions on the south of Ukraine.

Table 3 FAI and consumer price changes compared to the pre-war period, %

	FAI	Consumer prices
February 21-July 1	-47.6%	+25.7%
February 21-June 17	-40.5%	+10.6%
February 21-May 27	-38.5%	+7%
February 21-May 13	-37%	+4.4%
February 21-April 22	-37.9%	+5.8%

Source Own estimation

Although food shortages on the territories controlled by the Ukrainian Government are not expected, more sensitive population groups may need food support. The situation on the occupied territories is expected to be much worse, and provision of food aid to these people may give them a chance to survive.

3. Analysis of the future what-if scenarios

To assess the future perspectives of the Ukrainian agricultural sector and markets under different war-related scenarios, AGMEMOD model is applied. It is an econometric, dynamic, partial-equilibrium, multi-country, multi-market model. It covers all EU Members States, some non-EU countries, such as Ukraine, Balkan countries and Kazakhstan, and a stylized version of the rest of the world (RoW). The model provides annual projections until the year 2030 for markets of the main agricultural commodities. The markets are represented by equations for supply and demand, stocks, international trade and market prices. They reflect behavioral responses of economic agents to changes in prices and exogenous variables such as agricultural policy instruments, GDP, currency exchange rate, import tariffs etc. The equations' parameters are usually estimated as time series regressions. Following the partial equilibrium approach, commodity prices adjust to clear each commodity market. Lagged endogenous variables introduce (recursive) dynamic behavior when entered as determinants in the next period's equilibrium supply and/or demand (Nykolyuk et al. 2021).

Two scenarios are defined for the current study: Blocked exports (BE) and Open exports (E). Table 4 summarizes the assumptions for these scenarios.

Table 4 Scenarios description

Assumptions	Applies to crops (C), livestock (L)	Blocked export (BE)	Open export (E)
Level of export blockade	C	1.5 mil tons per month in total	entirely unblocked
Duration of war	C, L	2022-2023	
Reduction of grains area due to occupation and active fighting in 2022-2023	C	-13% from the 2021 grains area harvested in 2021	
Reduction of oilseeds area due to occupation and active fighting in 2022-2023	C	-20% from the 2021 oilseeds area harvested in 2021	
Increase in cost for fuel in 2022-2023 compared to 2021 (data of April 2022), %	C	+106.6	
Increase in costs for fertilizers in 2022-2023 compared to 2021 (data of April 2022), %	C	+20.4	
Factor of wheat, barley, rye and oats yield reduction due to limited availability of fuel and fertilizers in 2022-2023 (expert opinion), 100 kg/ha	C	-2.3	
Factor of maize yield reduction due to limited availability of fuel and fertilizers in 2022-2023 (expert opinion), 100 kg/ha	C	-5.1	
Factor of rapeseed yield reduction due to limited availability of fuel and fertilizers in 2022-2023 (expert opinion), 100 kg/ha	C	-9	
Factor of sunflower and soya beans yield reduction due to limited availability of fuel and fertilizers in 2022-2023 (expert opinion), 100 kg/ha	C	-7	
Domestic market prices in 2022	C L	Observed in June 2022, open sources data Observed in June 2022, producers' questionnaire	
Domestic market prices in 2023-2030	C, L	Defined by the model	
World market prices in 2022-2030	C, L	OECD-FAO Outlook 2022	
Crops storage assumption	C	Storage available	
GDP projections 2022-2030	C, L		

<p>IMF, April 2022</p> <p>SSSU projections</p> <p>Growth rate projected by USDA in 2021</p>		<p>2022-2023: - 35% compared to 2021</p> <p>2024: rebound by 12.5%</p> <p>2025-2030: +3.1% annually</p>
<p>GDP deflator</p> <p>As of July 2022, according to the National Bank of Ukraine</p> <p>According to the USDA 2021 projections</p>	C, L	<p>2022: 30</p> <p>2023-2030: +5% annual growth</p>
<p>UAH/USD currency exchange rate</p> <p>As of July 2022, according to the National Bank of Ukraine</p> <p>According to the USDA 2021 projections</p>	C, L	<p>2022-2023: 36.6</p> <p>2024-2030: +0.2% annual growth</p>
<p>Population</p> <p>Assuming 4 mil people left Ukraine considering 2021 USDA projections until 2030</p> <p>Return of all of the war refugees, according to 2021 USDA projections until 2030</p>	C, L	<p>2022-2023: -4 mil from the projected number</p> <p>2024-2030: according to the former projections</p>

Source Own elaboration

Areas sown in 2022 have been introduced into the model as data. According to the time series of SSSU, the difference with areas harvested rarely exceed 2%. Therefore, it is possible to already observe how shares in crop areas have changed with the war. The shares of areas harvested in 2023-2030 are projections. Figure 3 demonstrates the 2021-2030 shares of grains and oilseeds in the area of arable land.

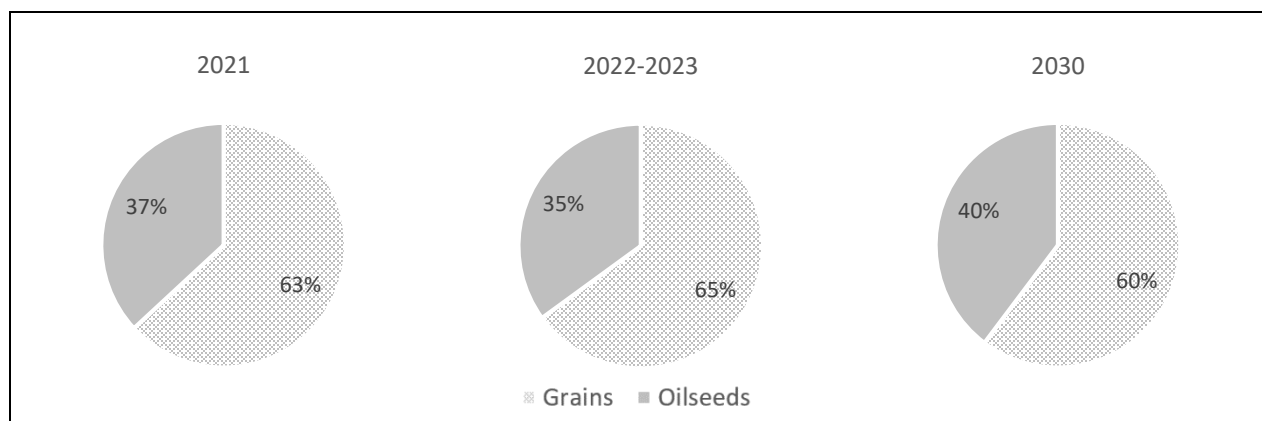


Figure 3 Shares of grains and oilseeds areas in 2021-2030 (scenarios BE (blocked export) and E (export) produce similar outcome), %

Source SSSU for 2021-2022, own estimation for 2023-2030

Before the RF invasion, shares of grains and oilseeds occupied, respectively, 63% and 37% of the arable land. With the changes in crops profitability in 2022-2023, which stems from changes in domestic market prices and production costs during the war-time, area of oilseeds reduced to 35% in favor of grains. In 2030, with stabilization of the prices and end of the war, area of grains reduces to 60% and of oilseeds increases to 40%. Such trend has been observed before the war. Change in relative profitability of the two groups of crops induced by the relative changes of the domestic and world market prices is the main reason for this. The model produces similar outcome for both scenarios.

Figures 3 and 4 demonstrate 2021-2030 changes in shares of areas of crops in the grains and oilseeds groups.

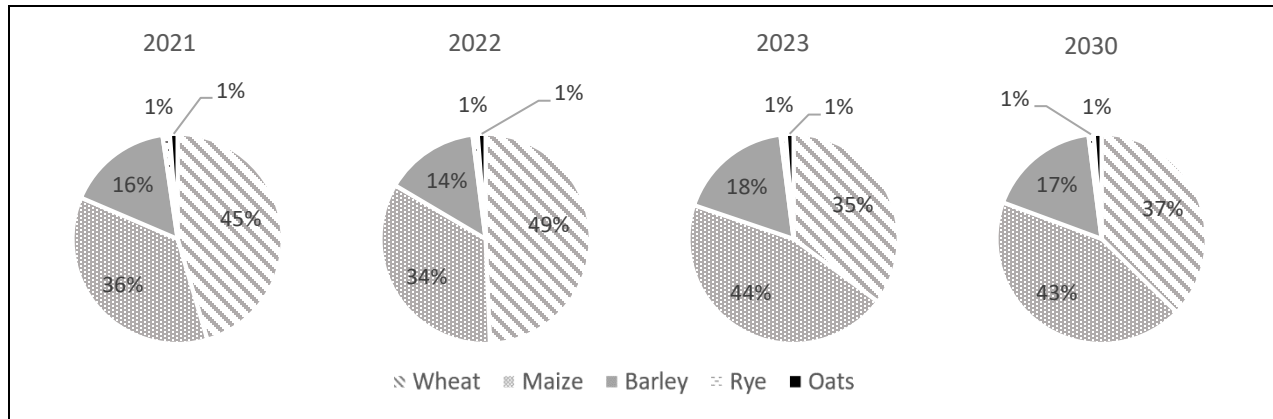


Figure 3 Shares of crops areas in the grains group in 2021-2030 (scenarios BE (blocked export) and E (export produce similar outcome), %

Source SSSU for 2021-2022, own estimation for 2023-2030

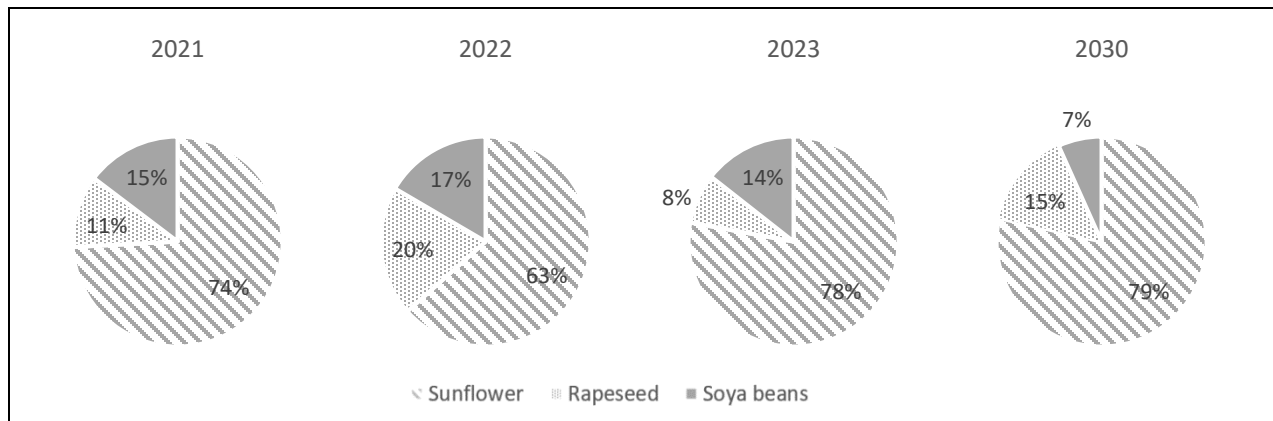


Figure 4 Shares of oilseeds areas in the oilseeds group in 2021-2030 (scenarios BE (blocked export) and E (export produce similar outcome), %

Source SSSU for 2021-2022, own estimation for 2023-2030

Before the RF invasion, the shares of wheat, maize and barley, the main agricultural crops in Ukraine (i.e., export-oriented crops), were, respectively, 45%, 36% and 16% of the total grains area. Oats and rye occupied around 1% each. In 2022, share of wheat increased by 4%, and shares of maize and barley drop by 2% each, demonstrating the substitution in favor of wheat. The shares of oilseeds were 74% for sunflower, 11% for rapeseed and 15% for soya beans in the total oilseeds areas. In 2022, they changed to, respectively, 63%, 20% and 17%. The changes in crops area shares result from changes in profitability of crops (within grains and oilseeds groups) relatively to each other. In the model, domestic market prices and production costs combine into the, so-called, expected gross margins. The latter represent profitability of crops production. Decreased prices (with the exception of sunflower seeds, domestic market prices for which increase by 2% in 2022) and increased costs in 2022 change this relative profitability in favor of wheat for the grains group, and in favor of rapeseed and soya beans for the oilseeds group. Thus, although, the areas of crops sown are introduced into the model as data, the relative profitability changes support these observations.

For 2023 the model assumes real production costs equal to those of 2022, and for 2023-2030 projects the recovery of domestic market prices by 27.7-56.6% depending on the crop (see Figure 5).

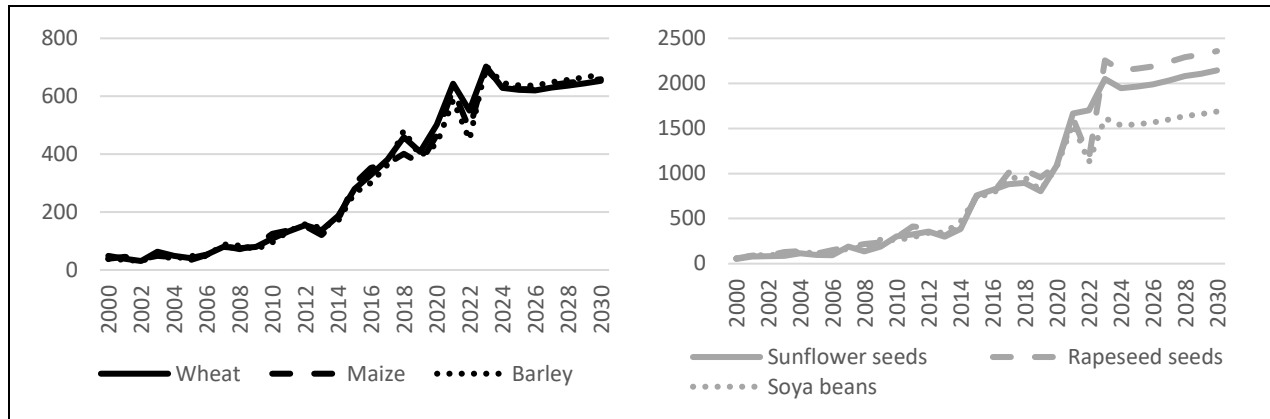


Figure 5 Domestic market prices for wheat, maize, barley, sunflower seeds, rapeseed seeds and soya beans in 2000-2030 (scenarios BE (blocked export) and E (export) produce similar outcome), UAH/100 kg

Source SSSU for 2000-2022, own elaboration for 2023-2030

The price recovery stems from two factors. First, is the assumption of storage availability during export blockade (scenario BE). It allows the producers to go on with their production plan even with the delayed export. Second, is the return of connectedness of domestic market prices to the world market prices coupled with the increased UAH/USD conversion rate (i.e., around 36 UAH per 1 USD in 2023-2030 as opposed to 29 UAH per 1 USD in 2021). Re-establishment of the price connection is based on the assumption that the producers, having available storage facilities, will not rush into selling their crops at low prices (to save the harvest and at least partially cover their production costs). Instead, they will be able to claim better market price. The model, however, does not include increased storage costs which occur due to longer storage period and increased storage capacity (i.e., investment/amortization costs).

With the change in relative gross margins in 2023-2030, wheat area will drop to 35-37% of the grains area, and maize and barley areas increase to, respectively, 44-43% and 18-17% (Figure 3). Increase in maize area will as well result from the long-term observed trend of change of weather conditions towards being more favorable for production of this crop. Sunflower and rapeseed area shares are expected to increase to, respectively, 79% and 15% at the expense of soya beans area.

Crop yields changes in 2022-2030 vary due to unequal relative changes in crops gross margins (which define the readiness of the producers to invest in crop protection products and fertilizers) and yield change factors (see Table 4). Thus, in 2022 maize yield drops significantly, by 42.8% compared to 2021, barley yield by 25.1% and wheat yield is affected the least, i.e., -1.6%. Yield of sunflower seeds drops by 7.2%, of rapeseed seeds by 37.9% and of soya beans by 33.8%. With the recovery of prices, the yields grow back and resume to steadily increasing trends by 2030.

Figure 6 demonstrates the projections for production and export of wheat, maize, barley, sunflower and rapeseed seeds, soya beans and the respective oils for 2023-2030.



Figure 6 Wheat, maize, barley, sunflower and rapeseed seeds, soya beans and oilseed oils production and export in scenarios BE (blocked export) and E (open export) in 2014-2030, thsd tons

Source SSSU for 2014-2022 for production (for oils 2014-2020, FAOSTAT), own elaboration for 2023-2030 for production and 2022-2030 for exports

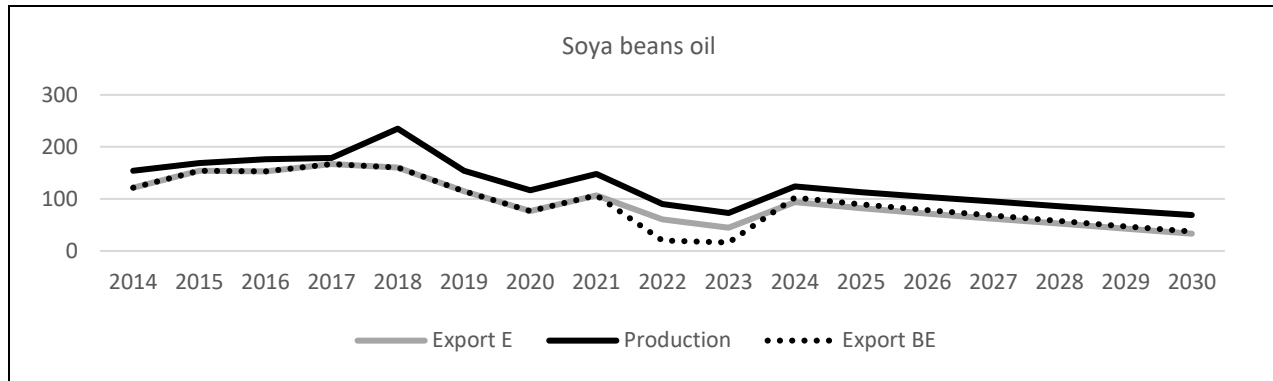


Figure 6 (cont.) Wheat, maize, barley, sunflower and rapeseed seeds, soya beans and oilseed oils production and export in scenarios BE (blocked export) and E (open export) in 2014-2030, thsd tons

Source SSSU for 2014-2022 for production (for oils 2014-2020, FAOSTAT), own elaboration for 2023-2030 for production and 2022-2030 for exports

Scenarios BE and E produce similar projections for production of grains and oilseeds due to the similar projected expected gross margins (see above). The projections for quantities exported, however, are different. In 2022-2023 scenario BE (blocked export) shows tremendous drop of exports, and starting from 2024 a quick recovery. Furthermore, exports often exceed production in this scenario. Quick recovery is explained by the fact that as long as the total volume of exports does not exceed the maximum loading capacity of the Ukrainian sea ports which is 75 mil tons per year, no obstacles for such trend are foreseen. Exports exceed production in scenario BE for many of the presented commodities, because non-exported produce which is accumulated in storage facilities in 2022-2023 is exported. In scenario E, exports follow production. Overall, we observe increase at a low steady rate production of maize, increase of production of sunflower and rapeseed seeds and of the respective oils, and decreasing production of wheat and soya beans and soya beans oil. Changes in production follow the changes in yields and areas harvested.

With the start of the war, production and export of poultry meat and eggs are projected to drop due to the increased production costs (Figure 7). Whereas poultry meat sector recovers in 2024, eggs sector leaps already in 2023. The latter is related to the households resuming their production activity. Scenarios BE and E produce similar results, because livestock commodities are not usually exported through the sea ports. Respectively, export remains unblocked for these products even in scenario BE. Although the production of bovine and pig meat are expected to be strongly affected by the war due to the shortages and increased prices of feed, as well as the loss of livestock heads due to the battles and occupation, the current model setting does not project the respective changes.

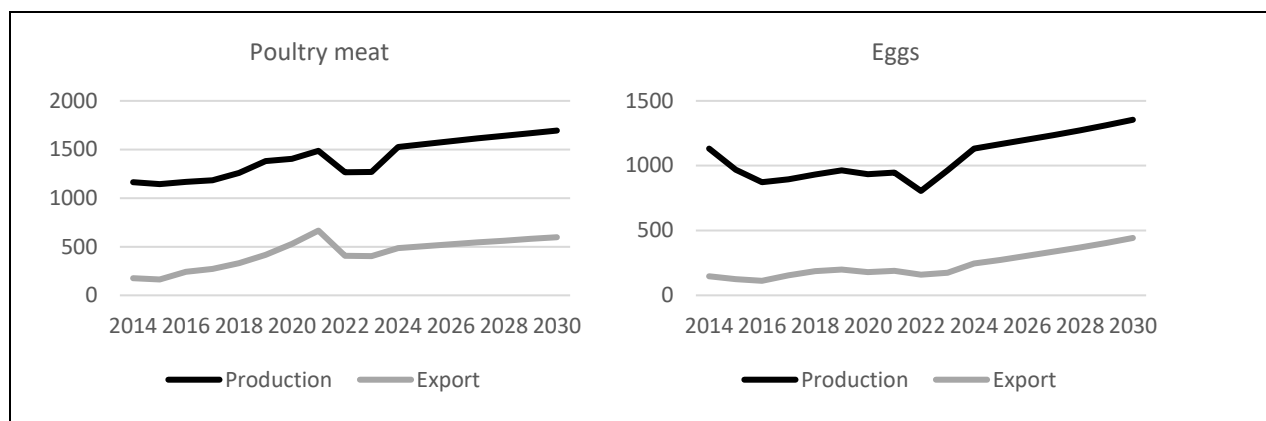


Figure 7 Poultry meat and eggs production and export in 2014-2030, thsd tons

Source SSSU for 2014-2021, own elaboration for 2022-2030

Discussion and conclusions: coping with the crisis

As the RF's war in Ukraine goes on by the date of writing this article, the producers struggle to cope with its consequences. High fuel and fertilizer prices, low domestic market prices for grains and oilseeds, reduced export possibilities due to the sea ports blockade and high level of infrastructure and production facilities' damage put the agricultural sector at risk of low profitability and production reduction. Since more than two thirds of grains and oilseeds harvest is exported, the main income from producing these kinds of agricultural commodities comes from external trade. The scenario analysis demonstrates that availability of storage facilities has the potential to support the producers in case of limited export: knowing that the harvest could eventually be sold, the producers would stay in the sector. For the harvest of 2022, however, neither the availability of additional storage capacities nor the improvement of export possibilities is certain.

To support agricultural producers, the domestic policies have been adjusted respectively. In particular, the changes valid in the wartime include reduction of the turnover tax to 2% and exception from value-added and profit taxes (for enterprises with annual turnover of less than 10 bil UAH), removal of excise tax on fuel, cancellation of import duties for majority of imported goods and of the requirement for domestic labeling, temporary release of agricultural employees from military duty, issuing phytosanitary certificate in electronic form, simplification of certification for producers of organic products, simplification of import and registration of pesticides and agrochemicals procedures and many others. Agricultural and water use policies have been liberalized. For example, carrying out land lease and placement of production facilities evacuated from the war zone were released from the obligation to use land auctions, construction of river ports (terminals) and railway logistics centers (production and transshipment complexes) can be done without the development of land management documentation and approved urban planning documentation, simplification of conditions for acquiring membership in Water Users' Organizations, etc. Adaptation of domestic and trade policies to the needs of producers in times of severe crisis, such as war, is very important for supporting continuity of agricultural production, producers' income and availability of food (see Bogonos et al. 2022).

Cooperation with international trade partners is extremely important as well, especially for a large importing or exporting country. In 2022, for example, temporary trade-liberalization measures supplementing trade concessions applicable to Ukrainian products under the Association Agreement were adopted by the EU. They included phasing out of entry price system and all tariff-rate quotas. Canada has phased out all tariffs applying to imports from Ukraine for 2022 as well. Although export from Ukraine has been severely limited, absence of tariff and quota barriers allow the Ukrainian producers gain more income and thus, support the survival of their enterprises.

International aid matters no less. By the end of June 2022, Ukraine received 42.0 bil EUR of humanitarian and financial aid from 41 countries. Together with military support it summed up to 76.7 bil EUR. The total of 3.9 bil EUR is the estimate of refugee support in 31 countries. The commitments by the EU Commission, EU Council, the European Investment Bank, the International Monetary Fund and the World Bank as well as by Australia, New Zealand, Norway, South Korea, Switzerland and Turkey expanded the total aid to 89.4 bil EUR. By June 1, the RF's invasion cost the Ukrainian agriculture 4.3 bil USD of damages – 15% of the total capital stock of the sector, and 23.3 bil USD of economic losses. Furthermore, by August 1, the total damage to the country's residential and non-residential buildings and infrastructure reached 108.3 bil USD and economic losses 128.8 bil USD. In this respect, continuous support programs during and after the war should, on one hand, encourage the economy to restore, and on the other hand, sustain its basic functionality during the war (Antezza et al. 2022 and KSE 2022).

Last but not least strategy of coping with negative impacts of war is ending the war. One of the mid- to long-term approaches of doing this includes sanctioning of the aggressor. For example, sanctions on RF by G7 countries include travel bans and asset freezes, increased tariffs on imports from RF and prohibition of importation of products such as, for example, gold, suspension of RF's broadcasting outlets, prohibition from purchasing goods and technologies, prohibition of new investment in the RF and of making debt payments with certain funds. Such measures are expected to weaken the economy of the aggressor-country to the degree, that continuing the war and building of new weapons are neither financially nor technically possible. In war, however, time matters. It is important that the penalties take effect before the unrecoverable damages, such as, for example, occupation and complete devastation of large territories, severe human capital loss, bankruptcy etc., are done to Ukraine and its economy.

With respect to the above mentioned, not a single but a group of coordinated actions must be taken by Ukraine and international community to halt the RF's war. Military aid, in case of proper volume, structure, management and use, assists in pushing the occupants back to the borders and protect the cities, inhabited areas, agricultural fields and facilities, industrial assets and infrastructure from missile and artillery attacks. Financial and humanitarian aids, domestic and trade policies, including trade policies of the international community, should help sustaining the economy and the agricultural sector in war time and motivate its recovery when the war ends. Finally, the penalties to the country-aggressor should discourage the latter not only from the current military assault but also from the future possible activities of such kind.

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