Public Disclosure Authorized

Public Disclosure Authorized

Policy Research Working Paper 10869

Micro-Level Impacts of the War on Ukraine's Agriculture Sector

Distinguishing Local and National Effects over Time

Klaus Deininger
Daniel Ayalew Ali
Nataliia Kussul
Guido Lemoine
Andrii Shelestov

WORLD BANK GROUP
Development Economics
Development Research Group
August 2024

Policy Research Working Paper 10869

Abstract

This paper uses remotely sensed and farm-level data to assess the micro-level impacts of the war in Ukraine. Remotely sensed, high-resolution data on areas of war-induced agricultural field damage in different periods are combined with crop cover data for a 2019–23 panel of about 10,000 village councils. Estimates suggest that there were significant negative effects of field damage on crop area, with persistent, direct impacts, the size of which increased over time. However, the economic losses due to conflict-induced increased transport costs reduced profitability by more than 60 percent, far surpassing the losses from direct crop damage in conflict areas. The lack of diversification into less transport cost sensitive, higher value crops—even in areas far from the conflict zone—points to constraints to adaptation and diversification. By increasing the resilience of farmers in non-conflict areas, removing such constraints could accelerate post-conflict recovery and complement efforts toward reconstruction in directly affected areas.

This paper is a product of the Development Research Group, Development Economics. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at kdeininger@worldbank.org, dali1@worldbank.org, guido.lemoine@ec.europa.eu, Nataliia.kussul@gmail.com, and Andrii.shelestov@gmail.com.

The Policy Research Working Paper Series disseminates the findings of work in progress to encourage the exchange of ideas about development issues. An objective of the series is to get the findings out quickly, even if the presentations are less than fully polished. The papers carry the names of the authors and should be cited accordingly. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

Produced by the Research Support Team

Micro-Level Impacts of the War on Ukraine's Agriculture Sector:

Distinguishing Local and National Effects over Time

Klaus Deininger[1]
Daniel Ayalew Ali[1]
Nataliia Kussul[2]
Guido Lemoine[3]
Andrii Shelestov[2]

JEL Codes: Q10, O13, H56, R14

Keywords: Ukraine, conflict/war, food security, agricultural production, agricultural input and output markets

1 The World Bank, 1818 H Street NW, Washington, DC, USA
2 Igor Sigorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
3 Joint Research Center of the European Commission, Ispra, Italy

The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent. Funding support from the European Union (ENI/2017/387-093 and ENI/2020/418-654) is gratefully acknowledged. We thank Denis Bashlyk, Eduard Bukin, Markiyan Dmytrasevych, Taras Gagalyuk, Ben Hell, Thea Hilhorst, Roman Hrab, Sergyi Kubakh, Vasyl Kvartiuk, Daria Manzhura, Andrii Martin, Sevara Melibaeva, Roman Neyter, Oleg Nivievskyi, Martin Petrick, Irina Schuman, Stefan von Cramon-Taubadel, Taras Vysotskyi and Sergyi Zorya for helpful discussions and insightful comments and as well as Tania Khorzovskaya for outstanding coordination and administrative support.

Micro-Level Impacts of the War on Ukraine's Agriculture Sector: Distinguishing Local and National Effects over Time

1. Introduction

The Russian Federation's invasion of Ukraine in February 2022 started a war that has to date displaced more than 8 million individuals and destroyed the productive capacity and infrastructure of vast stretches of territory. As Ukraine has been a major agricultural producer of grains and oilseeds, it has also given rise to concerns about effects on global commodity prices and food security that are explored by a growing number of studies. Compared to these, war impacts on agricultural production and rural livelihoods in Ukraine have received less attention. This paper aims to help fill this gap. Doing so poses two types of challenges. First, the immediate effects of the conflict, largely in terms of whether specific areas were taken out of cultivation, often occur in places that are inaccessible due to ongoing military action. Second, damages to infrastructure or closure of port facilities due to the war may affect the profitability of all Ukrainian producers through changes in terms of trade or logistics costs.

To address the first issue, we use a 2019–23 panel of remotely sensed data on areas cultivated with winter and summer crops, aggregated to the village council (VC) level for the entire territory of Ukraine, including areas beyond Ukrainian control. This is combined with an indicator of conflict-induced damage to agricultural fields constructed specifically for this purpose, to assess the direct and indirect impacts of the conflict on the area cultivated with agricultural crops. To address the second issue, we draw on public data on prices for outputs and inputs as well as a 2021–23 farm-level panel of data on areas not directly affected by the conflict, which provides information on areas allocated to specific crops, yields, inputs, and profits.

For area under cultivation, economywide conflict effects predominated initially but, consistent with adaptation by farmers outside the immediate conflict area, their relative importance declined over time. Local effects assumed greater relative importance but also persisted and even increased in size over time, possibly because land damaged by fighting was contaminated with landmines, or outmigration reduced economic activity in areas affected by heavy fighting. In the longer term, the impacts of the conflict on cultivated area are thus highly localized and concentrated in areas directly affected by military action.

In contrast, conflict-induced increases in the cost of transport—due to the closure of seaborne export routes or damage to physical infrastructure—have an economically significant effect on agricultural profitability. The implied decline in prices for output and the increase in prices for tradable goods triggered drops in profits of 62% and 50% in 2022 and 2023, respectively, for the producers in our sample. Such swings in relative prices, together with better access to European markets, provide opportunities for diversification into higher value crops that are less sensitive to transport cost. However, we find only small differences in profits and output values between small and large producers, suggesting that the war also impaired farmers' ability to invest in higher value crops (von Cramon-Taubadel and Nivievskyi 2023). Removing technical, financial, or market-related constraints to diversification in locations not directly affected by conflict could thus be a high priority for support to complement or, if active fighting continues, even precede activities such as de-mining, which aim to restore the productive capacity of areas directly affected by the conflict.

We contribute to three strands of literature. First, we show that freely available medium-resolution imagery can be used to construct an indicator of conflict-related damage to agricultural fields at high levels of spatial and temporal resolution. This indicator is particularly suitable if the affected areas are large and damage is visible at least for some period of time. It builds on a body of studies that use imagery with lower resolution to assess the effects of war (Alix-Garcia et al. 2013), land use change (Meyfroidt et al. 2016), grazing intensity (Dara et al. 2020), or changes in crop cultivation (Munteanu et al. 2017), often over longer periods of time (Matasov et al. 2019). This indicator can also complement data from the commonly used Armed Conflict Location and Events Data (ACLED) project (Raleigh et al. 2010), which uses the number of casualties, a measure that may be less meaningful in agricultural settings, as a proxy for conflict intensity. In the Ukrainian context, our measure improves on the use of press reports or nighttime light data (Zhukov 2023), which are less relevant for agriculture, and it can be applied consistently at a larger scale without the computational and cost burden that would be associated with scaling up the use of data with higher frequency and resolution (Duncan et al. 2023). Developing an automated classifier for conflict-related damage to rural fields would be a straightforward extension over the manual classification adopted here.

Second, we build on a growing body of work that combines high-quality training data and machine learning with remotely sensed data for analysis of changes in land cover not only at the global level (Potapov et al. 2022) or country level (Lark et al. 2017), but also at a more granular scale (Lobell et al. 2020), including the field level (Deines et al. 2021). This allows us to demonstrate the scope for using spatial data to assess the impact of the conflict (Witmer 2015) in a way that uses customized (Ben Yishay et al. 2024) or readily available information (Chiovelli et al. 2018). Use of remotely sensed data to assess effects of conflict on preservation of environmentally sensitive areas or yields can rely on similar techniques in principle if ground-truth data is available.

Third, we add to the literature arguing that the effects of conflict vary over time and extend beyond areas directly affected by violence (Miguel and Roland 2011). Studies show that long-term effects of conflict may arise from displacement (Chiovelli et al. 2021; Ibanez et al. 2022) as exposed individuals may reduce investment in human capital (Akresh et al. 2023; Büttner et al. 2022) or physical capital (Rockmore 2020; Sinha et al. 2022) and alter their risk perceptions (Federle et al. 2022) or activity choices (Arias et al. 2019; Fergusson et al. 2020). Conflict may also affect the cost of trade (Amodio and Di Maio 2018), the level of interaction (Couttenier et al. 2022), trust (Korovkin and Makarin 2023), and, as a consequence, economic returns of specific investments (de Roux and Martinez 2021). We find locally persistent effects of conflict and in our context, relative price changes emerge as a channel through which conflict affects outcomes well beyond the areas of active fighting.

The remainder of the paper is organized as follows. Section 2 provides context by briefly describing the nature of Ukraine's agriculture sector and recent reforms and the economic effects associated with the Russian invasion of Ukraine in February 2022. Section 3 discusses data on conflict, crop cover, and climate, together with the methodology used to estimate the effects of the conflict on area cultivated with the major crops at the VC level and key results. Section 4 complements this with 2021–23 output and input prices as well as revenue, input use, "profits," and output market participation, for a panel of approximately 1,200 small and medium-scale farmers, to provide suggestive evidence on how the war has affected the relative profitability of different farm size groups. Section 5 concludes.

2. Background and the impact of the war

To set the scene, we highlight key characteristics of Ukraine's agriculture sector, and how, together with the country's broader economy, it has been affected by the war and what this implies for farmers' behavior. We argue that the measures traditionally used as a proxy for conflict may not fully capture the nature and extent of the damage to agriculture. This provides a basis for discussing how remotely sensed imagery can be used to quantify conflict-induced crop damage at a high level of spatial and temporal resolution and how, linked to crop vegetation cycles, this can potentially improve on commonly used conflict indicators.

2.1 Ukraine's agriculture sector and aggregate impacts of the conflict

With more than 40 million hectares (ha) of some of the most fertile agricultural land globally, Ukraine has traditionally been a key global supplier of agricultural commodities, especially sunflower oil, maize, and wheat. Before the war, agriculture contributed about 10% to gross domestic product and 42% of the country's exports. The sector's structure was shaped by de-collectivization in the early 2000s when some 7 million landowners were provided with land shares of about 4 ha each. Approximately 20 million ha of Ukraine's agricultural land is farmed by large farms in the formal sector, often firms with links to foreign capital markets (Deininger et al. 2018) that lease land from the owners. About 12 million ha are estimated to be cultivated by small and household farms, many of which remain informal. In 2002, about 9.2 million ha were state or communal land, and an unknown share of this land was "privatized," often in nontransparent ways that imposed significant losses to the public (Nivievskyi 2020). With one growing season per year, winter crops, including wheat, rye, barley, and rapeseed, are sown in the fall, and summer crops, such as barley, maize, sunflower, and soybean, are sown in the spring.

In 2019 and 2020, the country enacted far-reaching land governance reforms that included stepwise lifting of a moratorium on land sales that had been in place since 2001. By allowing use of agricultural land as collateral for credit, this was expected to deepen domestic financial markets more broadly and, in the agriculture sector, support diversification away from land- and capital-intensive bulk commodities that add little value and generate little employment. Complementary reforms aimed to restructure institutions in ways that would increase transparency via digital interoperability, improve public land management by transferring ownership of such land to local governments subject to central land use controls and the requirement to transfer lease rights to such land via electronic auction,[1] and establish a partial credit guarantee facility to ease small producers' access to financial markets.

The war started by Russia's invasion in February 2022 halted the implementation of these reforms midway and had three major impacts. First, by blocking low-cost avenues to export grain through Ukraine's Black Sea ports, it necessitated a shift to more expensive alternatives (von Cramon-Taubadel 2022) that increased transport costs and reduced Ukraine's comparative advantage, with potentially far-reaching effects on long-term prospects and the profitability of its agriculture sector (Wilson et al. 2024). Second, 5.3 million individuals are estimated to have been internally displaced in the first three weeks of the war alone (Leasure et al. 2023). The number of displaced, including international migrants, is estimated to exceed 8 million, or 20% of the country's pre-war population (Adema et al. 2023). Together with military mobilization, this severely curtailed labor and human capital availability, with an extensive impact on the economy's human capital stock (Egert et al. 2023) Third, the war inflicted direct damages to the agricultural capital stock, which have been estimated to amount to US$ 10.3 billion (Neyter et al. 2024).[2]

Given Ukraine's importance as an exporter of agricultural commodities such as vegetable oil, wheat, and maize, the invasion also led to concerns about potential disruption of global agricultural markets (Balma et al. 2022; Lin et al. 2023), especially in highly import-dependent regions such as the Middle East (Abay et al. 2023a).[3] The invasion's effects on agricultural commodities turned out to be large but not historic (Smith 2023), with limited impacts on the quantity of grain and oilseeds traded globally (Ahn et al. 2023). One reason was that the higher prices stimulated supply (Zhou et al. 2024), including from Russia, to make up the shortfalls in Ukrainian production, leading to losses in producer surplus. For example, for wheat, Ukrainian producers are estimated to have lost US$1.4 billion in producer surplus (Devadoss and Ridley

---

[1] The mandatory shift from centralized, in-person to fully electronic auctions run by local authorities for any transfer of use rights to public land instantaneously increased lease prices by 175% (Deininger et al. 2023b).

[2] Of this total, 57% is for machinery, 18% for storage facilities, and the remainder for outputs, inputs, and crops or livestock.

[3] There was concern that this could provide a cover for protectionist policies (Ben Hassen and El Bilali 2022) with doubtful short-term political benefits that would be more than outweighed by negative externalities (Glauben et al. 2022).

2024), compounding the damages sustained in 2014 (Bluszcz and Valente 2022), while Russia had at most modest losses or may have gained market share (Rose et al. 2023).

2.2 Measuring data on the conflict that are relevant for agricultural production

Studies have traditionally used self-reported household survey data on conflict experience (Muriuki et al. 2023) or physical proximity to war zones (Akresh et al. 2022) to measure conflict exposure, although the subjective and static nature of these measures has long been recognized as a drawback. An important source of independent, time-varying data on conflict is the ACLED project (Raleigh et al. 2010), which relies on media reports on different types of violent events, together with the number of fatalities as a measure of severity, georeferenced to the nearest locality. Although it is not specific to the agriculture sector, the data it provides, combined with georeferenced household data, have been widely used to draw inferences on the household-level impacts of conflict. For example, in Ethiopia, exposure to an additional battle was found to increase food insecurity, mainly through reduced scope for nonfarm activities (Abay et al. 2023b). In Nigeria, more intense conflicts, measured by the number of fatalities, reduced the quantity and variety of foods eaten (George et al. 2020) and impeded medium-scale farmers' area expansion (Adelaja et al. 2023). In Mali, conflict significantly reduced the likelihood of using inputs, and cash transfers failed to reverse this (Sessou and Henning 2024).

To create a measure of time-varying conflict exposure that is relevant for agricultural production, we use publicly available Sentinel-2 imagery with medium spatial (10-meter pixel size) and temporal (five-day revisit cycle) resolution to identify conflict-induced damage to agricultural fields. We constructed a measure of the area of fields damaged by military actions such as crop burning, heavy vehicle movement, or artillery shelling in nine oblasts (districts) affected by fighting for every two-week period since the start of the war.[4] During the growing season, field damage is often visible only for a short period, although it may change a field's level of productivity in the long term, especially if unexploded ordnance is left behind. To ensure that our measure focuses on agricultural fields, we mask out areas that were not cultivated with agricultural crops in at least one of the pre-war years during 2019–21.[5] We complement this with a measure that indicates if a VC was occupied, involved in active fighting, or had troop presence, based on online daily situational reports from local and regional military administrations.[6]

---

[4] The work involved visual inspection by trained university students who, in the training phase and in cases of doubt, were also provided with higher resolution imagery. The presence of field damage was recorded as a zero/one dummy. Duncan et al. (2023) use a machine learning approach with higher resolution imagery to detect transitory artillery craters and draw out potential longer-term implications in the Ukrainian context. For Cambodia, Lin et al. (2021) discuss the longer-term damage wrought by unexploded ordnance and farmers' adjustment to the associated dangers. In Ukraine, the oblasts included are Kyiv, Chernihiv, Sum, Kharkiv, Luhansk, Donetsk, Zaporizja, Kherson, and Mykolaiv.

[5] While the measure used here is based on manual classification, Kussul et al. (2023) discuss the methodology and use of the data as an input into a machine learning model in more detail.

[6] Open-source data (https://novy.tv/ru/news/2022/06/02/karta-bojovyh-dij-v-ukrayini/ and https://liveuamap.com/ru/time).

Figure 1 graphically illustrates the nature of our data by comparing damaged area at the field level (in red) to public data from ACLED (in green) for one period, showing that the former are likely to contain more information on the intensity and location of damages that may be relevant for agriculture than the ACLED data. The spatial nature and time variation in the data, aggregated at the VC level, is illustrated for conflict incidence (figure 2) using official data (panel A) and ACLED data (panel B) for battles and explosions as well as intensity of damages (figure 3), based on satellite imagery (panel A) and ACLED data using the number of fatalities in battles and explosions (panel B). In all cases, VCs that were affected by the conflict before and after September 2022 are in red, and those affected by the conflict only before or after this date are in ochre or orange, respectively. While all the data sources point toward a large segment in the country's northeast that was affected by fighting before September 2022 but not thereafter, comparing panel B in figures 2 and 3 to panel A in figure 3 suggests that ACLED includes violent events far from the front in the country's interior, especially in cities, while providing less detail on it the incidence and severity of damages to agricultural fields close to the frontline.

Table 1 displays the resulting conflict measures for all two-week periods since the start of the war. Column 1 presents data on the share of VCs where some agricultural area was damaged; column 2, the mean area damaged per VC; column 3, the total extent of such crop damage; and column 4, an indicator of the share of VCs where publicly available data pointed to any type of conflict. This measure decreased from a high of 16.1% in period 2 to about 10% in the summer of 2022 and fluctuated at around 7%-8% for the remainder of the period. By comparison, the share of VCs experiencing field damage ranged from a maximum of 3% (in period 10) to a minimum of 0.4% (in periods 29 and 30), almost an order of magnitude smaller. With between 4,226 and 135,334 ha in periods 21 and 23, the total area damaged by conflict action at the national level in any two-week period remained small compared to a total cropped area of about 30 million ha. The correlation between this measure and the public information is low, suggesting that remotely sensed data contain information that is not captured by data from other sources.

To assess the effect of conflict-related damage on area cultivated with summer or winter crops, we match two-week periods to different phases of crops' vegetative development (planting, growing, and, for winter crops, dormancy) to the data on conflict incidence and intensity by two-week intervals. Columns 5 and 6 in table 1 display the classification of these periods for summer and winter crops, respectively. Panel B provides the means over the planting or growing seasons for winter or summer crops in 2022 or 2023, which are the variables included in the relevant area regressions. The area damaged per VC dropped from about 550 ha per affected VC in 2022 to 236 and 306 ha per affected VC in the 2023 growing season for summer and winter crops, respectively. Aggregating information from ACLED in the same way, in columns 7 to 10, highlights that, with between 0.5% and 1% of VCs reporting (between 9.8 and 30.9) fatalities in any two-week period and between 2.2% and 4.2% of VCs having any battles with fatalities and an insignificant and negative correlation of this measure with imagery-based analysis, the two variables indeed seem to measure very different aspects of violence.

3. Assessing the effects of the conflict on area cultivated with agricultural crops

Our outcome variable is the area cultivated with winter or summer crops in 2019–23 aggregated at the level of more than 10,000 VCs nationally. The regressions for cultivated area that adjust for time-varying factors such as weather point toward significant conflict effects that persist and even grow in size during the periods for which data are available.

3.1 Data on crop cover

To analyze the impact of the conflict on cropped area nationwide, we use the area cultivated with the main winter or summer crops at the VC level in each year during 2019–23. These crops traditionally made up more than 95% of Ukraine's agricultural output value (Deininger et al. 2018). Cultivated area is of first-order importance and, as the statistics in appendix table A1 illustrate, can be reliably predicted using existing data, in contrast to yield. Exploring the impact on winter and summer crops separately is justified as both differ in their vegetation periods; the temperatures most conducive to their growth (Fang et al. 2023); and as farmers may substitute summer for winter crops if the latter failed, were damaged by fighting, or faced less favorable terms of trade (for example, due to higher transport costs).

Crop maps for the entire territory of Ukraine in 2019–23 were obtained using on the methodology discussed by Kussul et al. (2017), Shelestov et al. (2017), and Shelestov et al. (2020). In each year except 2022, when in-situ data were collected only for summer crops as the conflict made collection in the spring impossible, training data were gathered in two rounds of in-situ data collection along main roads following standard guidelines (Waldner et al. 2019). Optical data from Sentinel-2 and Synthetic Aperture Radar data from Sentinel-1 during the vegetation period were then used for a convolutional neural network that was run on the Amazon Web Services cloud computing platform.[7]

Table 2 summarizes the data at the national level, showing that total area cultivated ranged from 27.3 million ha in 2019 (9.4 million and 17.9 million ha of winter and summer crops, respectively) to 24.88 million ha in 2023 (6.8 million and 18.1 million ha of winter and summer crops, respectively). A modest reduction in cultivated area (of less than 0.5 million ha) for the 2022 winter crop is consistent with the fact that this crop had been sown before the conflict. The fact that the 2023 winter crop area was 2 million ha

---

[7] Appendix table 1 shows the number of training samples collected each year as well as the F1 scores for the winter and summer crop maps, which exceed 95% in each of the years. Deininger et al. (2023a) provide a more detailed description of the methodology, including maps of the roads traveled in different years and a confusion matrix.

below the 2019–21 average could indicate a strong conflict effect, although a more modest decline of the summer crop area in 2022 (by 0.74 million ha from the pre-war average) and an increase (by 0.33 million ha) in 2023 suggest that, before drawing conclusions, other factors must be considered and controlled for.

Table 3 illustrates the need for difference-in-differences analysis of conflict effects by presenting the area cultivated for summer crops (panel A), winter crops (panel B), and fallow land (panel C) overall and separately for VCs that were or were not affected by the conflict, based on official data, or that experienced crop damage, based on satellite imagery from the 2023 or 2022 planting and growing seasons. While the first line in each panel replicates the national figures, the subsequent lines point toward clear differences across villages by conflict incidence. In VCs with war-related field damage based on remotely sensed data, the summer crop area was 880 ha (31%) or 871 ha (26%) below the pre-war mean in 2022 or 2023, respectively (panel A). In VCs without field damage, the summer crop area in 2022 and 2023 was 16.6 ha (or 1.0%) below or 108.2 ha (or 7.0%) above the pre-war mean, respectively. Differences for VCs where conflict was measured using open-source data rather than satellite imagery are of similar magnitude.

Panel B in table 3 points toward similarly large effects for winter crop area, with a reduction of 1,028 ha (or 45%) for VCs where crops were damaged, based on remotely sensed data in 2023 (788 ha for VCs with conflict based on open-source data), compared to 120-125 ha for those not affected by the conflict. As 2022 winter crops were planted before the Russian invasion in February 2022, it is not surprising that even for VCs that were affected by the conflict during the growing season for 2022 winter crops, the mean winter crop area was reduced by 228 ha only if satellite imagery is used, or by 106 ha if open-source conflict data are used.

Weather affects agricultural production in ways that are unrelated to conflict. To account for weather variation, we generate data on precipitation and minimum or maximum temperature from the US National Center for Environmental Prediction Global Forecast System, which produces weather forecasts every six hours. For the 2019–23 growing seasons, we use the first six-hour interval of each forecast, extracted using Google Earth Engine scripts, as a “nowcast” to derive daily aggregated values at the rayon level.

The temperature data are then converted into growing degree days (GDDs), using daily values of T_{min} and T_{max} with a sinusoidal distribution as suggested by d'Agostino and Schlenker (2016). In line with the literature, we then compute the cumulative GDDs as the number of hours with temperatures above 5° C (41° F) for summer crops (see figure 4) and 0° C (32° F) for winter crops (see figure 6). To complement GDDs, we also compute cumulative precipitation in each year for summer crops (figure 5) and winter crops (figure 7). The summer growing season in 2019 was very warm; in 2022, rainfall after mid-May remained below average; and 2023 had ample rain in the spring but a dry summer. For winter crops, 2023 combined high temperatures (similar to 2020) with higher precipitation, providing favorable conditions for crop growth. Failure to include weather-related variables may thus bias estimates of the effects of the conflict.

3.2 Methodology and results

To estimate the impacts of concurrent or past conflict on area cultivated with winter and summer crops at the village level, we use data from a panel data set covering 10,770 VCs over 2019–23. Indexing VCs by v and years by t, the model to be estimated is

$$Y_{vt} = \alpha_v + \beta \boldsymbol{CI}_{vt} + \delta \boldsymbol{CI}_{vt-1} + \boldsymbol{\gamma X}_{vt} + \lambda_t + \varepsilon_{vt} \qquad (1)$$

where Y_{vt} is the outcome variable of interest (area covered with summer or winter crops) in village v in year t; $\boldsymbol{CI}_{vt}$ is a vector of conflict indicators (intensity of conflict or area damaged by conflict based on satellite imagery at different stages of crops' vegetative cycle based on public sources); $\boldsymbol{X}_{vt}$ is a vector of time-varying variables including weather (number of GDDs) and precipitation at different stages of crop development and their squares and, for summer crops, the winter crop area to allow for substitution effects[8]; α_v are village fixed effects that control for time invariant factors such as agronomic suitability, access to infrastructure or economic opportunities, and quality of local leadership; λ_ts are time fixed effects; and ε_{vt} is a random error term.

Beyond providing an estimate of the effect of contemporaneous conflict (β), this regression allows testing whether there is persistence in the sense that exposure to conflict in the past affects current production *(δ)*, at least for one lag. Moreover, to the extent that α_v control for time invariant factors, such as access to infrastructure, soil quality, or village leadership, and $\boldsymbol{X}_{vt}$ as well as λ_t for periods before 2022 capture time-varying factors not affected by the war, λ_{2022} or λ_{2023} would provide an upper bound estimate of the indirect or macro effects of the conflict on area cultivated.

Table 4 presents the main coefficient estimates from (1) for winter crops in columns 1 and 2 and summer crops in columns 3 and 4. All the estimated coefficients from the full specification are reported in appendix tables A2 and A3. For each outcome variable, the first column uses data on conflict incidence from publicly available sources, and the second column adds information on damaged area obtained from remote sensing and, for summer crops, an interaction with winter crop area to allow for substitution effects. With R^2 values close to or above 0.9, all the coefficients of interest are significant at 1%. Three conclusions stand out.

First, our results suggest that omitting the measure of damaged area derived from remotely sensed imagery would result in underestimation of the impact of the conflict and reduce the regressions' explanatory power.

---

[8] We include levels and quadratic terms to allow for decreasing marginal effects from rain or temperature or negative flooding or drought effects.

The magnitudes of the estimated coefficients if area is included are higher by between 113% (for winter crops in 2022) and 16% (for summer crops in 2023) than for regressions with a VC-level conflict indicator alone.[9] We also note that the estimated elasticity of area loss with respect to crop damage differs across crops and years, with almost 80% of the damaged area in the growing season lost for summer crops compared to a much smaller size (25%) for winter crops.

Second, local impacts of direct and indirect conflict exposure persist over time. The tests in the bottom panel of table 4 suggest that estimated effect sizes increase significantly over time for both village-level ($\beta_t - \beta_{t-1}$) and field-level ($\delta_t - \delta_{t-1}$) damages. More data could help understand what drives this, e.g., unexploded ordnance for damages at the field level or depopulation and damage to infrastructure at the village level.[10] The elasticity of substitution between summer and winter crop areas is large: based on the point estimate, nearly 75% of the reduction in winter crops is compensated by planting summer crops, although we are unable to discern whether this can be attributed to the weather, conflict, or relative price changes.

Finally, even under the assumption that time dummies for 2022 and 2023 capture the effects of the war entirely (controls capture all the non-war-related intertemporal variation), the general equilibrium effects of the war, proxied for by the difference between λ_{22} or λ_{23} and the pre-war average of year fixed effects, are sizable. Across time periods, the size of such macro effects is largest for 2023 winter crops, at 13%, but no longer significant for summer crops in 2023. This suggests that, in summer 2023, the effects on area cultivated were largely confined to VCs that were directly affected by the conflict, and their profitability or output may still be affected.

As a robustness check, we report results with coefficients for all the right-hand-side variables and interactions for the outcome variables of interest in three specifications in addition to the one reported in table 4. In different specifications, the conflict indicator is (i) a dummy of whether or not the VC was affected by any conflict (column 1), (ii) the normalized number of two-week intervals during which the VC was affected by conflict (column 2), and (iii) the measure of damaged area. The results are robust in all cases. Appendix tables A4 and A5 report the results, together with the same equations estimated using ACLED data on battles, explosions, and number of fatalities as indicators of conflict incidence and intensity. Although the signs of the estimated coefficients are mostly consistent (exception for intensity measures for winter crops), using imagery-based conflict indicators is preferable for agricultural outcomes.

---

[9] For the 2022 winter crops, the area in conflict-affected VCs is estimated to drop by 80.37 or 171.07 ha (= 39.66 + 0.242 * 543) without or with accounting for damaged area, respectively. For the 2023 summer crops, the figures are 1,934 and 2,254 ha, respectively (595.39 + 90281 or 470.75 + 569.64 + 0.779 * 236 + 0.967 * 563).

[10] In principle, shapefiles for the farmstead and all parcels cultivated by a farm would allow assessing damages at the farm level as well.

3.3 Exploring the geographical incidence of conflict effects

An advantage of using remotely sensed rather than statistical data is that by using estimated coefficients to obtain predicted values of Y_{vt} for scenarios where either CI_t or λ_t are set to zero for t = 2022 or 2023, the above regressions allow us to obtain estimates of area cultivated in each VC under different counterfactuals. Aggregating these VC-level estimates at the national level (or for any subgroup of VCs) and subtracting from the values obtained in the full model can provide estimates of direct or indirect conflict effects for different geographical domains, including areas that are currently not under Ukrainian control.[11]

Table 5 presents the relevant estimates for total area with winter crops in 2022 and 2023 in the 10,002 VCs that cultivated such crops at any point during 2019–23 (panels A and B) and with summer crops in the same period for 10,556 VCs (panels C and D). The estimates in table 5 are for the counterfactual scenarios of no direct conflict (all elements of $\boldsymbol{CI}_{vt}$ or $\boldsymbol{CI}_{vt-1}$ are set to zero), in line 2; no macro or conflict effects ($\lambda_{22/3} = 0$ in addition), in line 3; and other scenarios for the entire country (column 1), for the 8,147 and 9,425 (in different time periods) VCs that were not affected or the 1,855 to 1,284 VCs that were affected by the conflict (columns 2 and 3) and, for the latter, VCs that were controlled by Ukraine (column 4) or Russia (column 5).

The estimates suggest that the conflict reduced the area cultivated with winter crops by 10% (0.84/8.47) and 24% (1.79/7.45) in 2022 and 2023, respectively, and it reduced the area cultivated with summer crops in the same years by 12% (2.16/17.89) and 10.5% (2.08/19.7), respectively. Although indirect or macro effects accounted for close to 90% (0.75/0.84) of the total for winter crops in 2022, their importance declined to about 61% for 2022 summer (1.33/2.16) and 2023 winter (1.09/1.79) crops, and to less than 25% (0.51/2.08) for 2023 summer crops. This may reflect adaptation to the conflict outside the areas directly affected. Finally, half to slightly less than three-quarters of the direct conflict effects on agricultural area (50% and 71% for winter and summer crops, respectively, in 2022, and 72% and 58% for winter and summer crops, respectively, in 2023) were on territory controlled by Russian forces. This contrasts to an increase of overall economic activity as measured by nighttime lights (Zhukov 2023), highlighting the importance of measuring outcomes in a way that is suited to the question at hand.

4. Assessing the effects of the conflict on farm profitability

Beyond changes in area cultivated, the conflict may have affected the profitability of agricultural production. Data on output and input prices point to large price effects, especially in the first year of the war. We combine these with information on input use and profitability from a panel of 1,206 small and

---

[11] In terms of the model results reported in table 3, column (6), scenario one involves setting the “any conflict” dummy and “damaged field area” to zero, whereas scenario two involves in addition setting the 2022 dummy to zero.

medium-scale farms for 2021, 2022, and 2023. Drops in output prices together with higher input costs more than halved farm profitability in 2022. In 2023, most output prices continued to decline, so lower input costs brought only limited respite. Price changes affect all farm sizes equally, suggesting that diversification into higher value crops that are less sensitive to transport cost remained limited.

4.1 Descriptive evidence

To complement image-based data on crop cover and conflict incidence, we use data on prices of key inputs and outputs that were collected in a consistent format every year from 2021 to 2023 for the country's main farming areas. In line with the literature that highlights the disruption caused by the loss of links to export markets through Ukraine's major Black Sea ports (Wilson *et al.* 2024), three trends can be discerned from panel A in table 6. First, output prices for the main crops almost halved in 2022 due to higher export costs, which can be attributed to the lower capacity at Ukraine's main ports and higher cost of alternative access points to global markets through Poland or Romania. Second, with unit transport cost increasing by 48% over pre-war levels in 2022, prices for imported fertilizers more than doubled and those for other inputs also increased markedly directly after the invasion. Prices for locally produced services or inputs, although less affected, also increased markedly. Third, while most input prices returned to within 10% of their pre-war levels by 2023, output prices for all crops except soybean declined further from their 2022 levels.

Although micro-data on agricultural profitability as used, for example, by Deininger et al. (2018), would be ideal for making inferences on the effects of the conflict, the State Statistics Service of Ukraine (SSSU) stopped making such data available in 2019. To assess the impact of the conflict on changes in farm profitability, we thus resorted to conducting our own survey of small and medium-scale farmers in areas not affected by the conflict. Annex A explains the sample, for which we used Ukraine's State Agrarian Register (SAR) as a sample frame, in more detail and compares it to the sample used by the SSSU. The data were collected by phone in two waves in winter 2022/23 (collecting data for the 2021 and 2022 agricultural seasons), and in winter 2023/24 (collecting data for the 2023 agricultural season). This provides a three-year panel with data from before and during the war for the same farms.

As might be expected in an environment with an active conflict, the levels of nonresponse and attrition were high: of 2,500 respondents in the 2022 round, only about 1,200 could be traced and provided answers in 2023. Further, as the SAR was a main vehicle for disbursing emergency assistance to registered farmers in cash or in kind, receipt of support or the expectation of future support seems to have increased the likelihood of farmers' response. Appendix table A7 suggests that those who benefited from the producer support grant (PSG) were10% more likely to respond, and application to another program increased the likelihood of response by 17%. Interpretation of the farm-level figures needs to account for the limitations of the sample and the potential selection effects they imply.

Table 6, panel B, presents the results on profitability for the entire sample and separately for farms with areas that are less than or greater than 120 ha, highlighting two points. First, the area cultivated remained approximately constant, consistent with the results from the remotely sensed data. Physical output for key crops decreased by between 6% and 21% for rapeseed and maize or sunflower, respectively, in the first year of the war but was only marginally (between 1% and 6%) below 2021 levels in 2023. These results support the focus on area rather than yield in our earlier analysis.

Second, revenue per hectare decreased by 34% between 2021 and 2022, from US$1,088 to US$714, with a further decline to US$597 (or 56% of the 2021 level) in 2023. Combined with an increase of 26% in input costs over 2021 levels in 2022, this implied a drop in profit per hectare by 60%, from US$778 to US$313. The share of output sold to the market decreased from 78% to 68% in 2022. While the level of market participation recovered to the original level in 2023, the share of output sold in 2023 remained at 62%, 20 percentage points below the share attained in 2021. Although lower input prices implied a small recovery of profits to US$397/ha, this was still only 54% of the 2021 level.

4.2 Farm-level analysis and variation of impacts by farm size group

The farm survey panel data can be used to run farm-level fixed effect regressions for the level of market participation, output value, input cost, and profits overall and by farm size group. In the absence of other confounding factors, year dummies for 2022 or 2023 can be interpreted as conflict impact and the difference between the two years as the result of farmers' adaptation overall or by farm size group. Columns 1, 3, 5, and 7 in table 7 present the results of the regressions for the overall sample. They suggest that the war resulted in a 30% reduction in output sold (α_1), but that adaptation reduced this effect by about 7% (α_2 - α_1) in 2023. Similarly, the value of output and the cost of inputs in 2022 were 47% below and 23% above the pre-war levels, respectively, with output value decreasing by a further 14% and input cost falling by 79% from the 2022 level in 2023. Profits, which had decreased by US$477 from 2021 to 2022, improved by US$86 in 2023.[12]

An exogenous increase in the cost of transport together with better access to European markets due to the opening of accession negotiations with the European Union on December 14, 2023, could benefit (small) producers of high-value crops and foster rural diversification. To assess whether the conflict-induced changes differed across farm size groups, we interact year dummies for 2022 and 2023 with pre-intervention farm size, classifying farms into large and small, based on whether they farm more or less than 120 ha. The magnitudes and significance levels in the bottom panel in table 7 are reported for whether small and large

---

[12] As they are strictly positive for all producers, we use the log of the dependent variable for regressions of output value and input cost, and absolute values for the share of output sold and profits.

farms differed from each other in the size of their reaction to the onset of the conflict in 2022 ($\beta_1 - \beta_2$) or subsequent adaptation ($\gamma_1 - \gamma_2$) and differences in the level of adaptation by small ($\gamma_1 - \beta_1$) and large ($\gamma_2 - \beta_2$) farms. The results suggest that although output market participation did not differ between the two groups, small farmers' value of output per hectare decreased marginally less than that of large farms in both the first year (by 7% versus 10%) and the second year (by 12.5% versus 16%) of the war. Although part of this was compensated by an increase in input cost that was about 35% larger for small as compared to large farms, this translated into a slightly less pronounced drop in profits for 2022 (by US$110) and 2023 relative to 2022 (by US$63). The modest size of these differences as well as the descriptive statistics reported earlier suggest that Ukrainian farmers failed to capitalize on the diversification opportunities that were inherent in the relative price changes triggered by the war. Identifying barriers to doing so and ways to reduce them would be relevant.

5. Conclusion and policy implications

The effects of conflict may be felt in areas not directly affected by military activity, and their nature and magnitude may change over time. To account for these factors in analyzing the economic impact of the war in Ukraine, we combined remotely sensed and farm survey evidence. We showed that freely available satellite imagery allows constructing a measure of conflict at high levels of spatial and temporal granularity that is more suitable for quantifying the intensity of the effects of the conflict on agriculture than existing alternatives. We employed regression analysis that linked this variable to a 2019–23 VC-level panel of area cultivated with winter and summer crops for the entire territory of Ukraine (including areas beyond Ukrainian control). This allowed us to analyze separately the direct (due to damage to a specific field) and indirect economywide effects of the conflict on area cultivated with agricultural crops. The economywide effects dominated initially, but their relative importance declined, whereas the direct impacts persisted and even increased in size over time.

Data on prices and actual production decisions from public sources and a farm survey in areas that were not directly affected by the conflict showed that although the direct and indirect effects of the war on cropped area are highly significant statistically, conflict-induced changes in transport costs—attributable to the closure of seaborne export routes and damage to physical infrastructure—have economically more important and far-reaching effects on agricultural profitability. Although such large changes in relative prices can provide an opportunity for diversification in a less volatile environment, the data show no evidence of a shift toward higher value crops even among small farmers, suggesting that even in areas not directly affected by the war, such shifts remained limited. Efforts to identify and remove technical, financial, or market-related constraints to farm-level diversification could be an important way to increase farmers' resilience to the negative impacts of the war.

Annex A: Sample description and representativeness

To obtain information on changes in welfare, production, and productivity in the small and medium-scale farm sector between 2021 and 2022, a nationwide phone survey of such farms in areas controlled by Ukraine was implemented from October to December 2022, in cooperation with the Ministry of Agricultural Policy and Food (MAPF), the Kyiv International Institute of Sociology, and the Kyiv School of Economics.[13] Although the original intent was to construct a sample frame using data from the State Statistics Service of Ukraine (SSSU), complemented by the company registry, these sources cover only registered legal entities whose registration details are often no longer current. To capture informal farms, which, based on expert estimates, cultivate 32% of Ukraine's agricultural area (Nivievskyi et al. 2021), a decision was taken to use the State Agrarian Registry (SAR) as a sample frame instead.

The SAR is an electronic registry that was established in August 2022, with the objective of transferring support to small and medium-scale farmers in a transparent yet expeditious way. It allows farmers of any legal status (a registered legal entity, a family-owned business (FOP), or individuals) to sign up at the SAR website (https://www.dar.gov.ua/) using their electronic signature and providing a minimum of personal information. The system then gathers information on all the land parcels to which the farmer has registered rights from the registry of rights and the cadaster and adds information on the farm from other registries.[14]

The MAPF or any authorized entity can use information in the SAR to target programs to support the agriculture sector and interact electronically with potential farmers. Farmers can carry out the required actions digitally rather than by filling paper forms, including uploading scanned documents and photos or providing authorization for providers of certain services to access specific types of personal information stored on the system. Use of the SAR to implement an EU-supported producer support grant (PSG) as well as other programs[15] facilitated rapid sign-up, especially by small and medium-scale farms, many of which had previously been in the informal sector.[16]

As the survey was launched in the second half of October, we set October 15, 2022, as the cut-off date to construct the sample frame by dropping farms without any registered land or a valid phone number. Appendix table A6 compares the resulting sample frame with all the registered farms in the database (Form 29) maintained by the SSSU in 2020, the last year for which such data are available, by farm size category (<50, 50-120, 120-500, and >500 hectares (ha)).

Panel A in appendix table A6 compares the number of establishments, showing that our frame includes 75,571 farmers, more than double the 36,167 in the Form 29 survey as used by the SSSU. Of these, 21% are legal entities, 11% FOPs, and 68% individuals, with the latter concentrated in the farm size class of fewer than 50 ha, of which 82% are individuals and 9% each FOPs and legal entities. Legal entities dominate in the larger farm size classes, making up 58%, 76%, and 97% of those in the 50-120, 120-500, and >500 ha groups, respectively. The SAR has better coverage, in terms of the number of farms, compared to Form 29, for the below 120 ha group (with 3.8 and 1.1 times the number of farms in the <50 and 50-120 ha groups, respectively) but worse coverage for farms that are larger than 120 ha, with SAR containing only

---

[13] The survey was implemented by the Kyiv International Institute of Sociology, with financial support from the European Commission.

[14] For example, the SAR automatically gathers information on any outstanding debts to the state (which would legally disqualify them from receiving state support) and on farmers' registered livestock from the animal registry. The government plans to add information from other registries, including the mortgage registry and the registry of court cases, in the near future.

[15] The PSG that targeted farmers who cultivated fewer than 120 ha provided a cash grant equivalent to US$100 for each hectare of land cultivated during the 2022 agricultural season in non-conflict-affected areas. Information from the SAR was first used to establish whether the farmer was below the 120 ha threshold. After subtracting land parcels registered in the names of farmers located in conflict-affected areas, maps with registered parcel boundaries were used to cross-check cultivation status against a crop map elaborated based on remotely sensed imagery to compute the total grant amount. The €50 million available under the program was fully disbursed by November 2022 and an evaluation that aims to compare differences over time in parcels by successful as compared to unsuccessful PSG applicants is currently underway. Beyond this, several donors are using the system to implement programs such as for the provision of short-term grain storage and delivery of seeds, fertilizer, or critical capital equipment (generators).

[16] The SAR simplifies program implementation by providing reliable and current information from official registries, simplifying program application by eliminating the need for repeated filling of paper forms, and leveling the playing field and increasing competition in factor markets by creating a base of potential clients to which service providers or banks can market their services.

0.62 and 0.44 times the number of operations in the 120-500 and >500 ha groups, respectively. Panel B illustrates that the farms covered by Form 29 and SAR cultivate 27.85 million and 11.6 million hectares, respectively. The total area registered in SAR amounts to 42% of the area in Form 29 at the national level and 150%, 127%, 67%, and 37% in the <50, 50-120, 120-500, and >500 ha groups, respectively.[17]

To quantify the extent of informality in Ukraine's agriculture sector, we use crop maps to identify the total area cultivated with crops in 2020, before the war, and then compare this area to what is covered by the available statistics (Form 29) and the SAR.[18] In appendix table A6, panel C shows that, based on these maps, Ukraine's total cultivated area amounted to 45.73 million ha whereas panel B illustrates that, with 27.8 million ha, SSSU's Form 29 thus covers 61% of the country's cultivated area in 2020, leaving an estimated 39% of cultivated area not covered by official statistics.

Using enterprise IDs to match farms between the SAR and Form 29 suggests that 7.5 million ha are cultivated by farms included in both the SAR and Form 29, while 3.36 million ha are registered in the SAR only. This suggests that in the three-month period from August 12 to October 15, 2022, registration in the SAR reduced the amount of land cultivated informally by 3.36 million ha, or about 7% of the total. Still, 14.5 million ha, more than the total agricultural area of Poland or Germany, are cultivated by farmers that are neither part of the SSSU's sample frame nor registered in the SAR, implying that their land is not reflected in any official statistics.

The follow-up survey was conducted one year after the baseline survey by the same survey firm, with a response rate of 54%. Two-thirds of the nonresponses were due to inability to reach the relevant contact, in most cases because phone lines were unreachable or disconnected or the enterprise had gone out of business. One-third was refusals.

To understand the determinants of attrition between the two survey rounds, we estimate a probit model with baseline covariates. Appendix table A7 presents the estimated marginal effects. The likelihood of attrition among PSG beneficiaries (-10%), applicants to other programs (-18%), those hoping to access credit (-7%), or FOPs (-12%) is much lower than for the rest of the sample. Respondent status (owner versus manager), perceived personal situation, experience of direct war damages, and region did not affect response rates, and larger farms were significantly less likely to respond.

Removing technical, financial, or market constraints to diversification in areas not directly affected by the conflict would thus be a high priority for support to complement and, while active fighting continues, even precede activities such as demining that aim to restore the productive capacity of areas directly affected by the conflict.

---

[17] As a plausibility check, we compare mean farm sizes between Form 29 and the SAR. For the above 50 ha group, average farm size in the SAR is 803 ha compared to 934 and 999 ha for areas controlled by Ukraine (ACUs) and areas affected by conflict (AACs), respectively. In Form 29, the corresponding figures for farms greater than 500 ha are 2,834, 2,255, and 2,137 ha, respectively, for the SAR and Form 29 in ACUs and AACs.

[18] As area cultivated in 2022 is likely to have been affected by the conflict and to avoid bias that might arise from the fact that 2021 was an exceptional year with very favorable growing conditions, we use both satellite imagery and Form 29 data from 2020. Area cultivated excludes forest, bare land, wetlands, water, and areas with artificial (built up) cover.

Table 1: Village council–level conflict indicators, based on open-source and crop damage data

	Crop damage			Any	Summer	Winter	Fatalities			Any
	Yes	ha/VC	Total	indic.	stage	stage	Yes	#/VC	Total	indic.
Panel A: Incidence of damage by two-week periods										
2022										
P1: Feb 24 - Mar 12	0.009	265	24,953	0.119	P	G	0.011	15.51	1,892	0.032
P2: Mar 13-26	0.022	446	104,015	0.155	P	G	0.009	23.55	2,143	0.028
P3: Mar 27 - Apr 10	0.006	161	10,156	0.095	P	G	0.007	11.39	866	0.023
P4: Apr 11 – 24	0.010	458	49,957	0.095	P	G	0.007	13.61	1,048	0.022
P5: Apr 25 - May 7	0.008	252	21,924	0.095	P	G	0.007	11.00	869	0.027
P6: May 8-22	0.009	184	17,688	0.094	P		0.008	17.36	1,510	0.031
P7: May 23 - Jun 3	0.013	286	40,372	0.094	G		0.007	11.07	786	0.029
P8: Jun 4-18	0.011	273	30,829	0.094	G		0.008	9.80	833	0.032
P9 Jun 19 - Jul 2	0.021	292	65,705	0.094	G		0.007	12.92	982	0.033
P10: Jul 3 - Jul 17	0.029	250	77,614	0.097	G		0.009	12.53	1,178	0.037
P11 Jul 18 - Jul 31	0.020	192	40,613	0.097	G		0.008	17.98	1,528	0.038
P12: Aug 1 – Aug 14	0.023	177	44,056	0.105	G		0.007	19.04	1,390	0.039
P13: Aug 15-28	0.022	121	28,307	0.102	G		0.008	18.39	1,545	0.039
P14: Aug 14 - Sep 11	0.011	121	14,134	0.097		P	0.009	20.71	2,071	0.042
P15: Sep 12-25	0.007	157	11,321	0.082		P	0.011	11.43	1,337	0.040
P16: Sep 26-Oct 10	0.012	211	25,989	0.083		P	0.011	14.99	1,739	0.040
P17: Oct 11-24	0.017	264	47,174	0.086		P	0.008	19.08	1,641	0.036
P18: Oct 25-Nov 6	0.002	181	4,333	0.078		P	0.007	30.89	2,286	0.032
P19: Nov 7-20	0.013	133	18,652	0.079		P	0.007	23.13	1,619	0.035
P20: Nov 21 - Dec 5	0.006	125	7,608	0.072		P	0.007	21.61	1,513	0.034
P21 Dec 6-18	0.002	222	4,226	0.070		D	0.007	12.78	946	0.029
P22: Dec 19-31	0.008	266	22,878	0.072		D	0.007	25.27	1,845	0.031
2023										
P23: Jan 1-15	0.016	791	135,334	0.076		D	0.008	14.03	1,122	0.031
P24: Jan 16-29	0.006	274	17,782	0.071		D	0.007	17.99	1,403	0.031
P25: Jan 30 - Feb 12	0.025	422	112,334	0.087		D	0.006	13.60	911	0.030
P26: Feb 13-26	0.024	303	77,450	0.083		D	0.005	16.82	942	0.032
P27: Feb 27 - Mar 12	0.010	268	28,907	0.074	P	G	0.007	12.63	998	0.032
P28: Mar 13-26	0.018	297	56,428	0.079	P	G	0.007	11.59	916	0.034
P29: Mar 27 - Apr 9	0.004	149	6,709	0.071	P	G	0.007	13.99	1,049	0.030
P30: Apr 10-23	0.004	173	6,939	0.071	P	G	0.006	20.58	1,420	0.027
P31: Apr 24 - May 7	0.019	184	36,349	0.076	P	G	0.008	17.13	1,405	0.032
P32: May 8 - May 21	0.012	136	16,847	0.074	P		0.007	20.80	1,643	0.034
P33: May 22 - Jun 4	0.013	136	18,805	0.073	G		0.008	15.90	1,383	0.035
P34: Jun 5 - Jun 18	0.011	129	15,067	0.074	G		0.009	15.27	1,542	0.035
P35: Jun 19 - Jul 2	0.013	150	21,341	0.073	G		0.008	16.70	1,436	0.033
P36: Jul 3 - Jul 16	0.010	109	11,846	0.073	G		0.010	12.94	1,359	0.030
P37: Jul 17 - Jul 30	0.020	115	23,872	0.078	G		0.010	12.68	1,293	0.031
P38: Jul 31 - Aug 13	0.020	150	32,606	0.081	G		0.009	12.43	1,168	0.032
P39: Aug 14 - Aug 27	0.031	133	43,259	0.085	G		0.007	14.41	1,124	0.033
Panel B: Means at different stages of winter and summer crop development										
Winter growing 22	0.038	522	211,006	0.176			0.026	24.88	6,818	0.069
Summer planting 22	0.039	543	228,694	0.176			0.029	27.04	8,328	0.076
Summer growing 22	0.055	563	327,496	0.111			0.027	28.92	8,242	0.077
Winter planting 23	0.035	342	129,211	0.106			0.031	37.21	12,206	0.086
Winter dormancy 23	0.058	600	370,004	0.104			0.021	31.72	7,169	0.062
Winter growing 23	0.041	306	135,332	0.090			0.018	30.46	5,788	0.056
Summer planting 23	0.047	305	152,179	0.093			0.020	35.05	7,431	0.061
Summer growing 23	0.066	236	166,796	0.104			0.023	37.22	9,305	0.064

Source: Interpretation of satellite imagery as described in the text (columns 1 to 3); computations using data from https://liveuamap.com/ru/time and https://novy.tv/ru/news/2022/06/02/karta-bojovyh-dij-v-ukrayini/ (column 4); ACLED battles and fatalities (columns 7 to 10).

Note: Data are for 10,666 VCs where 10,556 and 10,002 VCs that were under Ukrainian control in 2015 (excluding Crimea and areas occupied in 2014) that had a positive cultivated area in 2019–23 for summer and winter crops, respectively. The stages for winter and summer crops are as follows: P = planting; D = dormancy; G= growing. ACLED = Armed Conflict Location and Events Data; ha = hectares; indic. = indicator of conflict; VC = village council.

Table 2: Area with summer and winter crops or fallowed, 2019–23 (hectares, millions)

Agric. season	Total	Winter crop	Summer crop
2019	27.31	9.42	17.89
2020	25.76	7.51	18.26
2021	26.69	9.45	17.23
2022	25.43	8.38	17.06
2023	24.88	6.76	18.12
Average 2019–21	26.59	8.79	17.79
2022 – avg. 2019–21	-1.15	-0.42	-0.74
2023 – avg. 2019–21	-1.71	-2.04	0.33

Source: Computations based on data from publicly available crop maps (www.cropmaps-ua.com).

Table 3: Area planted with summer crops and uncultivated land, national and by VC and conflict status

		2019	2020	2021	2022	2023	2019–21	Difference to 2019–21		No. of VCs
								absolute	%	
Panel A Summer crops										
Total[a]		1,694.3	1,729.6	1,632.4	1,615.7	1,716.9	1,685.4	31.5	1.87	10,556
2023 conflict indicator										
Cropland damage	Yes	3,491.4	3,425.0	2,970.8	2,433.4	2,424.1	3,295.7	-871.6	-26.45	827
from imagery	No	1,541.5	1,585.5	1,518.7	1,546.2	1,656.8	1,548.6	108.3	6.99	9,729
Any conflict	Yes	3,262.1	3,233.6	2,793.2	2,307.7	2,322.0	3,096.3	-774.3	-25.01	1,131
public source	No	1,506.1	1,549.1	1,493.2	1,532.7	1,644.3	1,516.1	128.2	8.46	9,425
2022 conflict indicator										
Cropland damage	Yes	2,973.1	2,941.7	2,625.1	1,966.3	2,112.0	2,846.6	-880.3	-30.92	650
from imagery	No	1,610.4	1,650.1	1,567.3	1,592.7	1,691.0	1,609.2	-16.5	-1.03	9,906
Any conflict	Yes	2,561.5	2,558.1	2,319.8	1,926.9	2,041.8	2,479.8	-552.9	-22.30	1,895
public source	No	1,504.5	1,548.3	1,482.0	1,547.7	1,645.9	1,511.6	36.0	2.38	8,661
Panel B: Winter crops										
Total[a]		942.0	750.6	945.1	837.3	675.4	879.2	-203.8	-23.18	10,002
2023 conflict indicator										
Cropland damage	Yes	2,271.3	2,074.4	2,493.3	2,090.4	1,251.7	2,279.7	-1,028.0	-45.09	865
from imagery	No	816.1	625.2	798.6	718.7	620.9	746.6	-125.7	-16.84	9,137
Any conflict	Yes	2,273.6	1,970.1	2,452.4	2,074.5	1,443.7	2,232.0	-788.3	-35.32	1,284
public source	No	745.9	570.9	723.2	655.1	562.3	680.0	-117.7	-17.31	8,718
2022 conflict indicator										
Cropland damage	Yes	2,013.4	1,726.8	2,051.4	1,702.1	819.9	1,930.5	-228.4	-11.8	395
from imagery	No	897.9	710.4	899.7	801.8	669.5	836.0	-34.2	-4.1	9607
Any conflict	Yes	1,595.1	1,342.7	1,703.0	1,440.7	1,025.5	1,546.9	-106.2	-6.9	1786
public source	No	800.0	621.8	780.4	706.2	599.4	734.1	-27.9	-3.8	8216

Source: Computations based on data from crop maps for winter and summer crop area and Sentinel imagery in 2019–23.

[a] The reported absolute and percentage differences are between 2023 and the pre-conflict (2019–21) average, and the figures between 2022 and 2019–21 are -69.7 ha and -4.14% for summer crops and -41.90 and -4.77% for winter crops. VC = village council.

Table 4: Village fixed effects regressions for area with winter and summer crops

	Winter crop area		**Summer crop area**	
Conflict indicator (β_t)	-104.226***	-51.621***	-577.364***	-461.845***
	(16.547)	(16.521)	(14.393)	(13.420)
Conflict indicator Lagged (β_{t-1})	-376.087***	-174.551***	-874.098***	-577.472***
	(21.236)	(21.380)	(16.855)	(15.787)
Area damaged (DA) growing period (δ_t)		-0.244***		-0.800***
		(0.024)		(0.011)
DA growing period lagged (δ_{t-1})		-0.587***		-0.993***
		(0.029)		(0.013)
DA planting and dormancy		-0.608***		
		(0.020)		
Winter crop area			-0.646***	-0.719***
			(0.004)	(0.004)
Year 2020 (λ_{20})	-68.272***	-62.789***	-61.460***	-79.488***
	(15.090)	(14.777)	(13.087)	(11.900)
Year 2021 (λ_{21})	-73.541***	-77.702***	-167.837***	-154.500***
	(22.358)	(21.892)	(11.800)	(10.729)
Year 2022 (λ_{22})	-119.288***	-121.134***	-247.974***	-206.403***
	(13.635)	(13.350)	(15.779)	(14.354)
Year 2023 (λ_{23})	-151.201***	-157.758***	-152.950***	-127.412***
	(14.444)	(14.143)	(13.595)	(12.365)
Mean of dep. var.	830.096	830.096	1,677.799	1,677.799
STD of dep. var.	1,137.696	1,137.696	1,543.028	1,543.028
No. of obs. (VC*year)	50,010	50,010	52,780	52,780
R^2	0.886	0.891	0.958	0.965
Linear combination tests				
$\beta_t - \beta_{t-1}$	271.861***	122.930***	296.733***	115.627***
	(31.835)	(31.643)	(26.267)	(24.442)
$\delta_t - \delta_{t-1}$		0.343***		0.194***
		(0.033)		(0.016)
$\lambda_{22} - (\lambda_{20} + \lambda_{21})/2$	-48.382***	-50.888***	-133.326***	-89.409***
	(10.729)	(10.514)	(8.464)	(7.710)
$\lambda_{23} - (\lambda_{20} + \lambda_{21})/2$	-80.295***	-87.512***	-38.301***	-10.418
	(9.520)	(9.323)	(7.892)	(7.181)

Source: Original table for this paper.

Note: The results are from 2019–23 panel regressions with VCs as the unit of observation. The dependent variable is the land area allocated to winter or summer crops. Geographic coverage excludes Crimea and regions occupied in 2014. Summer crops include maize, soybean, sunflower, and summer cereals, while winter crops are winter cereals (wheat, barley, and rye) and rapeseed. The planting period for summer crops is March 16 to May 15, and growing period is from May 16. GDD (> 5°C) and its square, rainfall during the planting and growing season and its square, as well as zero rain days during the planting and growing period and a constant are included, with coefficients reported in appendix tables A2 and A3. Conflict indicators and damaged area are zero for all years before 2022. Standard errors are in parentheses, and * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. DA = area damaged due to conflict; GDD = growing degree days; VC = village council.

Table 5: Predicted direct and indirect effects of the conflict on winter and summer crop area, 2022 and 2023

	Total	**Conflict affected**		**…if yes, controlled by**	
		No	**Yes**	**Ukraine**	**Russian Federation**
Panel A: Winter crop area					
2022 cropping season					
(1) Full model (B)	8.38	5.68	2.70	0.70	2.00
(2) No conflict (S1)	8.49	5.68	2.81	0.75	2.06
(3) No macro and conflict (S2)	9.23	6.28	2.95	0.80	2.15
(4) Net conflict effect (S1-B)	0.11	0.00	0.11	0.05	0.06
(5) Net macro effect (S2-S1)	0.74	0.61	0.14	0.05	0.09
(6) Conflict and macro effect (S2-B)	0.85	0.61	0.25	0.10	0.15
No. of VCs	10,002	8,147	1,855	624	1,231
2023 cropping season					
(1) Full model (B)	6.76	4.79	1.97	0.46	1.50
(2) No conflict (S1)	7.09	4.79	2.31	0.54	1.76
(3) No macro and conflict (S2)	8.20	5.76	2.45	0.58	1.87
(4) Net conflict effect (S1-B)	0.34	0.00	0.34	0.08	0.26
(5) Net macro effect (S2-S1)	1.11	0.97	0.14	0.03	0.11
(6) Conflict and macro effect (S2-B)	1.45	0.97	0.48	0.11	0.37
No. of VCs	10,002	8,718	1,284	313	971
Panel B: Summer crop area					
2022 cropping season					
(1) Full model (B)	17.06	13.10	3.95	1.93	2.02
(2) No conflict (S1)	17.87	13.10	4.76	2.16	2.61
(3) No macro and conflict (S2)	19.22	14.21	5.02	2.29	2.73
(4) Adj. for w. crops in (3) (S3)	19.00	14.06	4.94	2.27	2.67
(5) Net conflict effect (S1-B)	0.81	0.00	0.81	0.23	0.59
(6) Net macro effect (S2-S1)	1.36	1.10	0.25	0.14	0.12
(7) Conflict and macro effect (S2-B)	2.17	1.10	1.07	0.36	0.70
(8) Adjusting for w. crop (S3-B)	1.94	0.95	0.99	0.34	0.65
No. of VCs	10,556	8,576	1,980	1,075	905
2023 cropping season					
(1) Full model (B)	18.12	15.48	2.64	1.21	1.43
(2) No conflict (S1)	18.68	15.48	3.20	1.33	1.87
(3) No macro and conflict (S2)	19.20	15.95	3.25	1.35	1.90
(4) Adj. for w. crops in (3) (S3)	18.06	15.12	2.95	1.26	1.68
(5) Net conflict effect (S1-B)	0.56	0.00	0.56	0.12	0.44
(6) Net macro effect (S2-S1)	0.52	0.47	0.06	0.02	0.03
(7) Conflict and macro effect (S2-B)	1.08	0.47	0.61	0.14	0.47
(8) Adjusting for w. crop (S3-B)	-0.06	-0.37	0.31	0.05	0.25
No. of VCs	10,556	9,425	1,131	442	689

Source: Original table for this paper.

Note: Figures are in millions of hectares and constructed based on regression results from table 4. VC = village council.

Table 6: Changes in prices and use of outputs and inputs as well as farm profitability, 2021–23

	2021	**2022**	**2023**	**Δ21-22**	**Δ21-23**
Panel A: Output and input prices					
Output prices (US$/t)					
Winter wheat	240	137	129	-0.43	-0.46
Winter rapeseed	675	360	302	-0.47	-0.55
Spring barley	214	120	100	-0.44	-0.53
Corn	224	132	123	-0.41	-0.45
Sunflower	657	348	303	-0.47	-0.54
Soybean	602	336	381	-0.44	-0.37
Input prices					
Seed (EU variety)	403	480	432	0.19	0.07
Fertilizer (ammonium nitrate)	383	615	410	0.61	0.07
Fertilizer (urea)	490	734	524	0.50	0.07
Pesticide	8.7	10.2	9.4	0.18	0.09
Plowing (1ha)	19.7	21.1	19.7	0.07	0.00
Harvesting (1ha)	38.7	41.0	38.3	0.06	-0.01
Grain transport (t/30 km)	4.0	5.9	4.5	0.48	0.13
Panel B: Farm-level data					
Overall					
Area cultivated (ha)	216.8	215.1	226.5	-0.01	0.04
Rapeseed yield (t/ha)	2.71	2.55	2.68	-0.06	-0.01
Maize yield (t/ha)	7.05	5.58	6.72	-0.21	-0.05
Sunflower yield (t/ha)	2.36	1.86	2.23	-0.21	-0.06
Soybeans yield (t/ha)	2.45	2.05	2.42	-0.16	-0.01
Wheat yield (t/ha)	4.25	3.45	4.03	-0.19	-0.05
Barley yield (t/ha)	3.69	3.09	3.59	-0.16	-0.03
Any sales	0.78	0.68	0.77	-0.13	-0.01
Share of output sold	0.82	0.60	0.62	-0.27	-0.24
Revenue per ha	1,088	714	615	-0.34	-0.44
Total input use per ha	305	385	197	0.26	-0.36
Profit per ha (US$)	778	313	418	-0.60	-0.46
Number of farms	1,206	1,206	1,206		
Farms <= 120 ha					
Area cultivated (ha)	54.4	58.2	57.2	0.07	0.05
Any sales	0.73	0.62	0.70	-0.16	-0.04
Share of output sold	0.84	0.63	0.63	-0.25	-0.25
Revenue per ha	1,034	690	584	-0.33	-0.43
Total input use per ha	275	358	196	0.30	-0.29
Profit per ha (US$)	753	316	390	-0.58	-0.48
Number of farms	817	817	750		
Farms >120 ha					
Area cultivated (ha)	527.5	531.6	495.1	0.01	-0.06
Any sales	0.87	0.80	0.87	-0.08	0.00
Share of output sold	0.80	0.55	0.60	-0.31	-0.25
Revenue per ha	1,215	773	662	-0.36	-0.46
Total input use per ha	377	453	198	0.20	-0.48
Profit per ha (US$)	839	306	463	-0.64	-0.45
Number of farms	389	389	456		

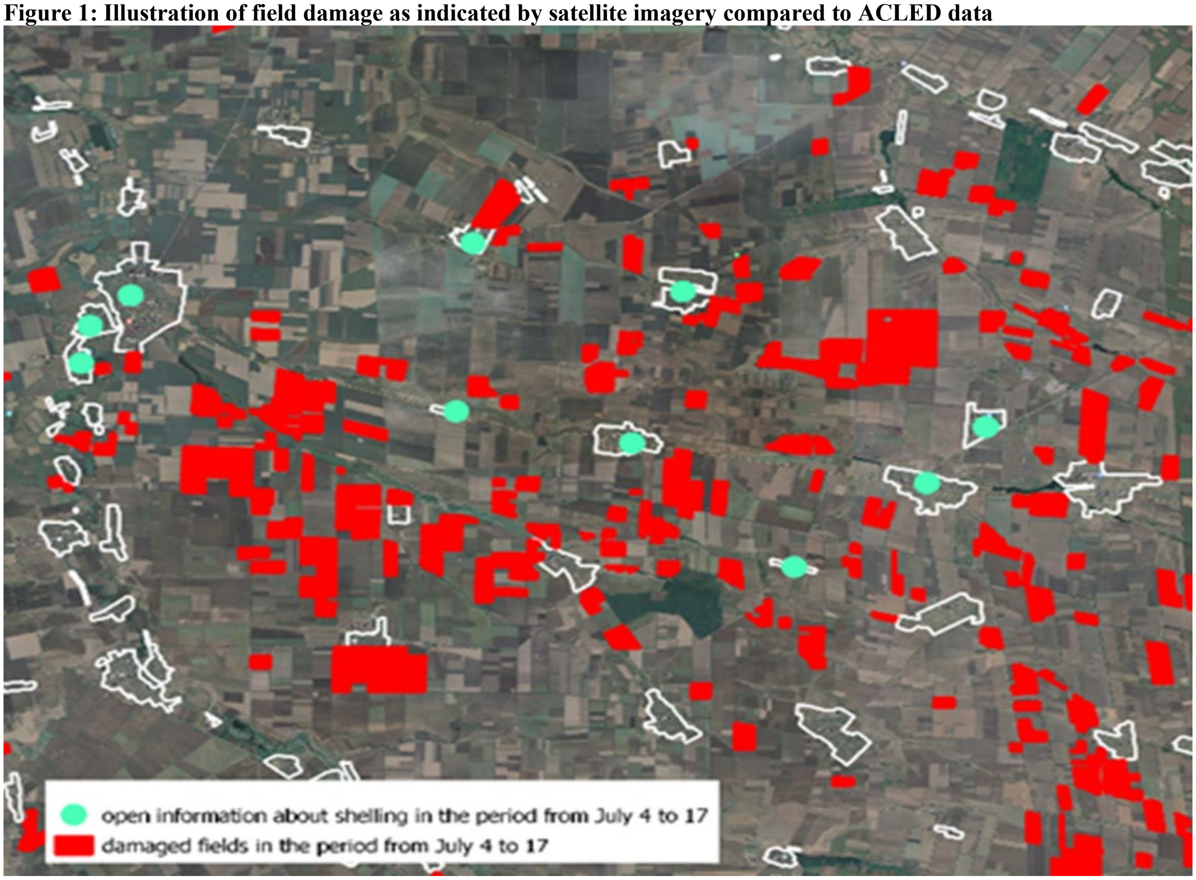
Source: UCAB price data for panel A and household survey panel data for panel B, as described in the text.
Note: Prices in panel A are in US$ and exclude value-added tax. Output prices are at the elevator in central Ukraine. Profit is the value of output net of purchased inputs, that is, it includes remuneration for fixed factors and family labor. The six main crops are wheat, barley, rapeseed, soybean, maize, and sunflower. ha = hectares; km = kilometer; t = ton.

Table 7: Farm fixed effect regressions

	Share of output sold		Value of output per ha		Cost of inputs per ha		Profit per ha	
2022 dummy (α_1)	-0.296***		-0.474***		0.227***		-476.9***	
	(0.013)		(0.017)		(0.046)		(15.779)	
2023 dummy (α_2)	-0.229***		-0.615***		-0.565***		-391.3***	
	(0.013)		(0.017)		(0.046)		(15.844)	
2022*Small (β_1)		-0.303***		-0.453***		0.253***		-444.40***
		(0.016)		(0.019)		(0.054)		(18.311)
2022*large (β_2)		-0.283***		-0.525***		0.178**		-557.39***
		(0.022)		(0.029)		(0.078)		(28.036)
2023*Small (γ_1)		-0.243***		-0.578***		-0.441***		-369.59***
		(0.017)		(0.020)		(0.056)		(19.103)
2023*large (γ_2)		-0.206***		-0.684***		-0.788***		-432.27***
		(0.021)		(0.027)		(0.074)		(25.809)
No. of obs. (farms)	3,419	3,419	2,180	2,180	1,942	1,942	2,180	2,180
R^2	0.189	0.190	0.512	0.516	0.199	0.209	0.418	0.423
Linear combinations								
$\alpha_2 - \alpha_1$	0.067***		-0.141***		-0.793***		85.681***	
	(0.013)		(0.017)		(0.046)		(15.828)	
$\beta_1 - \beta_2$		-0.020		0.072**		0.075		112.989***
		(0.027)		(0.034)		(0.092)		(32.601)
$\gamma_1 - \gamma_2$		-0.037		0.106***		0.347***		62.681**
		(0.026)		(0.033)		(0.090)		(31.174)
$\gamma_1 - \beta_1$		0.059***		-0.125***		-0.694***		74.810***
		(0.017)		(0.020)		(0.056)		(19.334)
$\gamma_2 - \beta_2$		0.077***		-0.160***		-0.965***		125.118***
		(0.023)		(0.030)		(0.082)		(29.072)
$(\gamma_1 - \gamma_2) - (\beta_1 - \beta_2)$		-0.017		0.034		0.272***		-50.308
		(0.028)		(0.037)		(0.101)		(35.461)

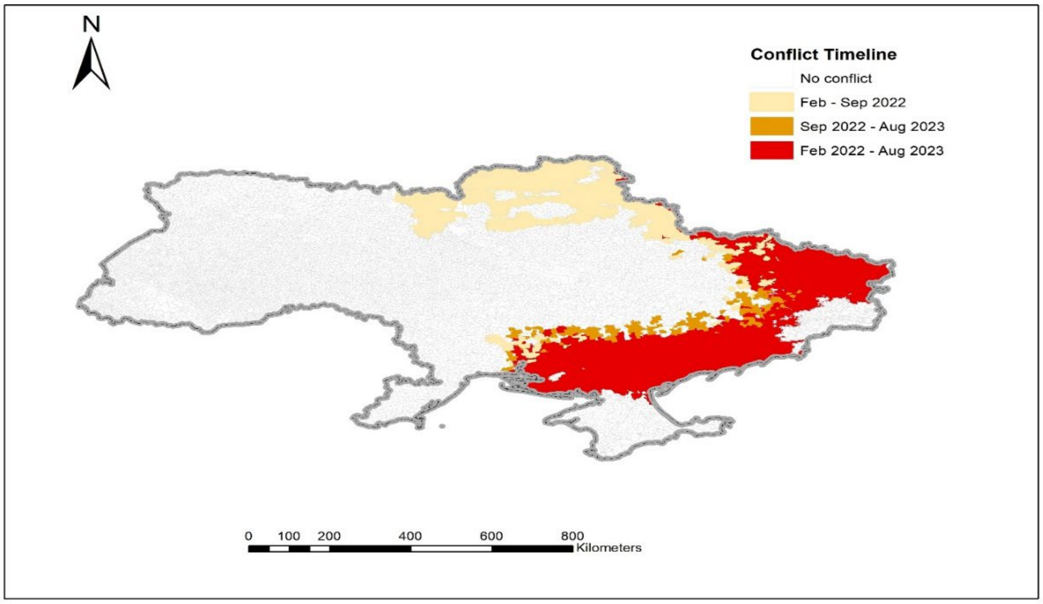
Note: Profit is the value of output net of purchased inputs, that is, it includes remuneration for fixed factors and family labor. Value of output and input/ha are in logs. Year fixed effects are included throughout but not reported. Standard errors are in parentheses, and * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. ha = hectare.

Figure 1: Illustration of field damage as indicated by satellite imagery compared to ACLED data

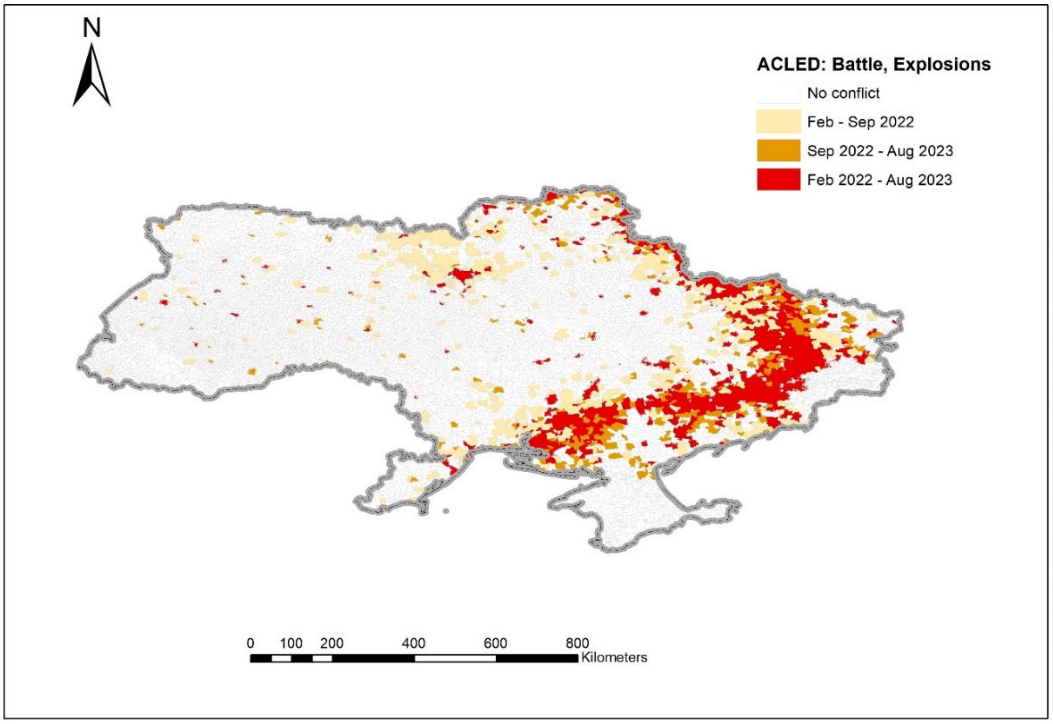


Note: The data are for July 4-17, 2022, in Novosilka city in Donetsk oblast. The boundaries of settlements are in white; fields that sustained damage from fighting are in red; and conflict activity reports about conflict activity as reported by the Armed Conflict Location and Event Data (ACLED), the methodology for which is described in more detail by Raleigh et al. (2010).

Figure 2: Measures of conflict incidence and its changes over time, 2022–23
Panel A: Ukrainian Ministry of Defense

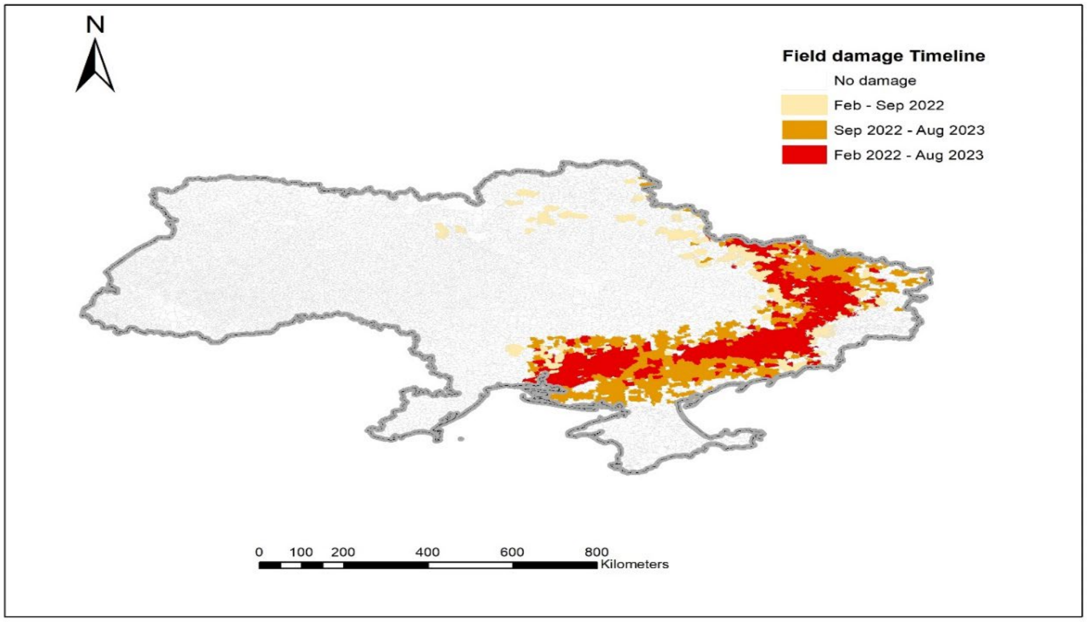


Panel B: ACLED

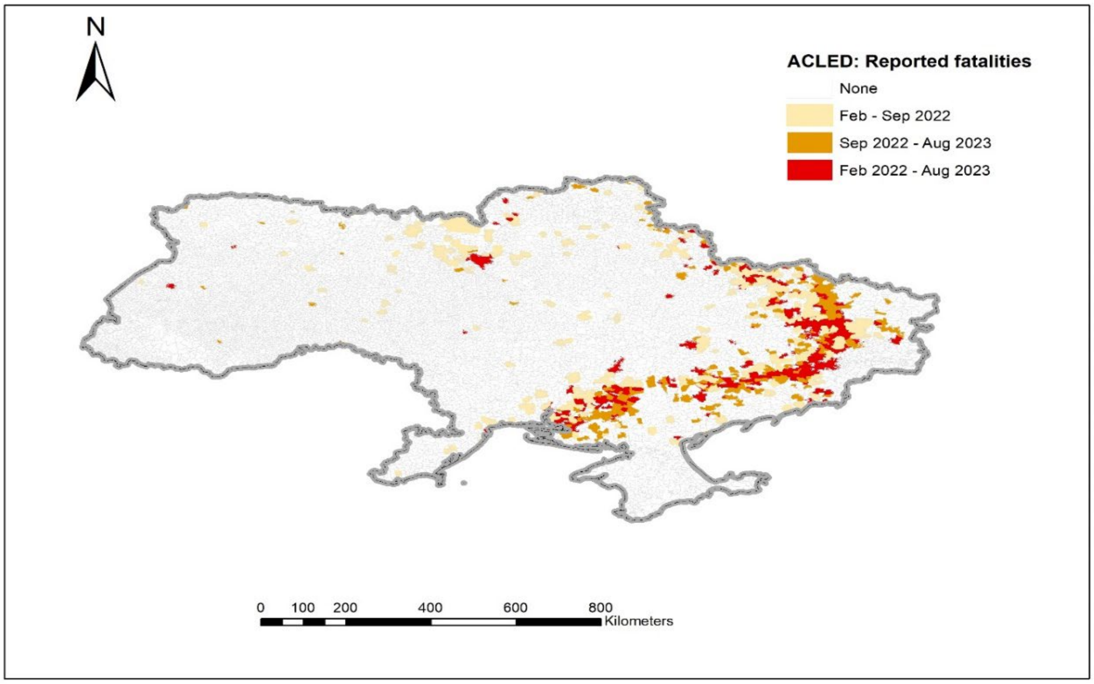


Note: ACLED = Armed Conflict Location and Events Data.

Figure 3: Measures of conflict intensity, 2022–23
Panel A: Conflict incidence based on satellite imagery



Panel B: Conflict incidence based on ACLED-reported number of fatalities due to battles and/or explosions



Note: ACLED = Armed Conflict Location and Events Data.

Figure 4: Cumulative growing degree days in the summer growing season, 2019–22

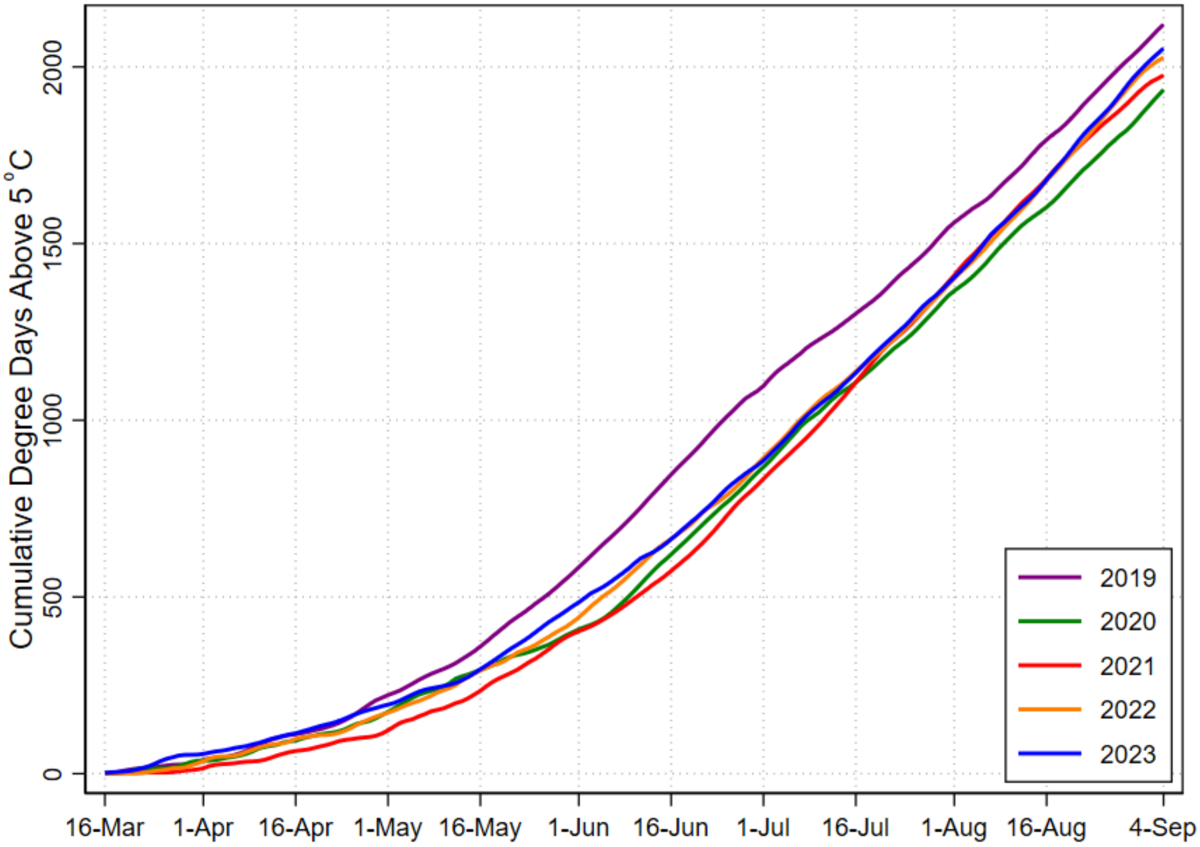
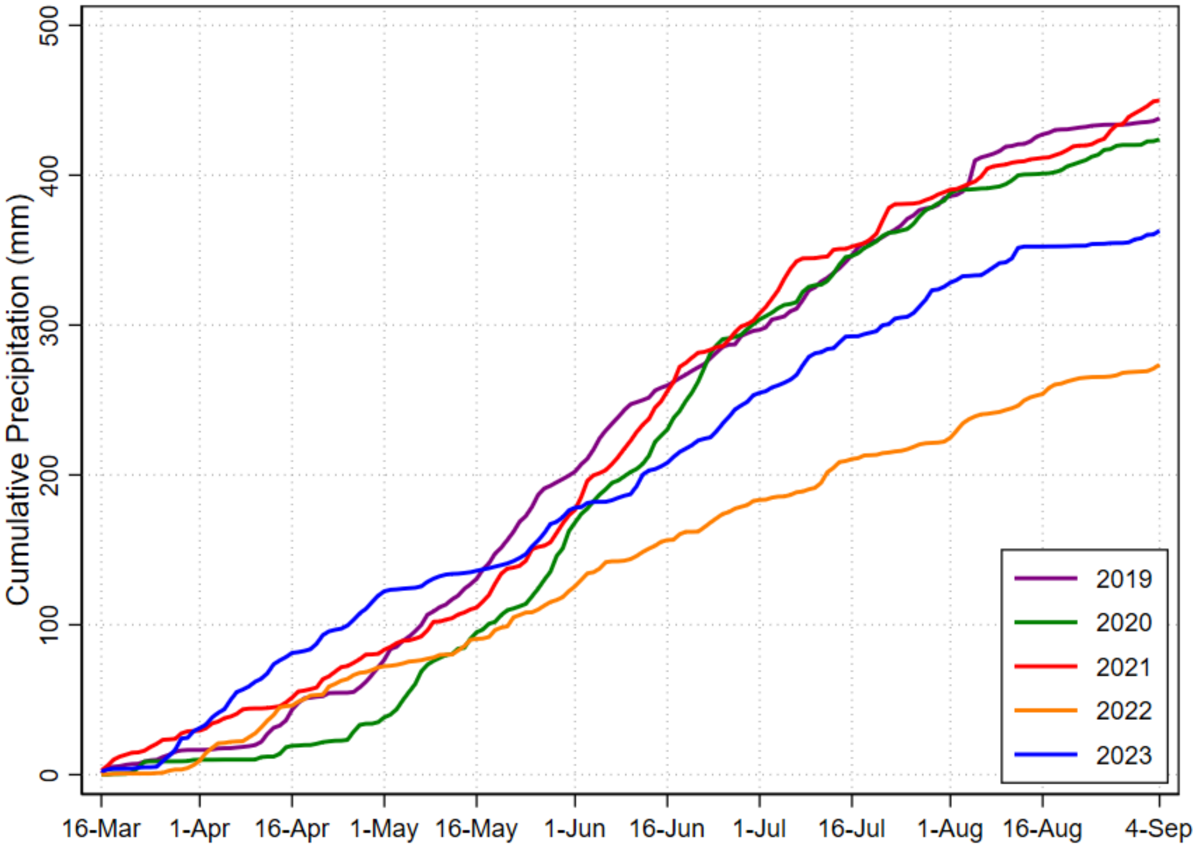


Figure 5: Cumulative rainfall in the summer growing season, 2019–22



Note: mm = millimeters.

Figure 6: Cumulative growing degree days in the winter growing season, 2019–23

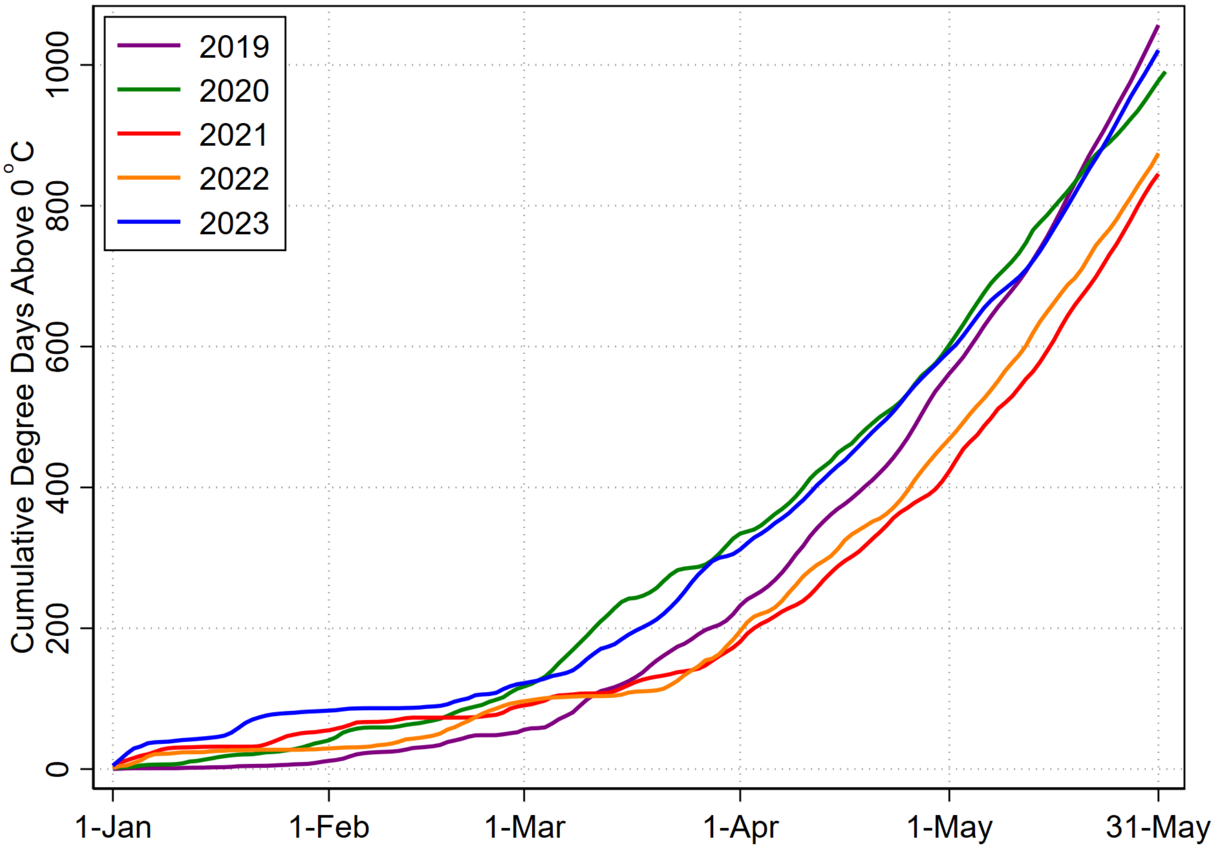
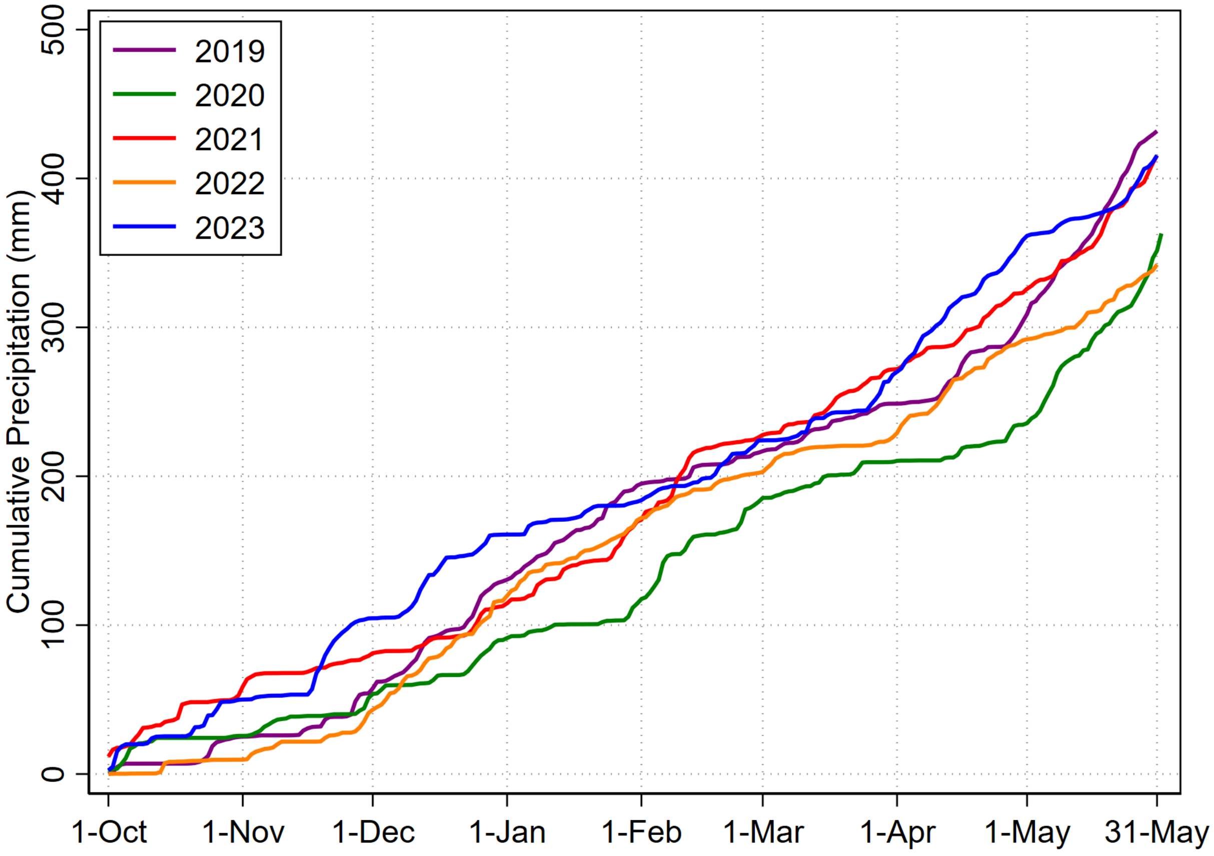


Figure 7: Cumulative rainfall in the winter growing season, 2019–23



Note: mm = millimeters.

Appendix table A1: Size of training samples and F1 scores for winter and summer crops

Year		Sample size		F1 score	
	Total	Winter crops	Summer crops	Winter crops	Summer crops
2019	2,481	779	1,702	99.3	97.9
2020	3,155	806	2,349	97.0	94.1
2021	3,644	991	2,653	99.9	98.5
2022	2,132	470	1,662	95.1	98.1
2023	3,285	404	2,881	97.5	96.5

Source: Original table for this paper.

Note The F1 score is TP/(TP+0.5*(FP+FN)) where TP is true positives, FP is false positives and FN is false negatives.

Appendix table A2: Village fixed effects regressions for winter crop area (imagery based)

	Intensity	Conflict intensity
Conflict indicator	-104.226***	-51.621***
	(16.547)	(16.521)
Lag conflict indicator	-376.087***	-174.551***
	(21.236)	(21.380)
Area damage growing period		-0.244***
		(0.024)
Lagged DA growing period		-0.587***
		(0.029)
DA planting and dormancy		-0.608***
		(0.020)
Rayon level GDD	1.289***	1.101***
	(0.219)	(0.214)
Rayon level GDD squared	-0.001***	-0.001***
	(0.000)	(0.000)
Total rainfall: fall (mm)	4.726***	3.599***
	(0.281)	(0.277)
Total rainfall: winter (mm)	1.124***	0.956***
	(0.301)	(0.295)
Total rainfall: spring (mm)	-1.191***	-1.122***
	(0.371)	(0.363)
Fall rainfall squared	-0.035***	-0.026***
	(0.002)	(0.002)
Winter rainfall squared	-0.001*	-0.001*
	(0.001)	(0.001)
Spring rainfall squared	-0.000	-0.000
	(0.001)	(0.001)
Zero rain days: fall	-3.498	5.296*
	(3.270)	(3.209)
Zero rain days: winter	5.564***	4.653***
	(1.272)	(1.246)
Zero rain days: spring	41.798***	40.330***
	(2.353)	(2.304)
Fall zero rain days squared	0.038	-0.093*
	(0.049)	(0.048)
Winter zero rain days squared	-0.122***	-0.110***
	(0.021)	(0.021)
Spring zero rain days squared	-1.064***	-1.041***
	(0.045)	(0.044)
year=2020	-68.272***	-62.789***
	(15.090)	(14.777)
year=2021	-73.541***	-77.702***
	(22.358)	(21.892)
year=2022	-119.288***	-121.134***
	(13.635)	(13.350)
year=2023	-151.201***	-157.758***
	(14.444)	(14.143)
Constant	160.077	163.452
	(126.260)	(123.608)
Mean of dep. var.	830.096	830.096
STD of dep. var.	1,137.696	1,137.696
No. of obs. (VCs)	50,010	50,010
R^2	0.886	0.891

Source: Original table for this paper.

Note: Conflict indicators and damaged crop area cover the periods from mid-August 2022 to mid-February 2023 (only for the year 2023 planting and dormancy period but zero all the other years) and end-February to mid-May (both 2022 and 2023 growing periods but zero in the pre-2022 years). Standard errors are in parentheses, and * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. DA = area damaged due to conflict; GDD = growing degree days; mm = millimeters; VC = village council.

Appendix table A3: Village fixed effects regressions for area cultivated with summer crops (imagery based)

	Intensity	**Conflict intensity**
Conflict indicator	-577.364***	-461.845***
	(14.393)	(13.420)
Lag conflict indicator	-874.098***	-577.472***
	(16.855)	(15.787)
Total damaged area		-0.800***
		(0.011)
Lag total damaged area		-0.993***
		(0.013)
Winter crop area	-0.640***	-0.719***
	(0.004)	(0.004)
Rayon GDD above 5 degrees	-1.464***	-1.429***
	(0.180)	(0.163)
GDD squared	0.000***	0.000***
	(0.000)	(0.000)
Total rainfall: sowing (mm)	1.413***	1.470***
	(0.274)	(0.249)
Total rainfall: growing (mm)	-1.100***	-0.702***
	(0.142)	(0.130)
Sowing rain squared	-0.006***	-0.006***
	(0.001)	(0.001)
Growing rain squared	0.001***	0.001**
	(0.000)	(0.000)
Sowing zero rain days	0.972	4.355***
	(1.732)	(1.576)
Growing zero rain days	37.623***	30.859***
	(1.197)	(1.091)
Sowing zero rain days squared	-0.155***	-0.243***
	(0.039)	(0.035)
Growing zero rain days squared	-1.114***	-0.896***
	(0.033)	(0.030)
year=2020	-61.460***	-79.488***
	(13.087)	(11.900)
year=2021	-167.837***	-154.500***
	(11.800)	(10.729)
year=2022	-247.974***	-206.403***
	(15.779)	(14.354)
year=2023	-152.950***	-127.412***
	(13.595)	(12.365)
Constant	3,343.763***	3,346.014***
	(146.351)	(133.054)
Mean of dep. var.	1,677.799	1,677.799
STD of dep. var.	1,543.028	1,543.028
No. of obs. (village councils)	52,780	52,780
R^2	0.958	0.965

Source: Original table for this paper.

Note: Conflict indicators and damaged crop area cover the period from mid-March to end-August in 2022 and 2023 and zero for other years. Standard errors are in parentheses, and * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. GDD = growing degree days.

Appendix table A4: Village fixed effects regressions for winter crop area

	Imagery based crop damage indicators			ACLED conflict indicators		
	Dummy	**Intensity**	**Area**	**Dummy**	**Intensity**	**Fatalities**
Conflict indicator	-513.661***	-1862.813***		-305.846***	-578.830***	
	(16.649)	(64.742)		(13.601)	(30.015)	
Lagged conflict indicator	-699.878***	-2620.708***		-296.976***	-517.607***	
	(24.991)	(76.371)		(20.022)	(45.371)	
DA or fatalities (F) growing period			-0.280***			0.418*
			(0.024)			(0.232)
Lagged DA or F growing period			-0.632***			-0.997**
			(0.029)			(0.428)
DA or F planting and dormancy			-0.648***			-0.700***
			(0.020)			(0.181)
Rayon level GDD	1.257***	1.360***	1.352***	1.487***	1.649***	1.880***
	(0.214)	(0.213)	(0.213)	(0.217)	(0.217)	(0.218)
Rayon level GDD squared	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Total rain: planting (mm)	4.793***	5.223***	4.192***	5.193***	5.459***	6.226***
	(0.270)	(0.268)	(0.271)	(0.274)	(0.274)	(0.275)
Total rain: dormancy (mm)	1.031***	1.050***	0.900***	1.262***	1.146***	1.009***
	(0.296)	(0.295)	(0.295)	(0.300)	(0.300)	(0.303)
Total rain: growing (mm)	-1.357***	-1.508***	-1.498***	-1.715***	-1.819***	-2.045***
	(0.363)	(0.362)	(0.362)	(0.368)	(0.368)	(0.371)
Planting rain squared	-0.033***	-0.037***	-0.030***	-0.037***	-0.039***	-0.046***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dormancy rain squared	-0.002*	-0.001*	-0.001	-0.002*	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Growing rain squared	0.001	0.001	0.001	0.002	0.002	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Zero rain days: fall	3.037	2.562	7.923**	0.683	1.556	1.200
	(3.209)	(3.200)	(3.204)	(3.253)	(3.261)	(3.284)
Zero rain days: winter	3.613***	3.778***	4.381***	5.872***	5.782***	4.972***
	(1.248)	(1.245)	(1.245)	(1.264)	(1.268)	(1.277)
Zero rain days: spring	40.598***	39.653***	36.773***	39.733***	37.051***	33.908***
	(2.293)	(2.285)	(2.283)	(2.327)	(2.328)	(2.342)
Planting zero rain days squared	-0.058	-0.051	-0.122**	-0.021	-0.027	-0.009
	(0.048)	(0.048)	(0.048)	(0.049)	(0.049)	(0.049)
Dormancy zero rain days squared	-0.077***	-0.078***	-0.110***	-0.116***	-0.123***	-0.123***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Growing zero rain days squared	-1.036***	-1.012***	-0.963***	-1.012***	-0.958***	-0.892***
	(0.044)	(0.044)	(0.044)	(0.045)	(0.045)	(0.045)
year==2020	-68.741***	-70.399***	-60.011***	-81.023***	-74.590***	-61.401***
	(14.823)	(14.784)	(14.786)	(15.036)	(15.073)	(15.174)
year==2021	-79.819***	-80.499***	-52.705**	-71.939***	-53.887**	-15.638
	(21.526)	(21.472)	(21.439)	(21.847)	(21.865)	(21.975)
year==2022	-106.375***	-107.024***	-118.580***	-107.430***	-109.293***	-113.429***
	(13.403)	(13.366)	(13.365)	(13.583)	(13.618)	(13.719)
year==2023	-164.721***	-166.447***	-160.158***	-160.896***	-162.945***	-155.189***
	(14.095)	(14.060)	(14.057)	(14.288)	(14.327)	(14.424)
Constant	117.946	100.886	51.410	24.148	-23.978	-90.438
	(123.326)	(122.964)	(122.919)	(124.913)	(125.215)	(126.131)
Mean of dep. var.	830.096	830.096	830.096	830.096	830.096	830.096
STD of dep. var.	1,137.696	1,137.696	1,137.696	1,137.696	1,137.696	1137.696
No. of obs. (VCs)	50,010	50,010	50,010	50,010	50,010	50,010
R^2	0.890	0.890	0.890	0.887	0.886	0.885

Source: Original table for this paper.

Note: Conflict indicators and periods for DA or F in different stages of vegetative development are as defined in table 1 in the main text. Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. ACLED = Armed Conflict Location and Events Data; DA = area damaged due to conflict; F = fatalities; GDD = growing degree days; mm = millimeters; VC = village council.

Appendix table A5: Village fixed effects regressions for area cultivated with summer crops

	Imagery based crop damage indicators			ACLED conflict indicators		
	Dummy	**Intensity**	**Area**	**Dummy**	**Intensity**	**Fatalities**
Conflict indicator	-825.879***	-3436.234***		-505.094***	-1228.522***	
	(12.071)	(62.124)		(11.395)	(26.131)	
Lag conflict indicator	-840.568***	-1518.063***		-400.526***	-994.131***	
	(16.745)	(76.555)		(13.809)	(36.626)	
Total DA or F			-0.975***			-1.252***
			(0.012)			(0.112)
Lag total DA or F			-1.145***			-0.855***
			(0.013)			(0.190)
Winter crop area	-0.683***	-0.687***	-0.705***	-0.633***	-0.634***	-0.598***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Rayon GDD above 5 degrees	-2.259***	-2.854***	-2.744***	-2.847***	-2.833***	-3.386***
	(0.177)	(0.178)	(0.170)	(0.186)	(0.185)	(0.192)
GDD squared	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Total rain: sowing (mm)	0.910***	0.341	0.474*	-0.279	-0.404	-0.181
	(0.270)	(0.272)	(0.260)	(0.284)	(0.283)	(0.294)
Total rain: growing (mm)	-0.010	0.161	-0.165	-0.302**	-0.327**	-0.416***
	(0.141)	(0.142)	(0.135)	(0.148)	(0.147)	(0.153)
Sowing rain squared	-0.004***	-0.002**	-0.003***	-0.000	0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Growing rain squared	-0.000**	-0.001**	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sowing zero rain days	-1.545	-15.255***	-12.950***	-13.727***	-15.178***	-26.224***
	(1.700)	(1.708)	(1.619)	(1.791)	(1.769)	(1.827)
Growing zero rain days	36.506***	41.243***	42.536***	47.362***	48.632***	55.669***
	(1.173)	(1.178)	(1.114)	(1.223)	(1.210)	(1.253)
Sowing zero rain days squared	-0.140***	0.127***	0.067*	0.141***	0.158***	0.347***
	(0.038)	(0.039)	(0.036)	(0.040)	(0.040)	(0.041)
Growing zero rain days sq.	-0.905***	-0.908***	-1.003***	-1.128***	-1.171***	-1.305***
	(0.033)	(0.033)	(0.031)	(0.034)	(0.034)	(0.035)
year=2020	-27.153**	-7.464	-21.125*	-62.969***	-45.522***	21.433
	(12.880)	(13.022)	(12.396)	(13.652)	(13.519)	(14.034)
year=2021	-153.385***	-179.766***	-188.026***	-219.690***	-216.532***	-224.233***
	(11.679)	(11.783)	(11.225)	(12.289)	(12.206)	(12.713)
year=2022	-225.931***	-257.814***	-270.329***	-311.593***	-321.606***	-349.788***
	(15.624)	(15.743)	(14.997)	(16.419)	(16.298)	(16.975)
year=2023	-167.703***	-267.750***	-265.770***	-272.639***	-287.130***	-367.202***
	(13.396)	(13.412)	(12.752)	(14.064)	(13.909)	(14.412)
Constant	3648.710***	4107.844***	4122.899***	4289.222***	4258.208***	4518.895***
	(144.451)	(145.642)	(138.779)	(152.278)	(151.066)	(157.205)
Mean of dep. var.	1677.799	1677.799	1677.799	1677.799	1677.799	1677.799
STD of dep. var.	1543.028	1543.028	1543.028	1543.028	1543.028	1543.028
No. of obs. (village councils)	52,780	52,780	52,780	52,780	52,780	52,780
R^2	0.959	0.958	0.962	0.954	0.955	0.951

Source: Original table for this paper.

Note: Conflict indicators, damaged crop area and fatalities cover the period mid-March to end-August in 2022 and 2023 and zero for other years. Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.010$. ACLED = Armed Conflict Location and Events Data; DA = area damaged due to conflict; F = fatalities; GDD = growing degree days; mm = millimeters.

Appendix table A6: Sample frame compared to national statistics

	Total	Farm size (ha)			
		<50	50-120	120-500	>500
Panel A: No. of farms and median/average farm size					
Total Form 29	36,167	16,138	5,400	7,142	7,487
Total SAR	75,571	61,705	6,127	4,444	3,295
….Legal Entities %	20.8	9.0	58.4	76.3	97.1
FOPs %	11.2	9.3	28.2	21.1	2.0
Individuals %	68.0	81.7	13.4	2.7	0.8
Ratio SAR/F29	2.09	3.82	1.13	0.62	0.44
Median farm size, SAR	6.65	4.92	74 .99	206.60	1,307.9
Med. farm size, Form 29	68.57	24.00	77.09	241.00	1,298.6
Avg. farm size SAR	154.0	9.75	88.70	283.11	2,802.5
Avg. farm size Form 29	777.7	25.07	79.43	264.67	3,392.9
Panel B: Area cult. (mn. ha)					
Total Form 29	27.85	0.40	0.43	1.89	25.14
Total SAR	11.64	0.60	0.54	1.26	9.23
….Legal Entities %	90.5	33.0	63.9	82.8	96.9
FOPs %	4.4	13.6	25.5	15.3	1.1
Individuals %	5.1	53.4	10.7	1.9	2.0
Ratio SAR/F29	0.42	1.49	1.27	0.67	0.37
Panel C: Informality					
Area cult. 2020 (mn. ha)	45.73				
F29 overlapping (mn. ha)	7.51	0.1	0.22	0.75	6.46
F29 non-overlap (mn. ha)	20.34	0.31	0.21	1.14	18.68
SAR only (mn. ha)	3.36	0.45	0.27	0.33	2.32
Informal (mn. ha)	14.51				

Source: Computation based on data from the SAR, 2020 Form 29 data from SSSU, and crop maps based on satellite imagery for 2020, as discussed in the text.

Note: Region is not reported in the SAR for 1,629 farms cultivating a total of 39,735 ha. FOP = family-owned business; ha = hectare; mn = million; SAR = State Agrarian Register; SSSU = State Statistics Service of Ukraine.

Appendix table A7: Likelihood of completing the follow-up survey

PSG beneficiary	0.097***	0.102***
	(0.025)	(0.026)
Applied to other programs	0.178***	0.176***
	(0.027)	(0.027)
Owner respondent	-0.021	-0.020
	(0.063)	(0.064)
Manager respondent	-0.012	-0.008
	(0.068)	(0.068)
Log holding size (ha)	-0.021**	-0.023**
	(0.010)	(0.010)
FOP	0.128***	0.123***
	(0.032)	(0.032)
Individual	0.063	0.058
	(0.041)	(0.042)
Managing multiple farms	-0.070**	-0.071**
	(0.031)	(0.031)
Considered applying for credit	0.071***	0.070**
	(0.027)	(0.027)
Personal situation on a scale of 1 to 10	0.007	0.008
	(0.006)	(0.006)
Not directly affect by conflict	0.046	0.048
	(0.039)	(0.041)
East		0.022
		(0.053)
North		-0.019
		(0.035)
South		-0.027
		(0.030)
West		-0.065*
		(0.035)
No. of obs. (farms)	2,101	2,101

Source: Original table for this paper.
Note: Standard errors in parentheses: * p < 0.10, ** p < 0.05, and *** p < 0.010. Coefficients reported are marginal effects from a probit model. FOP = family-owned business; ha = hectare; PSG = producer support grant.

References:

Abay, K. A., et al. 2023a. "The Russia-Ukraine War: Implications for Global and Regional Food Security and Potential Policy Responses." *Global Food Security* 36: 100675.

Abay, K. A., et al. 2023b. "Near-Real-Time Welfare and Livelihood Impacts of an Active War: Evidence from Ethiopia." *Food Policy* 119: 102526.

Adelaja, A., et al. 2023. "Stepping-Up: Impacts of Armed Conflicts on Land Expansion." *Journal of Agricultural and Applied Economics* 55 (4): 748-769.

Adema, J., C. G. Aksoy, Y. Giesing and P. Poutvaara. 2023. "The Effect of Conflict on Ukrainian Refugees' Return and Integration." CESifo, CESifo Working Paper Series: 10877.

Ahn, S., D. Kim and S. Steinbach. 2023. "The Impact of the Russian Invasion of Ukraine on Grain and Oilseed Trade." *Agribusiness* 39 (1): 291-299.

Akresh, R., G. D. Caruso and H. Thirumurthy. 2022. "Detailed Geographic Information, Conflict Exposure, and Health Impacts." *World Development* 155: 105890.

Akresh, R., S. Bhalotra, M. Leone and U. Osili. 2023. "First- and Second-Generation Impacts of the Biafran War." *Journal of Human Resources* 58 (2): 1-45.

Alix-Garcia, J., A. Bartlett and D. Saah. 2013. "The Landscape of Conflict: Idps, Aid and Land-Use Change in Darfur." *Journal of Economic Geography* 13 (4): 589-617.

Amodio, F. and M. Di Maio. 2018. "Making Do with What You Have: Conflict, Input Misallocation and Firm Performance." *Economic Journal* 128 (615): 2559-2612.

Arias, M. A., A. M. Ibáñez and A. Zambrano. 2019. "Agricultural Production Amid Conflict: Separating the Effects of Conflict into Shocks and Uncertainty." *World Development* 119: 165-184.

Balma, L., et al. 2022. "Long-Run Impacts of the Conflict in Ukraine on Food Security in Africa." Kiel Institute for the World Economy, Kiel.

Ben Hassen, T. and H. El Bilali. 2022. "Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems?" *Foods* 11 (15).

Ben Yishay, A., R. Sayers and K. Sing. 2024. "Landmine Clearance and Economic Development: Evidence from Nighttime Lights, Multispectral Satellite Imagery, and Conflict Events in Afghanistan." College of William & Mary, Blacksburg.

Bluszcz, J. and M. Valente. 2022. "The Economic Costs of Hybrid Wars: The Case of Ukraine." *Defence and Peace Economics* 33 (1): 1-25.

Büttner, N., M. Grimm and S. Soubeiga. 2022. "Political Instability and Households' Investment Behavior: Evidence from Burkina Faso." *Journal of Comparative Economics* 50 (2): 350-368.

Chiovelli, G., S. Michalopoulos and E. Papaioannou. 2018. "Landmines and Spatial Development." National Bureau of Economic Research, Inc, NBER Working Papers: 24758.

Chiovelli, G., S. Michalopoulos, E. Papaioannou and S. Sequeira. 2021. "Forced Displacement and Human Capital: Evidence from Separated Siblings." National Bureau of Economic Research, Inc, NBER Working Papers: 29589.

Couttenier, M., N. Monnet and L. Piemontese. 2022. "The Economic Costs of Conflict: A Production Network Approach." Centre for Economic Policy Research, Discussion Paper DP16984, London.

d'Agostino, A. L. and W. Schlenker. 2016. "Recent Weather Fluctuations and Agricultural Yields: Implications for Climate Change." *Agricultural Economics* 47: 159-171.

Dara, A., et al. 2020. "Annual Landsat Time Series Reveal Post-Soviet Changes in Grazing Pressure." *Remote Sensing of Environment* 239: 111667.

de Roux, N. and L. R. Martinez. 2021. "Forgone Investment: Civil Conflict and Agricultural Credit in Colombia." Johns Hopkins University, Washington DC.

Deines, J. M., et al. 2021. "A Million Kernels of Truth: Insights into Scalable Satellite Maize Yield Mapping and Yield Gap Analysis from an Extensive Ground Dataset in the Us Corn Belt." *Remote Sensing of Environment* 253: 112174.

Deininger, K., D. Nizalov and S. K. Singh. 2018. "Determinants of Productivity and Structural Change in a Large Commercial Farm Environment: Evidence from Ukraine." *The World Bank Economic Review* 32 (2): 287-306.

Deininger, K., et al. 2023a. "Quantifying War-Induced Crop Losses in Ukraine in near Real Time to Strengthen Local and Global Food Security." *Food Policy* 115: 102418.

Deininger, K. W., D. A. Ali and R. Neyter. 2023b. "Impacts of a Mandatory Shift to Decentralized Online Auctions on Revenue from Public Land Leases in Ukraine." *Journal of Economic Behavior & Organization* 213: 432-450.

Devadoss, S. and W. Ridley. 2024. "Impacts of the Russian Invasion of Ukraine on the Global Wheat Market." *World Development* 173: 106396.

Duncan, E. C., S. Skakun, A. Kariryaa and A. V. Prishchepov. 2023. "Detection and Mapping of Artillery Craters with Very High Spatial Resolution Satellite Imagery and Deep Learning." *Science of Remote Sensing* 7: 100092.

Egert, B., C. d. la Maisonneuve and B. Egert. 2023. "The Impact of the War on Human Capital and Productivity in Ukraine." CESifo, CESifo Working Paper Series: 10513.

Fang, M., S. Jin, K. Deininger and M. Gammans. 2023. "Heterogenous Climate Impacts on Crop Yields: Evidence from Ukraine." *Environmental Research Communications* 5 (10): 105015.

Federle, J., A. Meier, G. Muller and V. Sehn. 2022. "Proximity to War: The Stock Market Response to the Russian Invasion of Ukraine." CEPR Discussion Paper 17185.

Fergusson, L., A. M. Ibanez and J. F. Riano. 2020. "Conflict, Educational Attainment, and Structural Transformation: La Violencia in Colombia." *Economic Development and Cultural Change* 69 (1): 335-371.

George, J., A. Adelaja and D. Weatherspoon. 2020. "Armed Conflicts and Food Insecurity: Evidence from Boko Haram's Attacks." *American Journal of Agricultural Economics* 102 (1): 114-131.

Glauben, T., et al. 2022. "The War in Ukraine, Agricultural Trade and Risks to Global Food Security." *Review of European Economic Policy* 57 (3): 157-163.

Ibanez, A. M., A. Moya and A. Velasquez. 2022. "Promoting Recovery and Resilience for Internally Displaced Persons: Lessons from Colombia." *Oxford Review of Economic Policy* 38 (3): 595-624.

Korovkin, V. and A. Makarin. 2023. "Conflict and Intergroup Trade: Evidence from the 2014 Russia-Ukraine Crisis." *American Economic Review* 113 (1): 34-70.

Kussul, N., Lavreniuk, M., Skakun, S., Shelestov, A., 2017. Deep Learning Classification of Land Cover and Crop Types Using Remote Sensing Data. IEEE Geoscience and Remote Sensing Letters 14, 778-782.

Kussul, N., A. Shelestov and G. Lemoine. 2023. "Using Freely Available Imagery to Identify Damage from Military Action: A Machine Learning Approach Applied to Ukraine ", *Paper Presented at the 9th International Conference on Agricultural Statistics*, World Bank, Washington DC.

Lark, T. J., R. M. Mueller, D. M. Johnson and H. K. Gibbs. 2017. "Measuring Land-Use and Land-Cover Change Using the U.S. Department of Agriculture's Cropland Data Layer: Cautions and Recommendations." *International Journal of Applied Earth Observation and Geoinformation* 62: 224-235.

Leasure, D. R., et al. 2023. "Nowcasting Daily Population Displacement in Ukraine through Social Media Advertising Data." *Population and Development Review* 49 (2): 231-254.

Lin, E., C. D. Sprunger and J. Hwang. 2021. "The Farmer's Battlefield: Traditional Ecological Knowledge and Unexploded Bombs in Cambodia." *Agriculture and Human Values* 38 (3): 827-837.

Lin, F., et al. 2023. "The Impact of Russia-Ukraine Conflict on Global Food Security." *Global Food Security* 36: 100661.

Lobell, D. B., et al. 2020. "Eyes in the Sky, Boots on the Ground: Assessing Satellite- and Ground-Based Approaches to Crop Yield Measurement and Analysis." *American Journal of Agricultural Economics* 102 (1): 202-219.

Matasov, V., A. V. Prishchepov, M. R. Jepsen and D. Müller. 2019. "Spatial Determinants and Underlying Drivers of Land-Use Transitions in European Russia from 1770 to 2010." *Journal of Land Use Science* 14 (4-6): 362-377.

Meyfroidt, P., et al. 2016. "Drivers, Constraints and Trade-Offs Associated with Recultivating Abandoned Cropland in Russia, Ukraine and Kazakhstan." *Global Environmental Change* 37: 1-15.

Miguel, E. and G. Roland. 2011. "The Long-Run Impact of Bombing Vietnam." *Journal of Development Economics* 96 (1): 1-15.

Munteanu, C., et al. 2017. "Nineteenth-Century Land-Use Legacies Affect Contemporary Land Abandonment in the Carpathians." *Regional Environmental Change* 17 (8): 2209-2222.

Muriuki, J., et al. 2023. "Spillover Effect of Violent Conflicts on Food Insecurity in Sub-Saharan Africa." *Food Policy* 115.

Neyter, R., S. Zorya and O. Muliar. 2024. "Agricultural War Damages, Losses, and Needs Review ", Kyiv School of Economics, Kyiv.

Nivievskyi, O. 2020. "Where Is the State Agricultural Land Disappearing?", Economic Pravda, Kyiv.

Nivievskyi, O., O. Donchenko and P. Iavorskyi. 2021. "Assessing the Role of Small Farmers and Households in Agriculture and the Rural Economy and Measures to Support Their Sustainable Development." Kyiv School of Economics, Kyiv.

Potapov, P., et al. 2022. "Global Maps of Cropland Extent and Change Show Accelerated Cropland Expansion in the Twenty-First Century." *Nature Food* 3 (1): 19-28.

Raleigh, C., A. Linke, H. Hegre and J. Karlsen. 2010. "Introducing Acled: An Armed Conflict Location and Event Dataset: Special Data Feature." *Journal of Peace Research* 47 (5): 651-660.

Rockmore, M. 2020. "Conflict-Risk and Agricultural Portfolios: Evidence from Northern Uganda." *Journal of Development Studies* 56 (10): 1856-1876.

Rose, A., Z. Chen and D. Wei. 2023. "The Economic Impacts of Russia–Ukraine War Export Disruptions of Grain Commodities." *Applied Economic Perspectives and Policy* 45 (2): 645-665.

Sessou, F. E. and C. H. C. A. Henning. 2024. "Conflict and Farm Inputs Investment : Can Social Safety Nets Have Any Mitigation Effect?" *Applied Economics* 56 (17): 1991-2007.

Shelestov, A., Lavreniuk, M., Kussul, N., Novikov, A., Skakun, S., 2017. Exploring Google Earth Engine Platform for Big Data Processing: Classification of Multi-Temporal Satellite Imagery for Crop Mapping. Frontiers in Earth Science 5.

Shelestov, A., Lavreniuk, M., Vasiliev, V., Shumilo, L., Kolotii, A., Yailymov, B., Kussul, N., Yailymova, H., 2020. Cloud Approach to Automated Crop Classification Using Sentinel-1 Imagery. IEEE Trans. Big Data 6, 572-582.

Sinha, R., L. Aghabarari and A. Rostom. 2022. "Conflict and the Nature of Precautionary Wealth." *Oxford Economic Papers* 74 (2): 567-593.

Smith, A. 2023. "How Did Russia's Invasion of Ukraine Affect Global Food Supplies?" *Choices: The Magazine of Food, Farm & Resource Issues* 38 (2): 5-12.

von Cramon-Taubadel, S., 2022. Russia's Invasion of Ukraine – Implications for Grain Markets and Food Security. German Journal of Agricultural Economics 71, 1-13

von Cramon-Taubadel, S. and O. Nivievskyi. 2023. "Rebuilding Ukraine--the Agricultural Perspective." *EconPol Forum* 24 (2): 36-40.

Waldner, F., et al. 2019. "Roadside Collection of Training Data for Cropland Mapping Is Viable When Environmental and Management Gradients Are Surveyed." *International Journal of Applied Earth Observation and Geoinformation* 80: 82-93.

Wilson, W. W., P. Lakkakula and D. W. Bullock. 2024. "Implications of the Russian Invasion on the Logistical Competition for Corn Shipments from the United States and Ukraine." *Journal of Agricultural & Resource Economics* 49 (1): 162-184.

Witmer, F. D. W. 2015. "Remote Sensing of Violent Conflict: Eyes from Above." *International Journal of Remote Sensing* 36 (9): 2326-2352.

Zhou, W.-X., Y.-S. Dai, K. T. Duong and P.-F. Dai. 2024. "The Impact of the Russia-Ukraine Conflict on the Extreme Risk Spillovers between Agricultural Futures and Spots." *Journal of Economic Behavior and Organization* 217: 91-111.

Zhukov, Y. M. 2023. "Near-Real Time Analysis of War and Economic Activity During Russia's Invasion of Ukraine." *Journal of Comparative Economics* 51 (4): 1232-1243.