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RUSSIAN MISSILE ATTACKS ON SOUTHERN UKRAINE: IMPACT ON GLOBAL FOOD SECURITY AND GRAIN MARKET

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РОСІЙСЬКІ РАКЕТНІ АТАКИ НА ПІВДЕНЬ УКРАЇНИ: ВПЛИВ НА ГЛОБАЛЬНУ ПРОДОВОЛЬЧУ БЕЗПЕКУ ТА РИНОК ЗЕРНА

Russian missile and drone attacks in southern Ukraine raise critical concerns for global food security and trade. Ukraine is famous as one of the major global player in agricultural production, with significant contributions to the international supply of agricultural commodities like sunflower oil, wheat, and corn. However, the

outbreak of the Russian invasion radically changed the conditions of production and export of Ukrainian agricultural products, presenting unprecedented challenges to Ukraine's agricultural exports and, consequently, global food security. The war has disrupted vital supply chains, rendering Ukraine's status as a major grain exporter highly vulnerable.

This study assesses the frequency and intensity of missile and drone attacks by Russia on the territory of Ukraine, with a particular focus on attacks in the southern regions of Ukraine. The study employs a dataset spanning from September 2022 to October 2023, providing a nuanced understanding of the evolving conflict dynamics. The research emphasizes the critical role of southern Ukraine and Black Sea ports in grain production and export, making it one of a prime target for Russian military actions. This study provides valuable insights into the impact of these attacks on grain production and supply, as well as transportation networks. By understanding patterns in Russian missile attacks in southern Ukraine, policymakers can better address the challenges posed by conflict, ultimately safeguarding global grain supply chains and enhancing food security. This research contributes to a broader understanding of the geopolitical implications of such conflicts, benefiting policymakers, agricultural stakeholders, and the international community.

The article concludes by proposing strategic measures to mitigate the impact of these attacks on Ukraine's agricultural sector. Recommendations include enhancing air defense systems, seeking international support, and developing a comprehensive strategic plan for safeguarding port facilities.

Ракетні та безпілотні атаки Росії на південь України викликають серйозні занепокоєння щодо глобальної продовольчої безпеки та торгівлі. Україна є одним із провідних гравців на світовому ринку сільськогосподарської продукції зі значними внесками у міжнародне постачання сільськогосподарською сировиною, такою як соняшникова олія, пшениця та кукурудза. Однак широкомасштабне вторгнення російських військ радикально змінило умови виробництва та експорту сільськогосподарської продукції

України, ставлячи перед нею безпрецедентні виклики щодо експорту сільськогосподарської продукції та, відповідно, глобальної продовольчої безпеки. Війна порушила важливі ланцюги постачання, зробивши статус України як провідного експортера зерна надзвичайно вразливим.

Дане дослідження оцінює частоту та інтенсивність ракетних та безпілотних атак Росії по території України, акцентуючи увагу саме на атаках по південних регіонах України. Ми використовуємо набір даних, який охоплює період з вересня 2022 року по жовтень 2023 року та включає інформацію щодо інтенсивності російських ракетних та безпілотних атак. Дослідження підкреслює критичну роль південної України та чорноморських портів у виробництві та експорті зерна, роблячи їх однією з ключових мішеней для російських військових атак. Це дослідження надає цінні відомості щодо впливу цих атак на виробництво та постачання зерна, а також на транспортні мережі. Розуміючи, як ракетні атаки Росії впливають на південну частину України, політики можуть ефективніше реагувати на виклики, що виникають у зв'язку з конфліктом. Це сприяє забезпеченню безпеки у глобальних ланцюгах постачання зерна та підвищенню продовольчої безпеки. Дослідження також допомагає кращому розумінню геополітичних наслідків подібних конфліктів і приносить користь політикам, учасникам аграрного сектору та міжнародній спільноті.

Наприкінці запропоновано стратегічні заходи для пом'якшення впливу цих атак на аграрний сектор України. Рекомендації включають удосконалення систем повітряної оборони, пошук міжнародної підтримки та розробку комплексного стратегічного плану для захисту портів споруд.

Keywords: food security, grain production and supply, missile attacks, southern regions of Ukraine.

Ключові слова: продовольча безпека, виробництво та постачання зерна, ракетні атаки, південні регіони України.

General problem statement. Ukraine plays a pivotal role in global food supply, with its agricultural and food sector accounting for nearly 10% of its GDP. Agricultural products, including wheat, corn, and sunflower oil, constitute a significant portion of Ukraine's exports, impacting over 400 million people in regions traditionally prone to food shortages [1]. Russian missile attacks in southern Ukraine cause significant damage to the agricultural sector and port infrastructure of Ukraine, disrupts global grain supply chains and raise critical concerns for global food security and trade. Therefore, the analysis of historical data on the frequency and intensity of Russian air attacks and the study of the patterns of Russian missile attacks on southern Ukraine is currently an important practical issue. The insights derived from the analysis of historical data offer valuable information for policymakers. Understanding the patterns and trends in Russian missile attacks enables policymakers to anticipate and address challenges more effectively. By identifying key areas of vulnerability, policymakers can develop strategies to safeguard critical infrastructure, enhance security measures, and mitigate the impact on grain production and supply chains.

Analysis of recent research and publications. Despite the importance and extreme relevance of the topic, research on this issue cannot be considered exhaustive. An analysis of the latest research and publications on this topic shows the predominance of analytical reports such as, for example [2-4]. It should also be noted that there is significant and growing interest in this topic from both Ukrainian [5, 6] and international scientists [7-9], reflecting widespread recognition of the consequences of Russian missile attacks on southern Ukraine for the agricultural sector and global grain markets. The existing body of research lays the foundation for our study, which aims to provide additional information and a detailed understanding of the evolving conflict dynamics.

The purpose of the article is to analyze the frequency and intensity of Russian missile and drone attacks on southern Ukraine, using historical data. The primary goals are to assess conflict dynamics, provide actionable insights for policymakers,

contribute to a global understanding of geopolitical implications, and support future decision-making in safeguarding global food security.

Results of the study. As we have already noted, Ukraine is a key producer and exporter of cereals on the global food market. On an annual basis, an average of 50 million tons of agricultural products were traditionally exported from Ukraine. Since the onset of the Russian invasion, finding alternative suppliers to replace such substantial volumes of Ukrainian agricultural products has proven to be a formidable challenge. Experts contend that achieving this is practically impossible, even within the next 3-5 years [10].

The invasion of Russian army in Ukraine poses a significant threat to global food security, especially impacting certain countries in the MENA region (such as Egypt, Yemen, Lebanon, Israel, Libya, Tunisia, Morocco, Iraq, Saudi Arabia) and Asian nations (including Indonesia, Bangladesh, and Pakistan). These countries are major purchasers of wheat and corn in the global markets.

Approximately 25% of the world's cereal trade has been affected by the war, leading to an upsurge in global prices, food inflation, and restricted access to food for nations reliant on Ukrainian imports. The Russian attack has brought about a shift in the world's food supply chains. The inability of Ukraine to deliver its products to the global market has set off a chain reaction: developed nations are increasing their stockpiles, and many countries are imposing trade restrictions amidst the prevailing uncertainty. Consequently, prices are escalating further, heightening the risk of hunger in economically disadvantaged countries. [11].

Before the war, 89% of Ukraine's grain exports were directed through Black Sea ports. Odessa, Chornomorsk, Pivdennyi, and Mykolaiv together handled up to 6 million tons of grain per month in 2021. With the onset of the war, the maritime ports were blocked, and two of them, Berdiansk and Mariupol, were occupied by Russian forces.

In July 2022, Russia signed a “grain agreement” with the United Nations Organization and Turkey, promising not to shell the port infrastructure of three ports: Chornomorsk, Odessa, and Pivdennyi. In fact, the "grain agreement" worked

effectively for the first three months. From August to October 2022, 421 ships used it. They exported 9.7 million tons of wheat, corn, sunflower, and oil.

Afterward, Russia began sabotaging the corridor's operation and, instead of allowing five to six ships per day, it averaged one to two. During the corridor's operation, more than 32 million tons of grain were exported [12].

On July 17, 2023 Russia withdrew from the corridor and revoked guarantees of maritime safety within the Black Sea Grain Agreement. Two days later, Russia shelled two ports involved in the "grain agreement" The goal of the attack on grain terminals was to destroy any means of supplying grain to the global markets, said the Minister of Community Development, Territories, and Infrastructure of Ukraine, Oleksandr Kubrakov [13].

Currently, the ports of the Danube cluster remain the sole waterway for Ukrainian agro-exports and require protection with robust air defense systems.

According to the Minister of Infrastructure of Ukraine, Oleksandr Kubrakov, as of October 14, 2023 since Russia's exit from the grain agreement, Russian forces have carried out 17 mass attacks on the port infrastructure of Ukraine. As a result of Russia's attacks on Ukrainian ports, more than 100 objects of port infrastructure have been damaged and partially destroyed. Additionally, due to the attacks, the occupiers destroyed nearly 300,000 tons of grain [13].

The article focuses on analyzing missile and drone attacks in southern Ukraine, particularly in the Odessa, Kherson, and Mykolaiv regions. The research findings paint a comprehensive picture of the conflict's dynamics in southern Ukraine, revealing critical insights into the frequency, intensity, and patterns of Russian missile and drone attacks.

For our research, we used a dataset that is freely accessible and contains available information about launched and shot down missiles and drones during Russian massive missile and drone (UAV) strikes on infrastructure as part of its invasion of Ukraine. The data is available from September 28, 2022 to the October 15, 2023.

The dataset was created based on the official reports of Air Force Command of UA Armed Forces and General Staff of the Armed Forces of Ukraine published on social media such as Facebook and Twitter. The dataset is available on Kaggle platform [14] and includes the following information for each attack:

- time_start- start attack time;
- category - missile or drone (UAV) type;
- launch_place - city or region from missiles were launched;
- target - could be a city in Ukraine, or region of Ukraine or direction, or full Ukraine;
- carrier - missile launch platform;
- launched - number of launched missiles or UAVs;
- destroyed - number of destroyed missiles or UAVs;
- destroyed_ratio – percentage of destroyed missiles or UAVs.

Initially, we aim to provide a brief characterization of the intensity of Russian missile and drone attacks across Ukraine as a whole, covering the period from late September 2022 to to October 2023. The figure 1 provides a month-by-month count of Russian missile and drone attacks on the territory of Ukraine during the period under study.

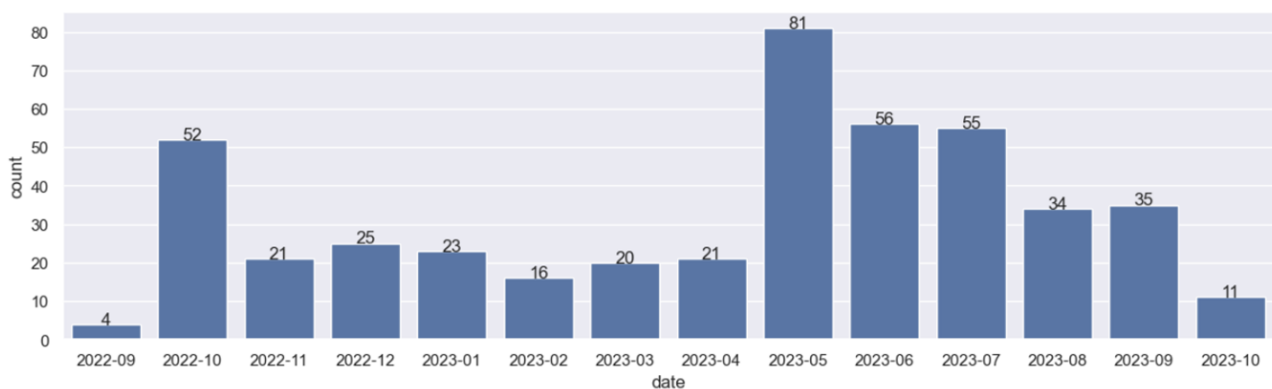


Figure 1. Month-by-month count of Russian missile and drone attacks on the territory of Ukraine from September 2022 to October 2023

Source: developed by the author based on [14]

Table 1 summarizes the information about launched and shot down missiles and drones (UAV) during Russian massive missile and drone strikes on infrastructure and destruction ratio for each attack from September 28, 2022, to October 15, 2023.

Table 1. Russian missile and drone attacks on Ukraine from late September 2022 to October 2023: intensity summary

category of weapon	year	launched, total	destroyed, total	destroyed_ratio, %
UAV	2022	459	432	94.12
	2023	2248	1935	86.08
ballistic missile	2023	14	10	71.43
cruise missile	2022	573	417	72.77
	2023	1017	758	74.53
guided bomb	2023	2	0	0
surface-to-air missile	2022	43	0	0
	2023	63	0	0
not given	2022	82	60	73.17
	2023	54	33	61.11

Source: developed by the author based on [14]

The data suggests a significant level of conflict, with various types of missiles and drones being employed, and different levels of success in countering them.

UAVs have been widely used, with a significant increase in the number of launches in 2023. The destruction ratio has decreased but remains relatively high.

Cruise missiles and ballistic missiles have also been used, with a relatively consistent destruction ratio in 2023. The use of guided bombs resulted in a 0% destruction ratio, indicating they were not effectively countered. Surface-to-air missiles were launched, but no information about their destruction is available. In cases where the weapon type is not specified, there is still a relatively high destruction ratio.

Further the focus of the article shifts towards a more in-depth analysis of the southern region of Ukraine, specifically targeting Odessa, Kherson, and Mykolaiv regions. This shift is prompted by Russia's strategic redirection of its strikes to these regions following the withdrawal from the grain agreement.

The regions of Ukraine were divided into two groups: "southern regions" (covering Odesa, Kherson, and Mykolaiv regions) and "other regions" (including all

other regions), and a comparative analysis of Russian missile and drone attacks was conducted separately for each group for the period from September 2022 to October 2023. The results are presented in Figure 2.

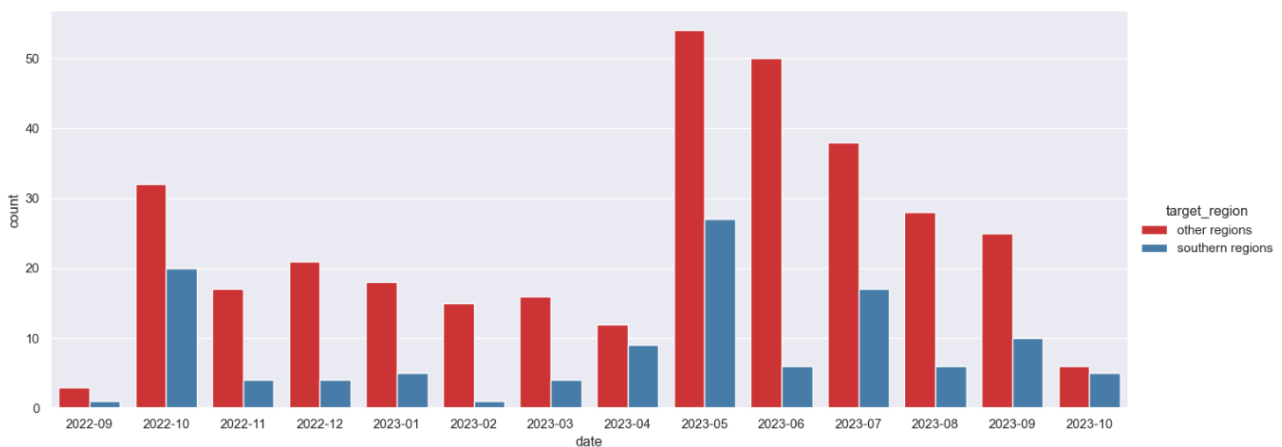


Figure 2. Comparative analysis of Russian missile and drone attacks: southern regions vs. other regions (September 2022 - October 2023)

Source: developed by the author based on [14]

The analysis reveals a dynamic pattern of attacks, with spikes in hostilities during specific months, notably in October 2022 and May 2023. When calculating the number of attacks, we included different types of weapons, including UAVs (unmanned aerial vehicles, commonly known as drones), cruise missiles and ballistic missiles.

Despite the smaller number of regions in the "southern region" group, it has experienced a noteworthy frequency of missile and drone attacks, surpassing that of the "other region" group. This suggests a heightened vulnerability in the southern regions. The specific targeting of the "southern region" group, characterized by elevated attack numbers relative to its geographical size, underscores its strategic significance and susceptibility to missile and drone strikes.

Contrastingly, the "other region" group, encompassing a larger number of regions, witnessed attacks of a higher overall count due to its extensive geographical coverage. However, the distribution of attacks across its member regions within this group may be less concentrated compared to the "southern region".

Further, an analysis of Russian attacks specifically on the southern regions of Ukraine is conducted during the period after July 17, 2023, when Russia revoked guarantees of maritime safety within the Black Sea Grain Initiative and initiated efforts to damage port infrastructure in southern Ukraine. Table 2 illustrates the intensity of Russian missile and drone attacks on the southern regions of Ukraine after July 17, 2023. The data is categorized by month, weapon type (UAV, ballistic missile, cruise missile), and includes the total number launched, the total number destroyed, and the destruction ratio.

Table 2. Russian attacks on Southern Ukraine post-maritime safety revocation: July 18 - October 15, 2023

month	category	launched, total	destroyed, total	destroyed_ratio, %
July	UAV	3	3	100
	ballistic missile	2	2	100
	cruise missile	52	14	26.92
August	UAV	48	39	81.25
	cruise missile	12	12	100
September	UAV	136	113	83.09
	cruise missile	24	17	70.83
October	UAV	99	71	71.72

Source: developed by the author based on [14]

There is a noticeable escalation in the number of attacks, particularly in the later months. After Russia's revocation of maritime safety guarantees, there was a significant increase in the intensity of attacks, reflecting an uptick in hostilities and an active phase of the conflict. The data (see Table 2) reflects an ongoing conflict in the southern region of Ukraine, with a combination of missile and drone attacks.

UAV attacks were the most prevalent throughout the specified period, with a gradual increase in numbers. The destruction ratio for UAVs remained relatively high, indicating effective defense.

Cruise missile attacks were also frequent, with a noticeable decline in their destruction ratio, suggesting that they presented a more significant challenge for defense systems.

Ballistic missile attacks were relatively less common but had a 100% destruction ratio, meaning all were successfully intercepted.

Overall, the data shows that the southern region of Ukraine experienced a sustained level of attacks, and the defense efforts were more successful in countering UAV and ballistic missile threats compared to cruise missiles.

Finally, we will analyze the geographical locations of missile and drone launches from the territory of Russia. The data presented in Table 3 offers insights into the geographic locations from which attacks on southern Ukraine were launched, along with the corresponding count of launches from each site.

**Table 3. Launch locations for attacks on Southern Ukraine:
proximity and distribution**

launch_place	launched
Black Sea	40
Crimea	145
Krasnodar region	34
Krasnodar region & Crimea	108
Kursk region	30
Saratov region	10

Source: developed by the author based on [14]

In light of this information, we will draw conclusions regarding the placement of these launch locations in relation to the southern region of Ukraine:

- *proximity to southern regions:* Notably, Crimea, the Black Sea, and the Krasnodar region exhibit close proximity to the southern regions of Ukraine. Consequently, there is a discernibly high frequency of attacks originating from these areas. This heightened incidence suggests that these regions serve as strategically pivotal points for launching drones, owing to their geographical adjacency to the southern border of Ukraine;

- *missile launch locations:* Conversely, the military airfields located in the Kursk and Saratov regions are geographically more distant from the southern regions and are predominantly used for launching missiles. The strategic choice of these locations for missile launches may be influenced by factors such as the type of weaponry employed, overarching strategic objectives, and the operational reach of the missile or drone systems involved.

In essence, the determination of launch locations appears to be a multifaceted decision influenced by the specific attributes of the weaponry, the broader strategic goals, and the operational capabilities of the missile or drone systems in use. This analysis contributes to a deeper understanding of the spatial dynamics governing the choice of launch sites in the context of the ongoing conflict in southern Ukraine.

Conclusions. The article proposes analytical findings regarding the frequency and intensity of Russian aerial attacks on southern Ukraine. Analysis of the provided dataset reveals a significant conflict dynamically unfolding in the southern region of Ukraine.

Throughout the study period, Russian attacks exhibited a discernible escalation in both frequency and intensity, particularly in the later months, signifying an amplification of hostilities marked by both minor-scale skirmishes and more substantial offensives concentrated on the southern regions of Ukraine. While the majority of Unmanned Aerial Vehicle (UAV) attacks demonstrated effective countermeasures, cruise missile attacks presented a more formidable challenge, characterized by a comparatively lower destruction ratio.

To address these challenges and fortify the resilience of the port infrastructure, several strategic measures are proposed:

- **Enhancement of air defense systems:** A crucial step involves substantial investments in advanced air defense systems, designed to effectively counter both missile and drone attacks. The continual refinement of defense capabilities is imperative to minimize potential damage to port infrastructure.

- **International support:** Seeking international collaboration is essential to denounce and deter further attacks on port infrastructure. Collaboration with

international partners is pivotal in ensuring the safety of maritime trade and the seamless export of grain.

- Strategic planning: The development of a comprehensive strategic plan emerges as a strategic imperative for safeguarding port facilities and critical infrastructure. This plan should encompass meticulous risk assessments, well-defined response strategies, and a continuous improvement framework.

- In instances where seaports face closure, alternative routes, such as those through the Danube ports, road, and rail transport, could serve as viable conduits for farmers to export their products. Notably, ongoing initiatives, including the construction of more than 12 new terminals along the Ukrainian section of the Danube River, exemplify proactive measures to diversify transportation options. Additionally, the creation of a government-backed fund, amounting to UAH 20 billion, stands as a financial mechanism aimed at compensating foreign shipowners for losses incurred due to potential damage from Russian attacks.

These proposed strategies collectively aim to fortify the resilience of the Southern region's port infrastructure and establish a secure foundation for the continued export of grain, mitigating the multifaceted challenges posed by the ongoing conflict.

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