Analyzing Escalation Timelines in the Russo-Ukraine War: A Geospatial Approach

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Introduction

Since 2014, the Russo-Ukraine conflict has been a focal point of international attention. It encompasses a series of events that began with the Donbas war, which erupted in 2014 following the Ukrainian Maidan protests in Kyiv. Donbas, consisting of the Donetsk and Luhansk regions, became the epicenter of separatist movements, leading to violent clashes and a protracted struggle for control. It's important to note that while the Donbas war did not officially conclude, a set of ceasefire agreements, called the Minsk agreements, were brokered, with numerous violations following. The conflict landscape, characterized by ceasefires and intermittent flare ups, continued to evolve but did not escalate into war until 2022.

In 2022, the world witnessed a rapid and intense escalation of the Russo-Ukraine conflict via the Russian invasion of Ukraine. This escalation saw an expansion of the occupation from Donetsk, Luhansk, and Crimea to mainly Kyiv, Kharkiv, Zaporizhzhya, and Kherson, which were later partially reclaimed by Ukrainian forces. This sudden escalation not only amplified the complexities of the ongoing conflict but also raised questions about the broader implications of these developments.

A concern in contemporary international relations is the perceived acceleration of conflict escalation timelines.This possibility poses a heightened risk of miscalculation, unintended conflict escalation, and reduced opportunities for diplomatic resolution(Johnson, 2022). Are heightening diplomatic tensions escalating to wars at an unprecedented pace? Can we discern tangible evidence of this trend? We can quantitatively investigate the timelines of conflict escalation to shed light on these questions. The Russo-Ukraine war is an ideal focal point for a case study on this issue. This conflict is emblematic of the geopolitical struggles between Russia and Western powers, with far-reaching consequences. That struggle in influence can be seen in this conflict via the United States and Russia, two major global powers that possess a substantial nuclear arsenal. This emphasizes the need to closely monitor the escalations in this conflict. Heightened escalations, if occurring more rapidly over time, could have far reaching consequences for global stability (Horowitz, 2019).

Within this context, this project seeks to assess whether the recent escalation in 2022 represents a more significant and rapid intensification compared to the initial escalation to violence in 2014. In order to accomplish this, the project will focus on three key objectives. First, identify critical junctures that delineate the start and end of each escalation period. These critical junctures serve as pivotal moments, marking significant events and decisions that shape the trajectory of the conflict further escalating. By delineating these junctures, the project aims to establish a framework for contextualizing and analyzing escalation patterns. Second, the project aims to quantify and visualize conflict each escalation using geospatial data and methodology. It will do so by analyzing The Institute for the Study of War's land occupation data at the Oblast level, The Armed Conflict Location & Event Data Project (ACLED) and Uppsala Conflict Data Program (UCDP)'s conflict data at the Hromada level, and Sentinel-1 satellite imagery at the city level. Lastly, the project seeks to compare the quantitative results of analysis between the initial phase of the Donbas war in 2014 and the 2022 Russian invasion. The expected results will be to provide side by side visual comparisons for occupied land, conflict events, and building damage per escalation.

Defining Escalation in the Ukraine-Russo War

In this context, an escalation is defined by the process of actors shifting from a state of no armed conflict and rising diplomatic tensions to an outbreak of sustained violence increasing with no apparent limit. An escalation period ends when violence stops rising or a de-escalating event occurs. This definition of escalation stems from Smoke's escalation definition(Smoke, 1977). This escalation framework includes the steps of an escalation from diplomatic talks to violent conflict. While useful, this framework proves too simplistic to fully grasp the complexity of violence escalation in the region. To accurately depict the escalation sequence in the Donbas War and Russian Invasion, we must acknowledge its uneven spread across space and time, with various thresholds being crossed by different actors at different moments. Additionally, we must extend the escalation model to consider causality, recognizing that each step may not necessarily be a prerequisite for subsequent ones. This is why we're using the framework of Hauter's concept of critical junctures—pivotal moments in each conflict that add causality to a following juncture, even if it is not the next juncture in a linear timeline(Hauter, 2021). This project will identify 11 critical junctures; six in 2014 and five in 2022. Critical junctures can be defined as events that meet the following requirements:

1. Must signify a substantial shift in the conduct of armed conflict, altering established norms that govern violence.
2. Choices that surpass the existing boundaries of warfare have a greater impact than those that adhere to these boundaries.
3. Should have a prolonged and significant impact beyond the immediate event.
4. The enduring legacy must be linked to armed conflict, either through sustained violence or prolonged damage that requires substantial time to rectify. Additionally, it may facilitate further escalation, leading to following critical junctures and perpetuating a cycle of violence.

Defining Critical Junctures in the 2014 Donbas War

Below are the eleven critical junctures delineating the start and end of each escalation period. The six critical junctures for the Donbas war are attributed to Hauter's' research, while the five critical junctures for the 2022 invasion have been identified based on the framework criteria outlined above(Hauter, 2021).

Juncture 1: Donetsk and Luhansk, Early April

The storming of state buildings in Donetsk and Luhansk on April 6th marked the first militarized footholds of separatism in the cities, laying the groundwork for armed conflict. The armed occupation and fortification of these buildings set the stage for later clashes and expanded hostilities.

Juncture 2: Sloviansk and Kramatorsk, Mid-Late April

Armed seizures of police stations in Sloviansk and Kramatorsk on April 12th triggered the launch of Ukraine's 'antiterrorist operation', leading to sustained armed clashes and the use of heavy weaponry. The intense fighting and deployment of tanks marked a significant escalation in the conflict, setting a precedent for future violence.

Juncture 3: Mariupol

Despite tensions reaching the armed conflict threshold in Mariupol, the city remained under Kyiv's control by mid-June, showcasing the failure of separatist efforts. While violence occurred, the city's swift re-consolidation under government control limited the conflict's spread.

Juncture 4: The Fighting Spreads, Late May

Hostilities rapidly expanded to new locations across the Donbas, including Volnovakha, Karlivka, and Donetsk Airport, significantly broadening the scope of the war. This expansion marked a crucial phase in the conflict's escalation, leading to continued violence and increased use of heavy artillery.

Juncture 5: Tanks and Heavy Artillery, June-July

The introduction of airstrikes, heavy artillery, and combat deployment of tanks by both Ukrainian forces and separatists became widespread, causing widespread loss of life. This escalation in firepower left a lasting legacy of destruction and intensified the conflict's brutality.

Juncture 6: Intervention of Regular Russian Forces, Late August

Allegations of cross-border shelling and the subsequent intervention of Russian forces in late August marked a critical turning point in the conflict. Russia's direct involvement prevented Ukrainian forces from regaining control and solidified its role as a primary driver of the ongoing conflict.

Defining Critical Junctures in the 2022 Russian invasion of Ukraine

Juncture 1: Buildup of armed demonstrations at the Ukraine border with Russia and Belarus

The buildup of armed demonstrations at the Ukraine border from Russia served as a pivotal precursor to conflict escalation. On 21 February, Vladimir Putin's official directive to deploy Russian forces into separatist republics in eastern Ukraine marked a decisive shift in the conflict's trajectory, effectively formalizing Russia's military involvement and escalating tensions to the brink of war.

Juncture 2: Russian Invasion of Ukraine

The Russian invasion of Ukraine on February 24 marked a critical turning point in the conflict, initiating a full-scale military operation in the eastern Ukrainian territory of Donbas. President Zelenskyy's declaration of martial law and severance of diplomatic ties with Russia underscored the gravity of the situation, prompting swift international responses such as the deployment of 7,000 U.S. military personnel across Europe by Secretary of Defense Lloyd J. Austin III.

Juncture 3: Increased Western Military Assistance to Ukraine

The increased Western military assistance to Ukraine, exemplified by the Department of Defense's notification to Congress, represented a critical juncture in the conflict. Through initiatives like the Ukraine Security Assistance Initiative (USAI), the U.S. pledged significant support, including $300 million in security assistance and the provision of advanced military technology such as Switchblade unmanned aerial vehicles (UAVs), significantly bolstering Ukraine's defense capabilities.

Juncture 4: Mariupol Siege

The fall of Mariupol on 17 May marked a critical juncture in the conflict, as Ukrainian forces surrendered to Russian and Donetsk People's Republic (DPR) troops after a prolonged siege. Despite defense efforts, the surrender of Mariupol signaled a significant loss for Ukraine, allowing Russian and DPR forces to secure control over the strategically important city.

Juncture 5: Counteroffensive in Kherson and Kharkiv

Ukraine's successful counter offensives in Kherson and Kharkiv marked a pivotal turning point in the conflict. With Ukrainian troops retaking control of Kherson by 11 November 2022 and launching a significant pushback in Kharkiv Oblast, these maneuvers demonstrated Ukraine's ability to reclaim territory. However, Russia's retaliatory campaign of massive strikes against Ukrainian infrastructure, beginning in October, showed the continued intensity and volatility of the conflict, continuing the escalation of violence.

Literature Review

Current research on the escalation timelines of conflicts shows several points of consensus and counter arguments based on historical trends. Favaro and Williams argue emerging technologies may create a sense of protection in state governments, leading them to overestimate the benefits and underestimate the risks of offensive military operations. This altered perception can increase the likelihood of rapid escalation and intensification of conflicts (Favaro, 2023). Johnson has argued that there is heightened risk of inadvertent escalation from this perception of opposition having a technological advantage in war (Johnson, 2022).

However, researchers such as Gleditsch and Beck contend that conflict escalation is not becoming more intense or gaining speed. The period of time after the cold war to the early 2000's shows decline in the global number of armed conflicts worldwide (Gleditsch, 2002). Conflict analysis data indicates that armed conflicts have reached their lowest levels since the early 1970s. It's also important to note that the availability and accuracy of conflict data represent a significant challenge when assessing trends in conflict escalation (Beck, 2000). Different datasets can yield varying results due to disparities in conflict definitions and information-sourcing processes including the level of local researcher involvement in data curation (Raleigh, 2023). This perspective emphasizes the need for caution in drawing broad conclusions based solely on conflict data.

While it is necessary to acknowledge the limitations of international conflict data collection, there are opportunities to provide empirical evidence to substantiate or disagree with the arguments above. This project will utilize geospatial tools to compare the speed and intensity of escalations in 2014 and 2022 on an Oblast, Hromada, and city level.

Data

Institute for the Study of War (ISW) Polygon shapefiles

For regional Oblast analysis, the project leverages the Institute for the Study of War's(ISW) polygon shapefile dataset, focusing on occupied land areas. This dataset, encompassing both the ongoing invasion and the initial escalation in the Donbas War, provides polygon areas under Russian occupation and reported advances that are updated daily(ISW, 2008). ISW is a non-partisan, non-profit, public policy research organization that focuses on the study of conflicts and national security issues.

ACLED Conflict Incident Point Dataset

The Armed Conflict Location and Event Data Project (ACLED) is a widely used dataset that tracks political violence and conflict events worldwide. It provides detailed information on various types of conflict-related incidents, including battles, protests, riots, and violence against civilians. ACLED collects data from a wide range of sources, including local and international news reports, humanitarian agencies, and NGO reports, and employs rigorous verification processes to ensure data accuracy and reliability.

The ACLED dataset structure typically includes several key attributes that are relevant for conflict analysis. These attributes often include the date and location of each event, details about the type of event (e.g., battle, protest), information on the actors involved (e.g., government forces, rebel groups), the number of fatalities, and whether civilians were targeted(ACLED, 2010). ACLED also provides contextual information about the broader conflict dynamics and the specific circumstances surrounding each event.For this project, the ACLED dataset covering the 2022 escalation is used as a source of information for understanding and analyzing conflict events at the Hromada level.

Uppsala Conflict Data Program (UCDP) Point Dataset

The Uppsala Conflict Data Program (UCDP) is a research initiative that collects and disseminates data on armed conflicts worldwide. Established by the Department of Peace and Conflict Research at Uppsala

University in Sweden, UCDP has been a leading authority in conflict data collection and analysis since its inception. The program's datasets encompass a wide range of armed conflict-related information, including conflict events, actors involved, conflict intensity, and geographical locations(Sundberg, 2013). UCDP's data collection methods and rigorous validation processes ensure the reliability and accuracy of its datasets. For the 2014 analysis, UCDP Point Dataset will be utilized instead of ACLED due to its comprehensive coverage and detailed data, containing similar data types involved while emphasizing UCDP's more extensive dataset for the specified period. ACLED's full coverage of Europe only launched in 2021, making it less viable for comparing both escalations.

Sentinel-1 GRD Imagery

The Sentinel-1 GRD imagery let us assess building damage across Mariupol, Luhansk, and Donetsk during the first year of each escalation. Sentinel-1 GRD (Ground Range Detected) is a synthetic aperture radar (SAR) satellite mission developed by the European Space Agency (ESA) as part of the Copernicus Programme. The Copernicus Programme is a European Union-led initiative that provides accurate, timely, and accessible Earth observation data for environmental monitoring, disaster management, and other applications. Sentinel-1, as part of this program, consists of a constellation of satellites equipped with SAR sensors, which enable all-weather, day-and-night imaging capabilities(ESA, 2014, 2022).

Sentinel-1 GRD data provides high-resolution radar imagery with wide spatial coverage, making it particularly valuable for applications such as land cover mapping and disaster response. The Ground Range Detected (GRD) mode of Sentinel-1 imagery involves processing raw radar data to produce images in which pixel values represent radar backscatter intensity. These images can be used to detect changes in land cover, monitor ground movements, and evaluate building damage, among other applications.

Landsat 8 Tier 1 Imagery

Landsat 8 Tier 1 Surface Reflectance (T1_SR) imagery provides multispectral data with a spatial resolution of 30 meters, covering visible, near-infrared, and short-wave infrared bands(USGS, 2014, 2022). These images are pre-processed to correct for atmospheric effects, making them ideal for land cover classification, change detection, and environmental monitoring. In this project, Landsat 8 T1_SR imagery will be utilized for vegetation and water classification to create masks, enabling accurate assessment of building damage by excluding non-building features from the analysis.

Methods

Oblast T-Test Comparison

For the regional Oblast analysis, the occupied land polygons for each of the specified oblasts (Crimea, Kherson, Zaporizhzhia, Luhansk, and Donetsk) were clipped from the ISW data using ArcGIS Pro. Then, the area of each polygon was calculated in hectares using the Calculate Geometry Attributes tool.

After recording the observations of land occupation for both years, a paired t-test was conducted to compare the differences between the two datasets using the SciPy library in Python. The paired t-test assesses whether there is a statistically significant difference in the means of two related groups.The t-statistic computed represents the magnitude of difference between the means of the two groups, relative to the variability observed within each group. The derived p-value serves as an indicator of the likelihood of encountering a difference as extreme as observed, under the assumption that there is no actual disparity between the two time periods. The results of the t-test are printed to the console. The Russian-occupied land in 2014 and 2022 were then mapped to visually illustrate the significance of the difference in land occupation between the two years.

Conflict Timelines and Hromada Hotspot Analysis

The analysis of conflict points data from ACLED and UCDP involved two parts. CSV files with the data per year were downloaded from each data portal. The data was then filtered by civilian targeted events. Filtering specifically for civilian targeted events was chosen due to their direct impact on critical infrastructure, including hospitals, schools, and residential areas. These events not only cause immediate harm to individuals but also result in the destruction of essential facilities and residential properties. By analyzing civilian-targeted events, the project can identify locations that may be most suitable for comparing building damage.

Once the relevant data for civilian-targeted activities was extracted, it was imported into RAWGraphs for further analysis and visualization. RAWGraphs is an online tool used to create customizable visualizations from datasets. It exports graphs as SVG files, allowing more design compatibility with adobe illustrator. Line charts were created to visualize conflict events in both 2014 and 2022. Additionally, the critical junctures identified in each year were overlaid onto the line charts. This integration allows for a nuanced understanding of how these pivotal moments influenced the occurrence of conflict events targeting civilians.These charts show the speed and intensity of conflict events surrounding critical junctures.

The second part of analyzing the conflict event points was to identify suitable locations to conduct the damage assessment locally based on conflict hotspots. This would be done through mapping the number of conflict events targeting civilians by administrative 3 units, Hromadas. To create the Hromada maps, the process began with integrating the conflict event points into ArcGIS Pro. These points were spatially joined with a Hromada polygon shapefile, attributing each conflict point to the Hromada it fell within. Then, the dissolve tool was utilized to aggregate the number of conflict points within each Hromada. This process was repeated for both the 2014 and 2022 datasets to create comparable maps illustrating conflict event distributions across Hromadas.

These maps provided a broad overview of conflict dynamics, showing concentrations of conflict hotspots. However, a higher frequency of events in a Hromada does not necessarily correlate with where there was significant building damage over either escalation.Given this, focusing on Hromadas with the highest number of conflict points was a good starting point to look for locations that have incurred building damage during each escalation. To identify those potential locations, a manual inspection of the type of event and details of each conflict event was conducted. This involved reviewing event descriptions and any accompanying notes to ascertain instances of conflict resulting in damaged buildings. Hromadas with the highest number of conflict events between the two years were prioritized, with a specific focus on those where at least some conflict events indicated building damage. This targeted approach ensured a more focused area of interest for damage assessments.

Building Damage Assessments

The three cities identified from the process outlined above were Mariupol, Luhansk, and Donetsk. Google Earth Engine (GEE) was used to conduct building damage assessments for each of these locations for 2014 and 2022. Google Earth Engine is a cloud-based geospatial analysis platform developed by Google, offering an array of satellite imagery datasets and powerful computational tools. With GEE, users can access and analyze satellite imagery and geospatial data without the need for extensive computational resources or data storage infrastructure. The code comprises two primary sections: "damage general" and "damage function". In the "damage general" segment, parameters are configured for the building damage assessment. This involves importing the main damage assessment function, setting parameters such as event dates and area of interest(AOI) location coordinates, and specifying manual orbit usage. Following this setup, the main damage function is invoked with the specified parameters.

Following the setup of parameters in the "damage general" section, image processing functions are established to manipulate satellite data effectively. Among these functions, vegetation indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) are utilized to classify and mask out areas covered by vegetation and water. By applying thresholds of 0.9 on these indices, the script identifies urban and non urban areas. Only the urban areas are taken into consideration for the building damage algorithm. To ensure this, the script incorporates additional cloud, snow, and shadow masking to exclude unwanted image classes. This processing approach seeks to eliminate noise and irrelevant information.

Following the preprocessing steps, the script proceeds to filter the Landsat and Sentinel-1 image collections, focusing on the defined AOI and the specified date range. Within this narrowed selection, images captured at the beginning and end of the date range are selected. The script applies the gradient backscatter algorithm to analyze radar intensity changes. By examining the rate of change in backscatter intensity between before and after images, the algorithm identifies areas potentially impacted by damage. This method aims to detect subtle variations in radar return signals, which may indicate structural alterations caused by the disaster event.Finally, the script exports the resultant damage map to Google Drive at 20 meter resolution.

After generating the output .tif files for 2014 and 2022 in all three locations, I proceeded to examine them in ArcGIS Pro to determine the threshold values for accurate building damage assessment. Initially, I anticipated that the damage values would fall within the range of 1 to 2 of potentially damaged to severely damaged, based on the code documentation. However, upon comparison of the data to imagery from each time period, I discovered that the thresholds varied, yielding some clear false positives at the value of 1. According to the source code, any value above 1 is detected as damage(van Heyningen, 2018). The range in values demonstrates how much the gradient values have changed per pixel between the start and end images. Once the thresholds were found, the Extract by Attributes tool in ArcGIS Pro was utilized to isolate the pixels that met this criteria. Then, I conducted a pixel count for observed damaged areas per hectare in Mariupol, Donetsk, and Luhansk for each year. These six observations served as the basis for another T-test, allowing for an assessment of the significance of the observed damage between each year.

Results

Land Occupation T Test

Fig. 1 Map of Ukraine depicting land occupation based on ISW data. The salmon colored areas represent territories occupied in 2022, while the diagonal red lines denote territories occupied in 2014

The results of the t-test conducted on the data comparing land occupation in 2014 and 2022 show a statistically significant difference between the two time periods. With a two tailed P-value of 0.0331, below the conventional threshold of 0.05, the observed difference in mean values is statistically significant. The mean land occupation in 2022, shown in the map above, significantly exceeded that of 2014 by approximately 1,243,001 hectares. In addition, the 95% confidence interval for this difference suggests that we can be reasonably confident that the true difference in means is within the range of -2,323,804 to -162,199 hectares. These findings indicate an outsized increase in land occupation over the course of 2022 compared to that of 2014.

Escalation Timelines

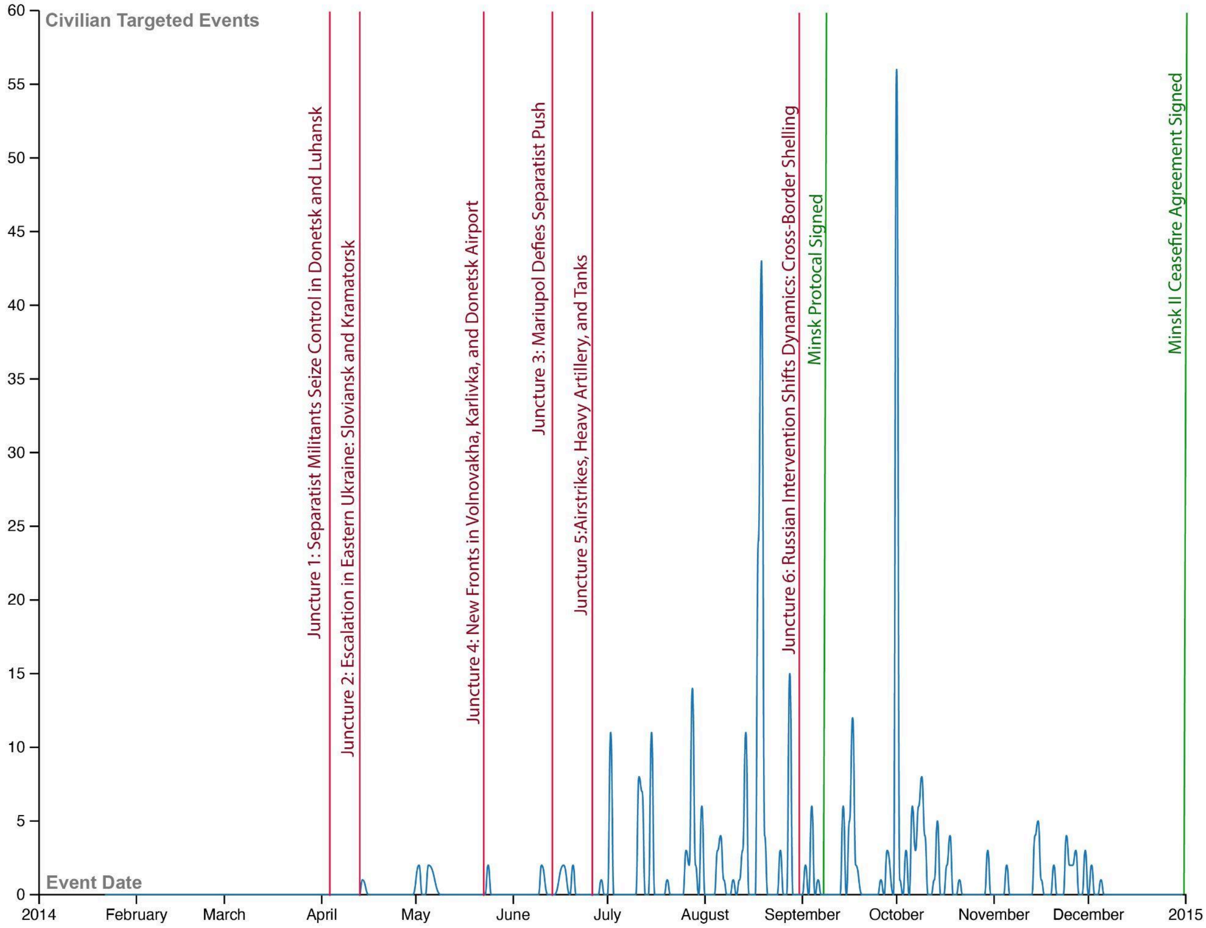


Fig. 2 Line chart illustrating civilian targeted conflicts in 2014. The chart includes markings for the six critical junctures (in red) and the two Minsk agreements (in green) along the timeline

Upon reviewing the timelines of civilian targeted conflict events in both 2014 and 2022, which can be seen above and below respectively, several key observations can be seen. In comparison to 2014, 2022 witnessed a significantly higher frequency of events within a shorter period of time. In 2014, particular attention was drawn to the locations coinciding with critical junctures 5 and 6, pivotal moments during that year's conflict. These junctures serve as reference points for understanding the spatial distribution of conflict events and their implications for affected areas. The spike in events between July and September are between an increase in heavy artillery and cross border shelling. Where these events occurred helped narrow the focus for the following Hromada mapping. Moving forward to March 2022, coinciding with increased Western aid to Ukraine, there is a notable surge in civilian-targeted conflict. This period of heightened activity suggests the time period to focus on for creating the Hromada maps. Additionally, the prominence of Mariupol in both the 2014 and 2022 escalations suggests its strategic importance.By honing in on locations associated with critical junctures, high-conflict periods, and recurrent escalation points, the next step in mapping conflict at the Hromada level can be more targeted.

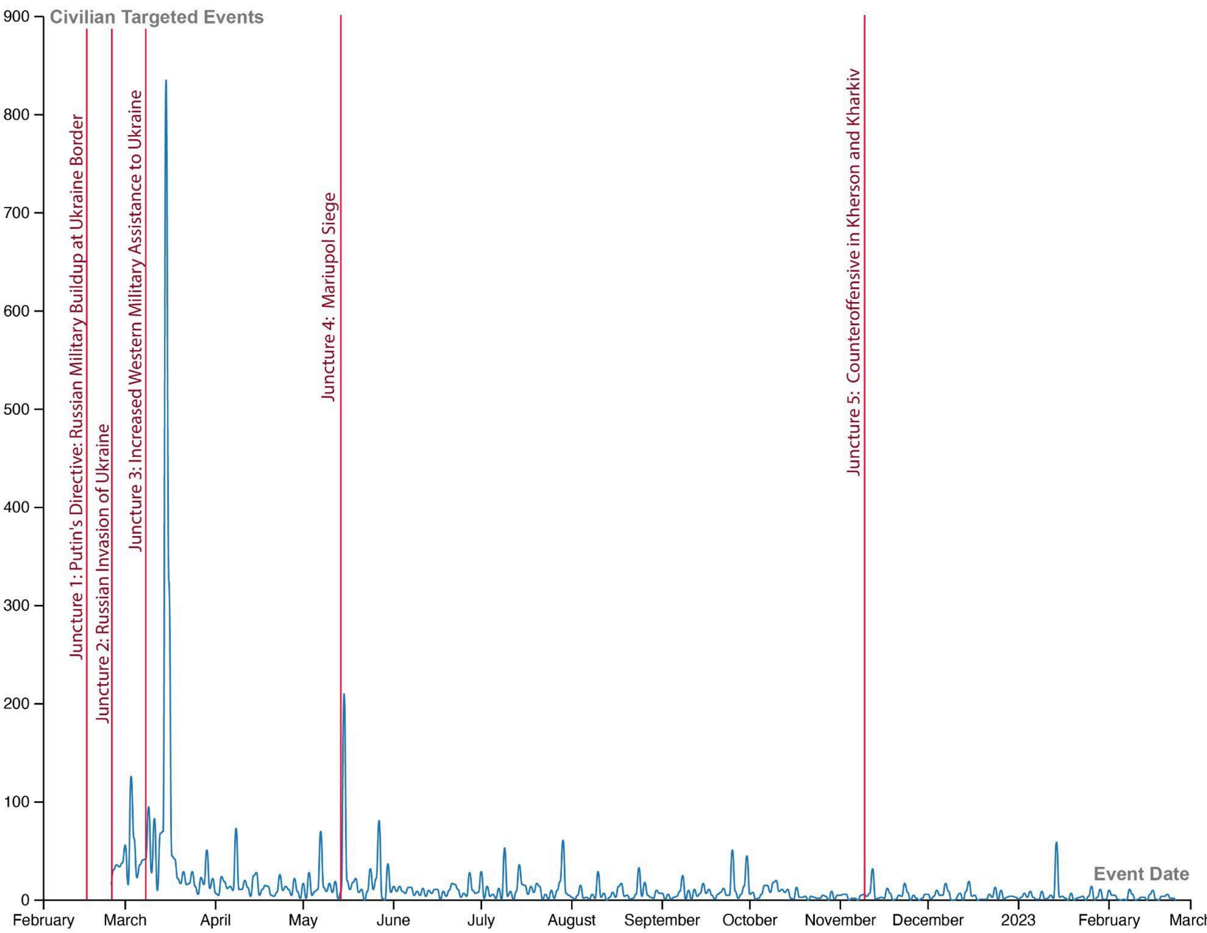


Fig. 3 Line chart illustrating civilian-targeted conflicts in 2022. The chart includes markings for the five critical junctures (in red) along the timeline

Conflict Events by Hromada

Fig. 4 Map of Ukraine showing civilian-targeted events aggregated at the Hromada level during 2014

Based on the line charts depicting conflict events over time, it became evident that certain areas, particularly Mariupol, experienced significant conflict intensity during both the 2014 and 2022 escalations, notably coinciding with periods of heavy artillery deployment. While the 2022 timeline revealed a more widespread dispersal of conflict events compared to 2014, the focus was drawn towards Luhansk, Donetsk, and Mariupol. These areas emerged as focal points due to their consistent involvement in both escalations and notable prevalence of civilian-targeted conflict events on the Hromada maps. Conflict events in 2014 can be seen in Donetsk and Luhansk above, while events in 2022 can be seen more extensively in the map below. Detailed examination of conflict event data notes indicated instances of infrastructure damage in all three locations during both years. Due to this, these were chosen as the three cities to conduct the building damage assessment.

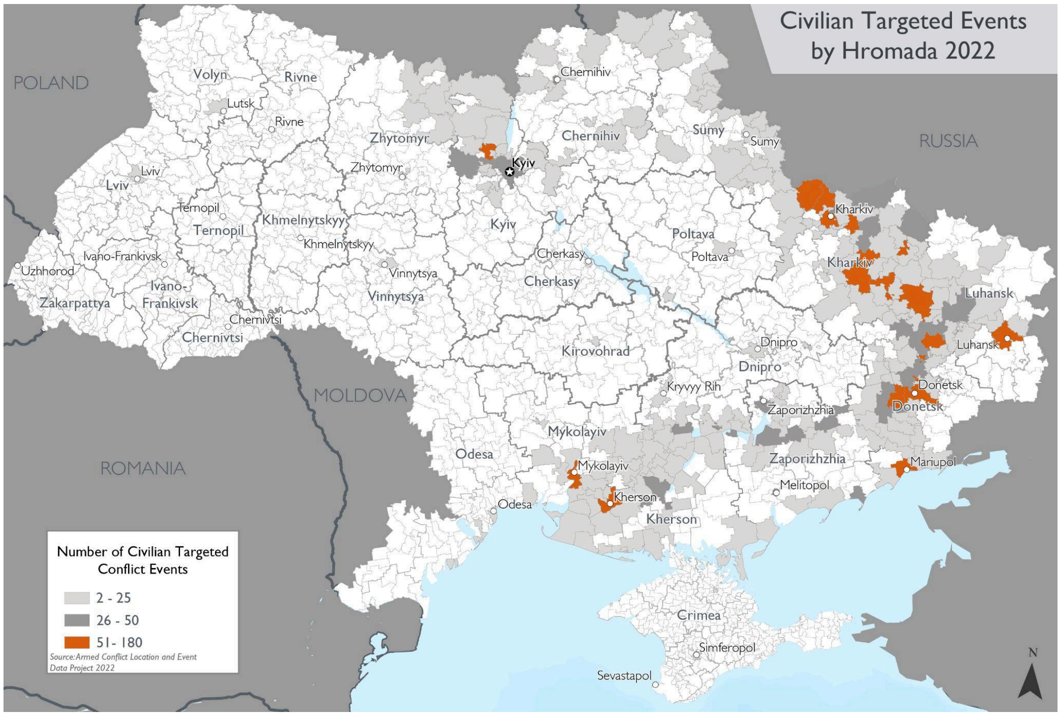
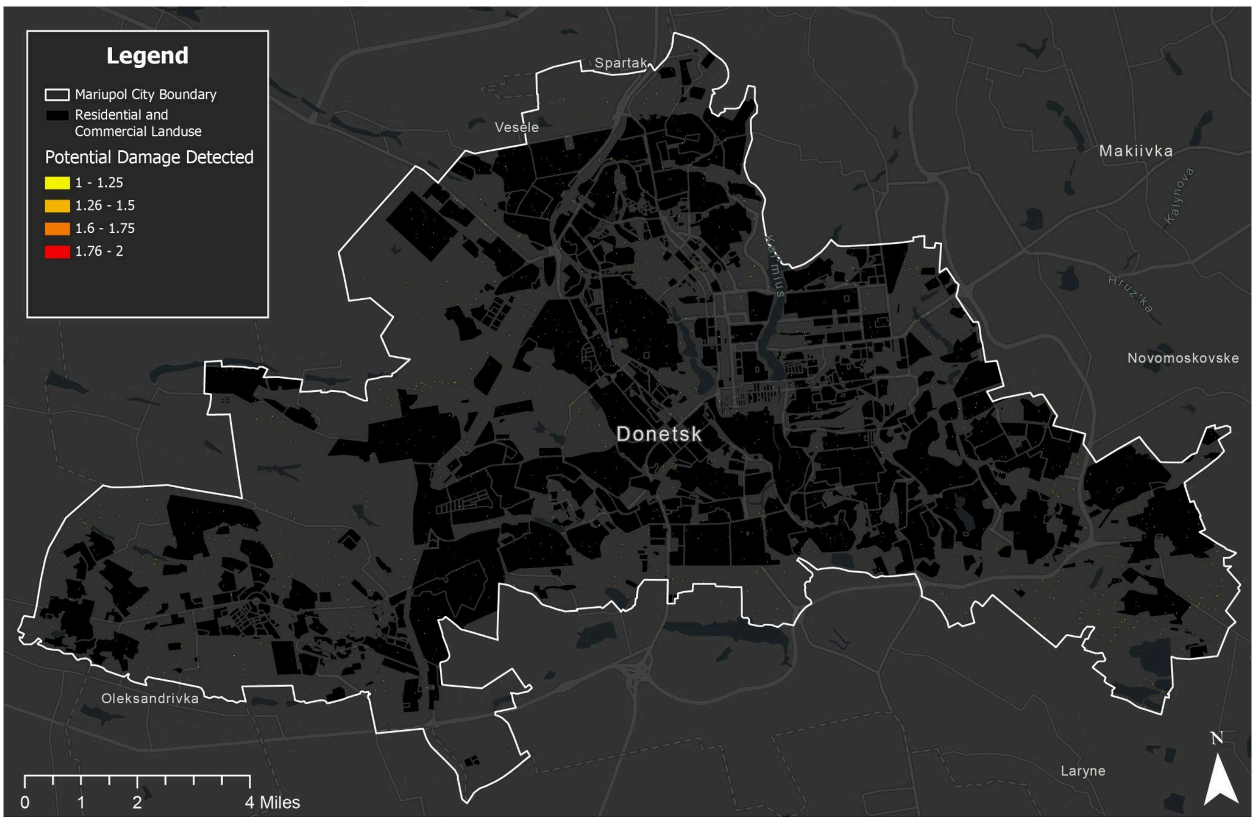


Fig. 5 Map of Ukraine showing civilian-targeted events aggregated at the Hromada level during 2022

Building Damage Assessment

Fig. 6 Comparison of potential building damage in Mariupol. Left: Potential building damage in 2014. Right: Potential building damage in 2022

Building damage assessments conducted in Donetsk, Luhansk, and Mariupol showed notable differences in the extent of damage between the years 2014 and 2022. The damage, quantified in hectares, demonstrated a significant increase from 2014 to 2022 across all three cities. In 2014, the average damage per hectare was 76.2 in Donetsk, 45.28 in Luhansk, and 50.68 in Mariupol. However, in 2022, these figures escalated significantly, with Donetsk experiencing an average damage of 177.66 hectares, Luhansk with 189.66 hectares, and Mariupol with 114.66 hectares.



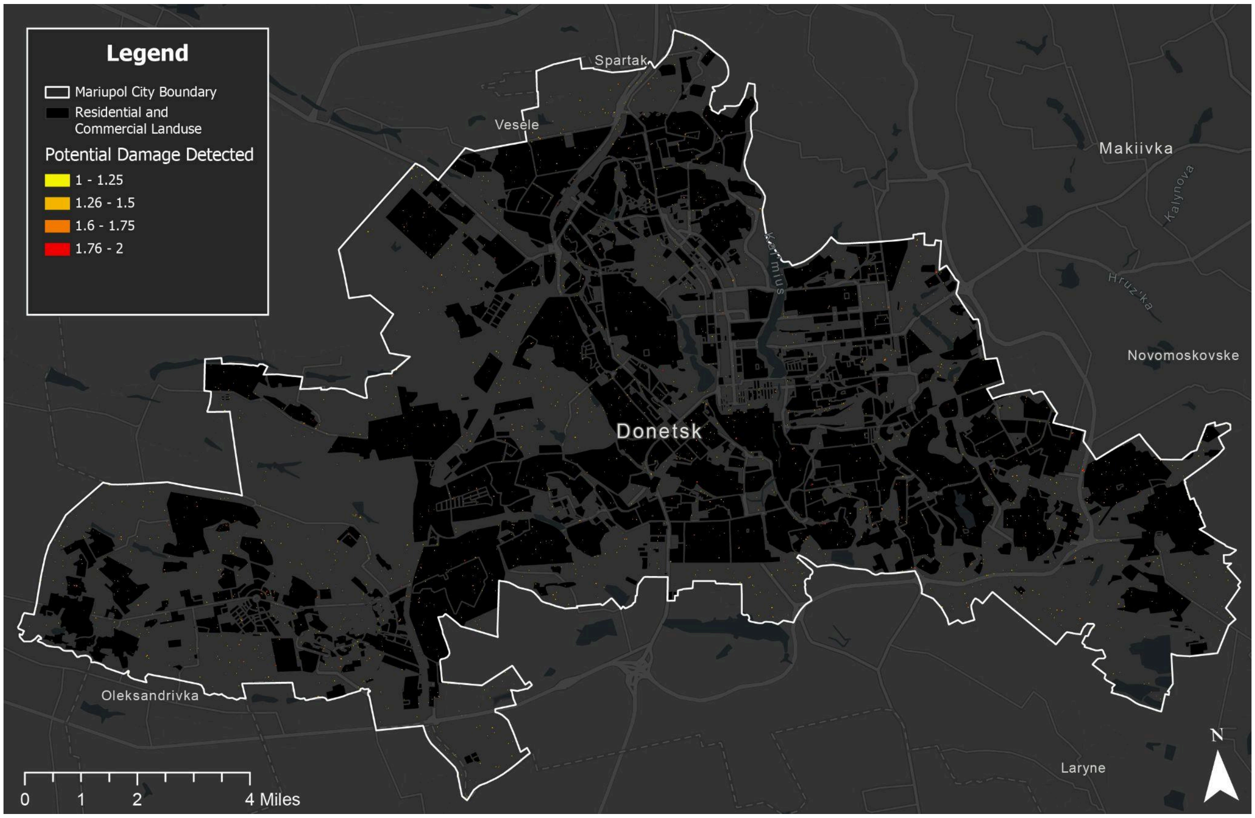


Fig. 7 Comparison of potential building damage in Donetsk. Top: Potential building damage from 2014. Bottom: Potential building damage from 2022

Statistical analysis using a paired t-test indicated a significant difference in building damage between 2014 and 2022 (p = 0.0203). The two-tailed p-value suggested statistical significance, indicating that the observed increase in damage from 2014 to 2022 was unlikely due to random chance alone. Moreover, an analysis of the affected areas revealed that slightly over 50% of the damaged areas in both 2014 and 2022 were residential or industrial zones across the three cities. These comparisons can be seen in the paired maps throughout this section, with residential and industrial areas in black and potential building damage in a gradient from yellow to red, providing four classes of certainty. For this project, all potential damage was counted for the T test.However, it's important to note that the results come with certain caveats.

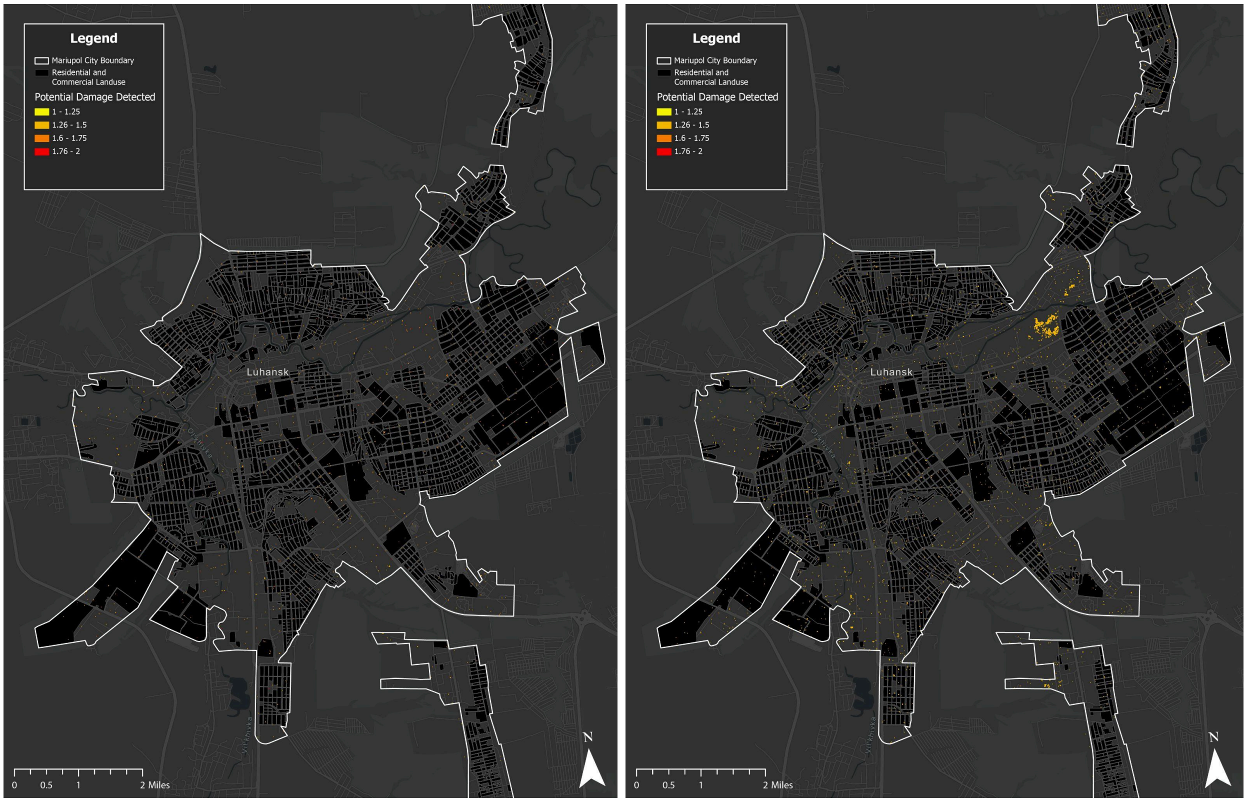


Fig. 8 Comparison of potential building damage in Luhansk. Left: Potential building damage from 2014. Right: Potential building damage from 2022

GEE Algorithm Issues


Fig. 9 Misclassified pixels in Donetsk forest and farm land, falsely identified as potential building damage

The building damage assessment code used in Google Earth Engine presented challenges throughout implementation. While it provided a broad understanding of potential building damage, its use for real world scenarios is limited. As the original author of the damage algorithm in the code noted, “the algorithm encountered difficulties in identifying individual collapsed buildings, particularly in dense urban environments where approximately 50% of such buildings were misclassified. However, the accuracy improved when examining clusters of damaged buildings or individual structures equal to or larger than the size of a SAR resolution cell, especially in less dense urban areas(van Heyningen, 2018).” The limitations in this project could be seen in Donetsk, where the algorithm identified parks and farms bodies as damaged areas, which should have been excluded during processing. In Mariupol, there were instances of obvious building damage being overlooked, such as in the example below. These challenges underscore the need for caution when interpreting results from densely populated regions and the importance of cell size resolution for the scope of a project.

Fig. 10 Instance of building damage not detected in Mariupol, showing limitations in the assessment process and using 20 meter resolution

Exploring smaller, more targeted areas at higher resolutions, such as a 5 meter resolution, for analysis could potentially mitigate some of these issues. However, when attempting to export that level of resolution to Google Drive, the large size of the exported data posed practical challenges. Such an approach may be more feasible when examining specific locations post-shelling or artillery fire, where targeted assessments are essential.

Conclusion

In conclusion, this project aimed to provide a geospatial understanding of the Russo-Ukraine conflict escalation, comparing the 2014 Donbas War with the 2022 Russian invasion of Ukraine. Through an analysis of land occupation, conflict events, and building damage assessment, it is clear that the 2022 Russian invasion of Ukraine has escalated at a faster and more intense pace than in 2014. The comparison of land occupation revealed a significant expansion of Russian-controlled territories during 2022, indicating a more extensive and aggressive incursion compared to the initial stages of the Donbas War. The timeline of each escalation demonstrated a notable increase in conflict intensity and frequency of civilian targeted events during the 2022 invasion, particularly coinciding with critical junctures and in locations like Mariupol. The analysis of conflict events by Hromada showed a drastic expansion of conflict over Ukraine and highlighted specific areas, such as Mariupol, Luhansk, and Donetsk, as focal points of conflict activity during both periods. The building damage assessment also showed a substantial increase in damage from 2014 to 2022 across all three cities.

While these results are unsurprising, they are important to quantify. Studying escalations contributes to a deeper understanding of the evolving nature of conflicts, equipping us with the tools needed to anticipate and mitigate future escalatory trends. The capacity to quantitatively track how rapidly and intensely a conflict begins provides decision makers with insights into the severity of a conflict and informs strategies for addressing it. The ability of conflict to break perceived limits of international agreements poses significant challenges for global security and stability. While this paper doesn't provide all the answers, it provides a way to investigate further: Is the current situation significantly worse than before, and if so, by how much? Unfortunately for this particular conflict, it has become worse by multiple metrics.

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