A GEOSPATIAL STRATEGY TO DETECT AND IDENTIFY POTENTIAL CLANDESTINE MASS GRAVES IN UKRAINE

by
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Abstract

This study seeks to improve the understanding of how social media analysis and hyperspectral remote sensing can be applied in a multi-modal target-centric approach to detect and identify clandestine mass graves in Ukraine. Fifteen mass graves have been discovered in central, southern, and eastern Ukraine since the Russian invasion of Ukraine on 24 February 2022. This geospatial strategy recommends conducting retroactive searches for additional potential clandestine mass graves and prospective searches for suspicious activities that may be indicative of future or ongoing potential clandestine mass grave locations in areas currently under Russian control. This social media collection and analysis will direct targeted hyperspectral imagery collection on areas of interest. The resulting hyperspectral data will be further analyzed using spectral signature libraries, statistical methods, and vegetation indices to identify any vegetation anomalies with unusually high or low Nitrogen concentrations - a proxy signature for clandestine graves.

This research will first present background information on the historical use of clandestine mass graves and the targeting of civilians in conflict. Second, it will examine the methodologies presented in this proof-of-concept. Third, it will evaluate the limitations of this geospatial strategy. This thesis provides new insights for detecting and identifying clandestine mass graves in Ukraine and provides potential audiences with another tool to locate and document these atrocities.

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Finally, to my mother, father, and uncles, I'd like to extend my deepest gratitude and love. Without your encouragement and never-ending support, none of this would have been possible.

Dedication

This research is dedicated to the innocent victims of the Russo-Ukrainian War and all the families still searching for their loved ones.

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List of Abbreviations

AOI	Area of interest
EO	Electro-optical
EU	European Union
GCI	Green chlorophyll index
GDPR	General Data Protection Regulation
GNDVI	Green normalized difference vegetation index
GPS	Global positioning device
HSI	Hyperspectral imagery
HTML	Hypertext markup language
IMU	Inertial measurement unit
IR	Infrared
LiDAR	Light detection and ranging
MRENDVI	Modified red edge NDVI
MRESRI	Modified red edge simple ratio index
NDREI	Normalized difference red edge index
NDVI	Normalized difference vegetation index
NIR	Near-infrared
OPSEC	Operational security
OSINT	Open source intelligence
RENDVI	Red edge NDVI
REPI	Red edge position index

SAR	Synthetic aperture radar
SGI	Sum green index
SOCINT	Social media intelligence
SWIR	Short-wave infrared
TCARI	Transformed chlorophyll absorption reflectance index
UAV	Unmanned aerial vehicle
URL	Uniform resource locator
VPN	Virtual private network

1. Introduction

1.1 Research Objective

This research seeks to propose a prospective geospatial strategy to identify potential clandestine mass graves in Ukraine using hyperspectral imagery (HSI) and social media analysis. While this case study is tailored to Ukraine, the proposed geospatial strategy methodology should be effective globally if site-specific geographic factors are accounted for. The primary goal of this plan will be to identify potential clandestine mass graves resulting from the ongoing war in Ukraine and to provide investigators, nongovernmental organizations, and international regulatory bodies with another tool to aid in locating and documenting these atrocities. All collection and analytic methods utilized by this strategy are unclassified for this reason.

1.2 Key Intelligence Questions

1. What are Ukraine's geospatial, climatic, and geographic characteristics that may influence the rate of decomposition of human remains?
2. Where are mass graves most likely to occur, based on currently known mass graves and previous and current Russian occupation zones?
3. Can a consistent grave typology be identified for mass graves that have been created in Ukraine during 2022, or are there visible or spectral indicators that may increase the likelihood of a mass grave occurring nearby?
4. What vegetation HSI signature is indicative of an anomaly that may indicate the presence of buried human remains?
5. What processes will be required to collect and analyze the initial data to create an actionable final product?
6. What revisit capabilities would be necessary for monitoring this issue?

7. What limitations does this geospatial strategy have?

1.3 Research Organization

This research will first provide background information on the historical use of clandestine mass graves, the targeting of civilians in the ongoing conflict in Ukraine, Ukraine's social media profile, Ukraine's geography, and factors that influence the rate of decomposition of human remains. Second, it will examine the approach of the geospatial strategy and methodologies proposed in this proof-of-concept. Third, it will evaluate the limitations of this strategy and potential solutions, where applicable.

2. Background

2.1 Historical Overview of Targeting Civilians in War

While precise figures are not available, it has been estimated that 43 million to 54 million civilians were killed by war-related causes in the 20th century alone[1], with some estimates as high as 86 million.[2] Since the 18th century, the world has seen a steady increase in the frequency, duration, and death tolls of wars. Killing in warfare has become devastatingly indiscriminate, and deliberately targeting civilians in war as a matter of strategy or tactics has become a frequently used method by democratic and authoritarian governments alike to achieve their goals.[3] It is important to note, however, that while some strategies or tactics intentionally target civilians, other strategies are not aimed at purposefully targeting them, but nevertheless, these strategies or tactics do not discriminate between combatants and civilians and still fall under the category of violence against civilians.

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[1] Alexander B. Downes, *Targeting Civilians in War* (Ithaca, NY: Cornell University Press, 2012), 1.

[2] William Eckhardt, "Civilian Deaths in Wartime," *Bulletin of Peace Proposals* 20, no. 1 (March 1989): pp. 89-98, https://doi.org/10.1177/096701068902000108, 90.

[3] Downes, 244.

Explaining the forces that drive individuals and organizations to target non-combatants is complex, but it can be reduced to two main ideologies. The first ideology centers around the idea that targeting civilians is motivated by a desire to reduce their own casualties and costs or to prevent defeat by coercing the enemy to give up.[4, 5] This ideology is backed by the strategic decisions of the US firebombing of Japan (1945), the German "Blitz" on Britain (1940-1941), farm burning and Boer and African civilian imprisonment in concentration camps during the Second Anglo-Boer War (1900-1902), and the French razzia or "scorched earth" policy in French Algeria (1840s).

The second ideology stems from the idea that targeting non-combatants comes from a desire to seize and annex enemy territory, and doing so makes this objective easier.[6] The Russian annexation of Abkhazia and South Ossetia during the Russo-Georgian War (2008), the Bosnian Genocide (1992-1995), the Rwandan Genocide (1994), the German Einsatzgruppen massacres in the U.S.S.R. (1941-1942), and the Armenian genocide (1915-1916) are all examples of a State participating in targeting non-combatants to remove them from their territory.

While not all violence targeting civilians results in mass killings, certain factors increase the likelihood of it. Wars of attrition and wars with a goal of annexation increase the likelihood of mass killings by approximately 31 and 37 times respectively.[7] These mass killings contradict the long-held and widely believed principle that certain groups should be protected from the brutalities of war, e.g., noncombatants and vulnerable groups such as women, children, and the elderly. Willfully killing civilians in war directly violates Article 8 of the Rome Statute of the

[4] Downes, 29.
[5] Hugo Slim, *Killing Civilians: Method, Madness, and Morality in War* (New York, NY: Oxford University Press, 2010).
[6] Downes, 35.
[7] Downes, 53.

International Criminal Court and the Geneva Conventions of 1949 and their Additional Protocols, and customary international law, which forbids intentional attacks on civilians and critical civilian infrastructure.[8] As such, mistreatment of civilians and prisoners of war are considered war crimes, however, in cases of mass killings or genocide, these crimes are covered more broadly under crimes against humanity by international humanitarian law.

2.2 Mass Graves in the 20th and 21st Centuries

Currently, there is no international consensus on a single definition of what constitutes a mass grave. Some definitions emphasize the number of bodies, and others the process used to create them. For this purpose, the definition put forward by Jessee and Skinner will be used:

> A mass grave is any location containing two or more associated bodies, indiscriminately or deliberately placed, of victims who have died as a result of extra-judicial, summary, or arbitrary executions, not including those individuals who have died as a result of armed confrontations or known major catastrophes.[9]

While mass graves have been discovered by archaeologists dating as far back as the Mongol invasion of Kievan Rus in 1238[10], the archaeological record shows a steep increase in their use after international humanitarian law was codified by the Hague Conventions in 1899 and 1907[11], which prohibited certain methods of warfare. The Spanish Civil War, the Second Sino-Japanese War, and World War II marked a drastic increase in the use of clandestine mass graves by States to hide victims' remains and conceal evidence of committed war crimes. An

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[8] "United Nations Office on Genocide Prevention and the Responsibility to Protect," United Nations (United Nations), accessed October 5, 2022, https://www.un.org/en/genocideprevention/war-crimes.shtml#:~:text=Even%20though%20the%20prohibition%20of,law%20of%20armed%20conflict%2C%20was.

[9] Erin Jessee and Mark Skinner, "A Typology of Mass Grave and Mass Grave-Related Sites," *Forensic Science International* 152, no. 1 (May 3, 2005): pp. 55-59, https://doi.org/10.1016/j.forsciint.2005.02.031, 56.

[10] Mindy Weisberger, "13th-Century Death Pit Reveals Murdered Family in the 'City Drowned in Blood'," LiveScience (Purch, July 27, 2022), https://www.livescience.com/family-massacre-mongol-army.html.

[11] "United Nations Office on Genocide Prevention and the Responsibility to Protect".

estimated 2,000 clandestine mass graves resulted from the Spanish Civil War (1936-1939)[12] while Nazi Germany and Imperial Japan engaged in mass killings on an unprecedented scale during World War II (1939-1945) and the Second Sino-Japanese War (1937-1945), disposing of many of their victims in clandestine mass graves. These atrocities sparked international outrage and led to the renewed effort to enforce a standard of prohibiting violence against noncombatants through the Geneva Conventions and its Additional Protocols.

The latter half of the 20th century was filled with a mix of asymmetric, extra systemic, and interstate wars and genocides that resulted in the widespread massacre of non-combatants. Many of these mass graves are still being located and excavated today through various anthropological, archaeological, and geophysical approaches. These excavated mass graves frequently serve as evidence of war crimes and human rights violations during international tribunals.

Meanwhile, the 21st century has seen a continuation of violence from the previous century as hybrid and irregular warfare between States and non-state actors has increased in light of religious and political extremist movements and territorial disputes. As modes of war become increasingly interconnected and the distinction between combatants and noncombatants becomes blurred, more civilians are falling victim to indiscriminate attacks by aggressors. Some of the most recent victims include Ukrainian civilians buried in mass graves in Bucha, Borodyanka, Havronshchyna, Motyzhyn, Myrotske, Chernihiv, Kherson, Manhush, Mariupol, Pioners'ke,

[12] Bojana Djokanovic, "Spain's Missing," ICMP Spain's Missing, accessed October 4, 2022, https://www.icmp.int/news/spains-missing/.

Rubhizhne, Izium, Lyman, during the Russian occupation of those regions throughout the ongoing Russian-Ukrainian War.[13, 14, 15, 16]

2.3 The Russo-Ukrainian War

The Russo-Ukrainian War began on 20 February 2014 when Russia initiated hostilities and invaded Ukraine very quickly after its Revolution of Dignity. Pro-Russian separatists in the eastern and southern regions of the country rose up in protest and occupied government offices in Donetsk, Luhansk, and Kharkiv oblasts, while Crimea was simultaneously invaded and annexed by Russia. By early March these pro-Russian groups were quickly removed by local police and replaced with new political figureheads.[17] This change marked the official beginning of the separatist movement.[18] These new leaders had economic interests in Russia and ties to the Russian security services and military. Using their experience, they launched insurgency paramilitary forces in the Donbas region and proclaimed the territories under their control as the Donetsk People's Republic and the Luhansk People's Republic.

Armed conflict between the Ukrainian military and Russian-backed paramilitary forces continued as an "active stalemate"[19] for the next seven years, with regular border

[13] Eman El-Sherbiny and Benjamin den Braber, "Mass Graves after the Russian Invasion: Bucha, Mariupol, Chernihiv, Kherson," Centre for Information Resilience (Centre for Information Resilience, July 15, 2022), https://www.info-res.org/post/mass-graves-after-the-russian-invasion-bucha-mariupol-chernihiv-kherson.

[14] Associated Press, "Bucolic Ukraine Forest Is Site of Mass Grave Exhumation," VOA (Voice of America (VOA News), June 13, 2022), https://www.voanews.com/a/bucolic-ukraine-forest-is-site-of-mass-grave-exhumation-/6616015.html.

[15] Ross Burley, "The Yalivshchyna Burial Site: Mass Graves after Russian Invasion," Centre for Information Resilience (Centre for Information Resilience, April 10, 2022), https://www.info-res.org/post/the-yalivshchyna-burial-site-mass-graves-after-russian-invasion.

[16] Hugo Bachega and Matt Murphy, "Ukraine War: Hundreds of Graves Found in Liberated Izyum City - Officials," BBC News (BBC, September 16, 2022), https://www.bbc.com/news/world-europe-62922674.

[17] Michael Kofman et al., "Lessons from Russia's Operations in Crimea and Eastern Ukraine" (RAND Corperation, 2017), https://www.rand.org/pubs/research_reports/RR1498.html, 38.

[18] Michael Kofman et al., 38-39.

[19] The Center for Preventive Action, "Conflict in Ukraine | Global Conflict Tracker," Conflict in Ukraine (The Center for Preventive Action, September 12, 2022), https://www.cfr.org/global-conflict-tracker/conflict/conflict-ukraine.

skirmishes and artillery shelling. In late 2021, intelligence assessments of massive Russian military build-up along the Ukrainian-Russian border and in neighboring Belarus led to the conclusion by American analysts that a Russian invasion of Ukraine was almost certain. In mid-December Russia's foreign ministry demanded NATO and the U.S. limit military activities in Eastern Europe, ban Ukraine from joining the organization in the future, and cease NATO's eastern expansion[20] or else face a military response.

Tensions continued to rise and on 24 February 2022, President Putin authorized a full-scale "special military operation" in Ukraine with the goals of "demilitarizing and denazifying Ukraine and ending the genocide of Russians within Ukrainian borders".[21] The first phase of the war from late February to late March marked a Russian offensive to occupy Ukraine and replace its government. The second phase lasted from late March to early July and included a shift to Russian operational goals to refocus on eastern Ukraine and a two-pronged Ukrainian counteroffensive in the north and south. This shift has also relegated most fighting to Ukraine's southern and eastern regions.

The third phase spanned early July until the end of August and included Russian forces expanding their revised operational goals to include Kherson and Zaporizhia oblasts and an increase in Ukrainian partisan fighting. The shift to include Zaporizhia and its nuclear plant sparked international worry about a nuclear disaster. Phase four began in early September and was marked by strong Ukrainian advances in Kharkiv oblast and revitalized counteroffensives, especially in the south. As of October 5th, the war has

[20] Andrew Roth, "Russia Issues List of Demands It Says Must Be Met to Lower Tensions in Europe," The Guardian (Guardian News and Media, December 17, 2021), https://www.theguardian.com/world/2021/dec/17/russia-issues-list-demands-tensions-europe-ukraine-nato.
[21] Andrew Osborn and Polina Nikolskaya, "Russia's Putin Authorises 'Special Military Operation' against Ukraine," Reuters (Thomson Reuters, February 24, 2022), https://www.reuters.com/world/europe/russias-putin-authorises-military-operations-donbass-domestic-media-2022-02-24/.

entered a new phase. Russia's illegal annexation of four Ukrainian territories[22] and the threat of nuclear weapons by the deputy head of the Russian Security Council Dmitry Medvedev[23] may indicate another widening of the war.

2.4 Technical and Historical Background of Hyperspectral Imagery to Locate Mass Graves

HSI, developed by NASA's Jet Propulsion Laboratory in the 1970s, is a passive remote sensing system that operates by collecting and processing reflected radiance from objects across the electromagnetic spectrum in a contiguous set of narrow wavelength bands. The region of the electromagnetic spectrum observed by HSI typically spans the visible and infrared (IR) portions of the electromagnetic spectrum. The visible region of the electromagnetic spectrum ranges from 0.4 µm to 0.7 µm. The IR portion can be subdivided into reflected and thermal IR, of interest here is the reflected IR portion, spanning approximately 0.7 µm to 3.0 µm. This can further be divided into the near-

[22] Adam Schreck, "Putin Signs Annexation of Ukrainian Regions as Losses Mount," AP NEWS (Associated Press, October 5, 2022), https://apnews.com/article/russia-ukraine-putin-international-law-donetsk-9fcd11c11936dd700db94ab725f2b7d6.

[23] Al Jazeera, "Ukraine War Enters New Phase as Annexation Votes Draw to Close," Russia-Ukraine war News | Al Jazeera (Al Jazeera, September 27, 2022), https://www.aljazeera.com/news/2022/9/27/annexation-votes-to-end-in-russia-occupied-ukraine.

infrared region (NIR) from approximately 0.7-1.3 μm and the short-wave infrared (SWIR) from approximately 1.3-3 μm.

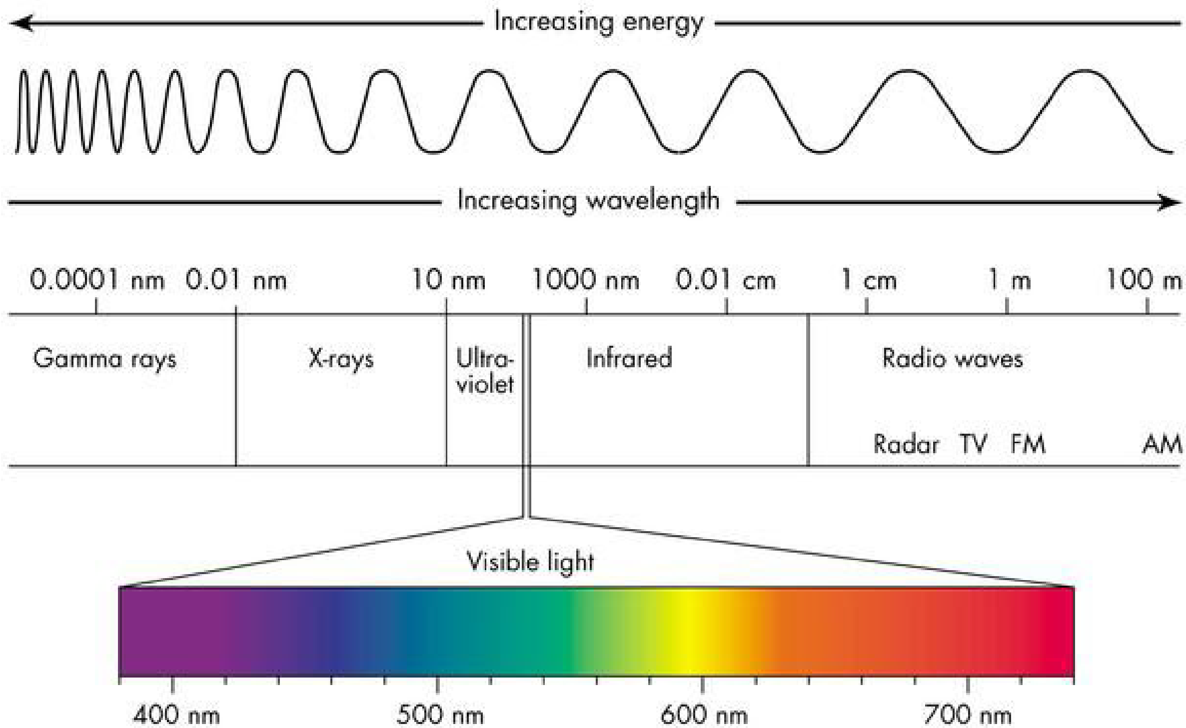

Figure 1. An illustration of the electromagnetic spectrum. Data is from Principles of Structural Chemistry.[24]

The goal of this is to record the spectral signature of each pixel in an image and to identify specific objects, materials, or processes. Objects, materials, and processes have unique spectral signatures that result from the presence or absence, position, and shape of absorption features on their surface. These unique signatures enable object, material, and process identification from HSI and aid in creating signature databases, as well as locating and identifying future targets. Here the target of interest for HSI is identifying and locating vegetation spectral signatures that may indicate the presence of buried

[24] *Principles of Structural Chemistry* (Coe College), accessed October 17, 2022, https://sites.google.com/a/coe.edu/principles-of-structural-chemistry/relationship-between-light-and-matter/electromagnetic-spectrum.

human remains. While human burials do not have a spectral signature of their own, secondary effects of these burials can be observed using HSI, and when aggregated with multiple datasets, potential clandestine mass grave locations can be determined.

Of specific interest to this application of HSI is the secondary effect of vegetation associated with disturbed ground containing buried human remains. Previous research at the University of Tennessee Knoxville has shown that vegetation spectra are influenced by ground disturbance and can be differentiated from vegetation spectra of undisturbed sites at a rate greater than chance.[25] This is likely due to altering the nutrient content in the soil, impacting chlorophyll concentration in vegetation which can be detected using HSI. Adjacent research in plant science[26] and forensic science[27] has shown that human decomposition follows a predictable chemical and physical process that influences the ecosystem surrounding burial sites and alters soil chemistry that positively affects vegetation development. This chemical source-sink relationship between buried human remains and vegetation may alter vegetation spectra in response to inputs to the soil via nutrients from human decomposition.

When this spectral signature is identified and aggregated with other datasets, such as social media analysis, eyewitness testimony, satellite imagery, light detection and ranging (LiDAR), and synthetic aperture radar (SAR), potential clandestine mass graves may be identified. It is important to note that since proxies are used to detect potential

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[25] Katie Ann Corcoran, "A Characterization of Human Burial Signatures Using Spectroscopy and LIDAR," *A Characterization of Human Burial Signatures Using Spectroscopy and LIDAR* (dissertation, University of Tennessee Knoxville, 2016), https://trace.tennessee.edu/utk_graddiss/4090/, 220.

[26] Holly Brabazon et al., "Plants to Remotely Detect Human Decomposition?," *Trends in Plant Science* 25, no. 10 (2020): pp. 947-949, https://doi.org/10.1016/j.tplants.2020.07.013.

[27] Marcin Cholewa, Małgorzata Bonar, and Marcin Kadej, "Can Plants Indicate Where a Corpse Is Buried? Effects of Buried Animal Tissues on Plant Chemistry: Preliminary Study," *Forensic Science International* 333 (2022): pp. 1-11, https://doi.org/10.1016/j.forsciint.2022.111208, 9.

mass graves in remote sensing, it is imperative to have at minimum 2-3 datasets from various reliable sources to validate anomalies and produce statistically significant results.

2.4.2 Review of Previous Research

Some of the first experimental studies exploring the utility of HSI as a method for detecting mass graves begin in the late 2000s when Kalacska and Bell[28] and Kalacska *et al*.[29] studied an experimental mass grave using cattle as human analogs in Northwest Guanacaste, Costa Rica. These studies focused on testing the efficiency of in situ terrestrial and airborne spectral imaging in a tropical moist forest climate with a mass grave measuring 5 m^2. The spectral data collected from airborne collection showed an advantage of using NIR and SWIR to differentiate between identically constructed control and experimental graves. Terrestrial spectra data also showed differentiation between disturbed ground without a burial and the experimental grave until the experiment concluded after 16 months.[30, 31]

In 2012, Caccianiga *et al*. published a study examining the relationship between decomposition and soil and vegetation structure in northern Italy in a suboceanic climate. The study used swine as human analogs and found that soil disturbance was the primary factor that influenced vegetation cover, while decomposition was a less critical secondary factor.[32] Leblanc *et al.* were the first to perform a blind test using airborne HSI to

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[28] M. Kalacska and L.S. Bell, "Remote Sensing as a Tool for the Detection of Clandestine Mass Graves," *Canadian Society of Forensic Science Journal* 39, no. 1 (2006): pp. 1-13, https://doi.org/10.1080/00085030.2006.10757132.

[29] Margaret E. Kalacska et al., "The Application of Remote Sensing for Detecting Mass Graves: An Experimental Animal Case Study from Costa Rica*," *Journal of Forensic Sciences* 54, no. 1 (2009): pp. 159-166, https://doi.org/10.1111/j.1556-4029.2008.00938.x.

[30] Kalacska and Bell, 12.

[31] Kalacska et al., 165.

[32] Marco Caccianiga, Stefania Bottacin, and Cristina Cattaneo, "Vegetation Dynamics as a Tool for Detecting Clandestine Graves," *Journal of Forensic Sciences* 57, no. 4 (March 5, 2012): pp. 983-988, https://doi.org/10.1111/j.1556-4029.2012.02071.x.

successfully predict the unknown locations of two unmarked single graves - 4 years old and 1 month old respectively, within a 10 m GPS error using swine carcasses in Ottawa, Canada.[33] This study relied on the presence of exposed soil and the ability to isolate the chemical compound hydroxyl, a spectral signature that indicates clay in the soil.

More recently, Corcoran became the first to study HSI to detect clandestine mass graves using human cadavers to characterize human burial spectra signatures. The author concluded that differences in the visible narrow red, NIR, and SWIR spectral signatures between disturbed vegetation and undisturbed vegetation allowed for the vegetation to be separated into discrete groups, and that better separation was achieved in the visible red region of the electromagnetic spectrum.[34] However, the terrestrial wavelengths failed to successfully differentiate disturbed and undisturbed vegetation when scaled up to an airborne HSI sensor.

Silván-Cárdenas *et al.* built upon previous research using terrestrial HSI sensors and swine to discover that the spectral separability of a mass grave is at least as large as the separability of a smaller grave and that the presence of lime does not significantly reduce the spectra separability of a grave.[35] Additionally, the vegetation indices GNDVI and NDREI, which are sensitive to Nitrogen content, were able to be used to detect burial sites at 3 1/2 months post-burial and 4 months post-burial respectively.

Law enforcement agencies have also begun utilizing HSI to aid in criminal, search and rescue, and search and recovery investigations. A mineralogist at Miami

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[33] G. Leblanc, M. Kalacska, and R. Soffer, "Detection of Single Graves by Airborne Hyperspectral Imaging," *Forensic Science International* 245 (2014): pp. 17-23, https://doi.org/10.1016/j.forsciint.2014.08.020.
[34] Corcoran, 220.
[35] J.L. Silván-Cárdenas et al., "Assessing Optical Remote Sensing for Grave Detection," *Forensic Science International* 329 (2021): p. 111064, https://doi.org/10.1016/j.forsciint.2021.111064.

University has been awarded a grant of more than $500,000 by the National Institute of Justice to create a spectral library of "human materials" including blood, skin, hair, clothing, and bone.[36] This "human materials" spectral signature library now contains more than 300 clothing signatures in both wet and dry conditions, 110 skin tone signatures from a variety of ethnicities and ages, and over 8,000 individual spectral signatures of fresh and dried blood on various materials. Also included were items that may be misconstrued as blood, drugs, or other objects of interest. However, this forensic tool is still in development and largely focuses on exposed surface remains and not clandestine graves.

These experimental studies have laid important groundwork for future research in utilizing HSI for detecting clandestine mass graves. However, much of the research mentioned utilized animal carcasses as human analogs, which presents a problem when applying this research to real-world cases. Animals such as cattle and swine have different rates of decomposition and release varying amounts of nutrients when decomposing than human remains. Human and swine decomposition processes remain consistent with each other until approximately 25 days after burial, whereas swine remains begin to skeletonize more rapidly than human remains.[37] Further, swine decomposition occurred at a more rapid rate than human decomposition. So, while the two share similar decomposition patterns and swine are a more suitable proxy for humans

[36] James Dawson and Danielle McLeod-Henning, "Hyperspectral Imaging and the Search for Humans, Dead or Alive," National Institute of Justice (National Institute of Justice, April 17, 2020), https://nij.ojp.gov/topics/articles/hyperspectral-imaging-and-search-humans-dead-or-alive.

[37] Dawnie Wolfe Steadman, "Multidisciplinary Validation Study of Nonhuman Animal Models for Forensic Decomposition Research," Multidisciplinary Validation Study of Nonhuman Animal Models for Forensic Decomposition Research (U.S. Department of Justice Office of Justice Programs, March 2018), https://www.ojp.gov/ncjrs/virtual-library/abstracts/multidisciplinary-validation-study-nonhuman-animal-models-forensic, 6.

when compared to cattle or rabbits, they still differ in overall decomposition processes. This makes swine a suitable proxy for human remains when conducting baseline decomposition experiments, but they will lack the variability seen in actual human remains. For an application such as detecting clandestine mass graves, where subtle secondary effects are used as proxies, using human analogs in experimental studies may provide restricted or incomplete results.

Another limitation is that much of the experimental research has employed terrestrial-based collection plans, which has severely limited the real-world application of this technique in active conflict zones. Employing in situ remote sensing in hostile areas has been one of the application's greatest limiting factors. While it has been proven that airborne HSI sensors are capable of sensing large mass graves, less work has been done utilizing the platform due to scalability and sensitivity issues. Due to the only recent inclusion of human cadavers in experimental studies, preference for super fine spectral and spatial resolution terrestrial sensors, and the differences in operating environment between a controlled experimental study and an active conflict zone, a geospatial strategy to fuse social media analysis and HSI to detect potential clandestine mass graves in an active war zone has never been created.

2.5 Geography and Climate of Ukraine

Figure 2. Geopolitical reference map of Ukraine. Data is from the United Nations Office for the Coordination of Humanitarian Affairs.[38]

Ukraine is an Eastern European country and the second largest country by land mass on the continent after Russia. It is bordered by Belarus in the north, Russia in the east, the Sea of Azov and the Black Sea in the south, Romania and Moldova to the southwest, and Poland, Slovakia, and Hungary to the west. The country lies in the southwestern region of the Russian Plain.[39] Ukraine is home to the Ukrainian Carpathian and Crimean Mountain ranges, but only approximately 5% of the country's land mass is mountainous. Much of the country consists of

[38] Oleksandr Shcheglov, "Ukraine Reference Map," ArcGIS Online (ESRI, October 5, 2022), https://gisanddata.maps.arcgis.com/home/item.html?id=1b2ff0cd509846879fcf00ec9c90a2ce.
[39] "Ukraine," Encyclopædia Britannica (Encyclopædia Britannica, inc.), accessed October 11, 2022, https://www.britannica.com/place/Ukraine.

level plains at an average elevation of 175 m above sea level,[40] interspersed with highlands and lowlands running from the northwest of the country to the southeast in a continuous belt.

Three general agroecological zones are found in Ukraine in addition to the two mountain zones mentioned above. Sandy podzolized soils can be found in the northern and northwestern Polissya forest zone and make up approximately 20% of the country's area.[41] These soils develop in moist climates under coniferous or mixed boreal forests and are typically acidic. They are poor soils for agriculture and require extra nutrients to be added to the soil if they are to be farmed due to their sandy nature and low levels of nutrients and moisture.

Central Ukraine's forest-steppe zone occupies approximately 35% of the land mass but has a belt of extremely fertile, black Ukrainian chernozems running through it. This chernozem belt covers approximately 66% of the country's area[42] and continues through the eastern and southern Steppe zone, which makes up the rest of the country's land mass. This soil contains a high percentage of dark organic matter. The percentage of humus in the chernozem soil gradually drops from north to south in this belt until there is very little humus in the soil in the south of the country. It is extremely fertile soil and has a high moisture retention rate. Gray forest soils and podzolized black-earth soils can also be found in this zone among the uplands, lowlands, and around the northern perimeters of the chernozem zone.[43]

40 "Ukraine,".
41 "Ukraine,".
42 "Ukraine,".
43 "Ukraine,".

In addition to this chernozem belt, Southern and Eastern Ukraine have a small percentage of chestnut saline soils, approximately 2% of Ukraine's land mass.[44] These soils become increasingly salinized closer to the Black Sea. Salinized soils can have detrimental effects on plant growth, plant yield, and soil erosion. In extreme cases, salinized soils can become sodic, limiting or preventing water drainage from the soil.

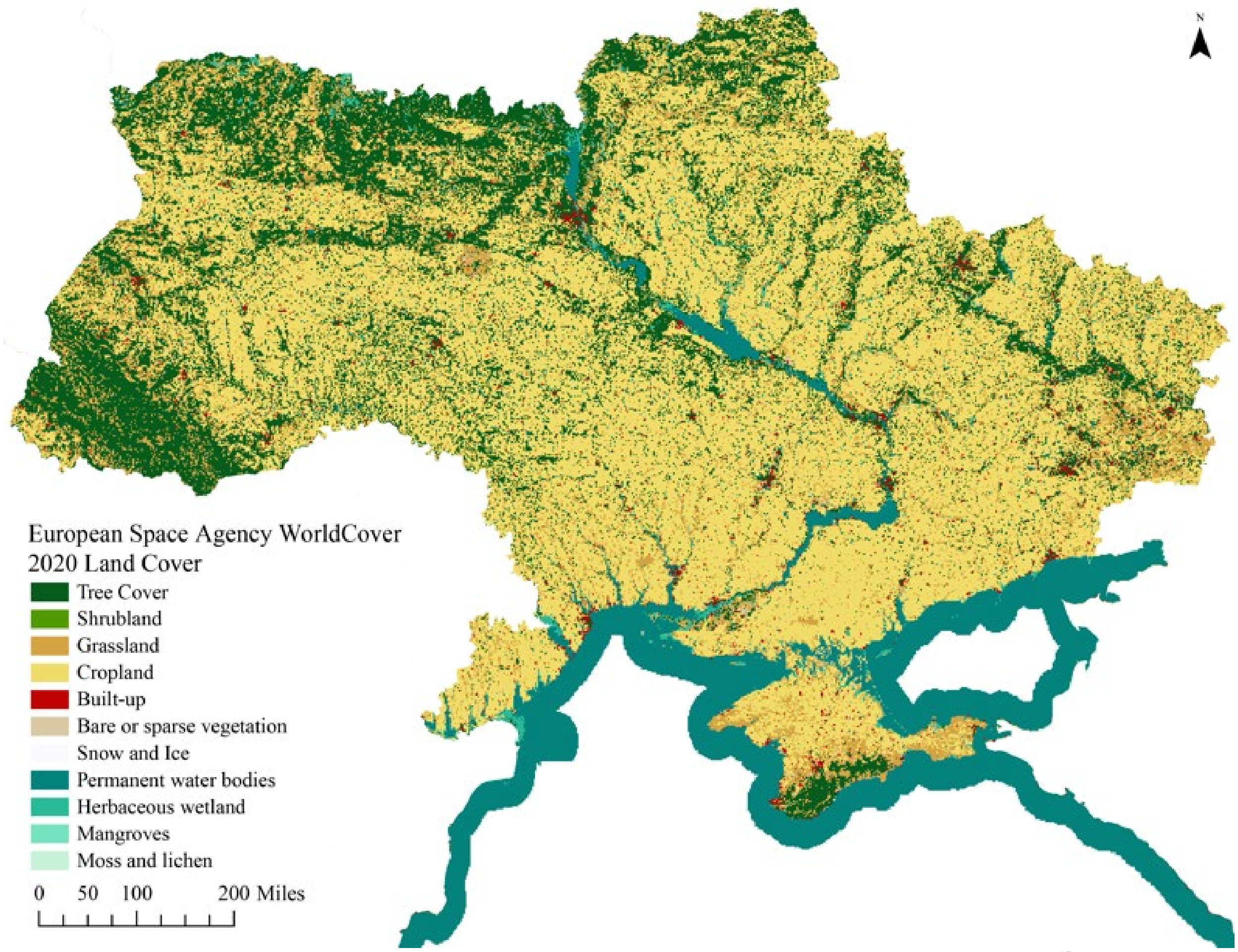

Figure 3. European Space Agency 2020 Land Cover Classification of Ukraine. Data is from ESRI.[45]

[44] Turi Fileccia et al., "Ukraine - Soil Fertility to Strengthen Climate Resilience: Preliminary Assessment of the Potential Benefits of Conservation Agriculture: Main Report (English)" (The World Bank, 2014), pp. 1-79, https://www.researchgate.net/publication/312136260_Ukraine_Soil_fertility_to_strengthen_climate_resilience_preliminary_assessment_of_the_potential_benefits_of_conservation_agriculture_Main_report_English.

[45] ESRI, "European Space Agency WorldCover 2020 Land Cover," ArcGIS Online (ESRI, February 22, 2022), https://gisanddata.maps.arcgis.com/home/item.html?id=e28b7e1da5414010ba4f47dd5a3c3ebb.

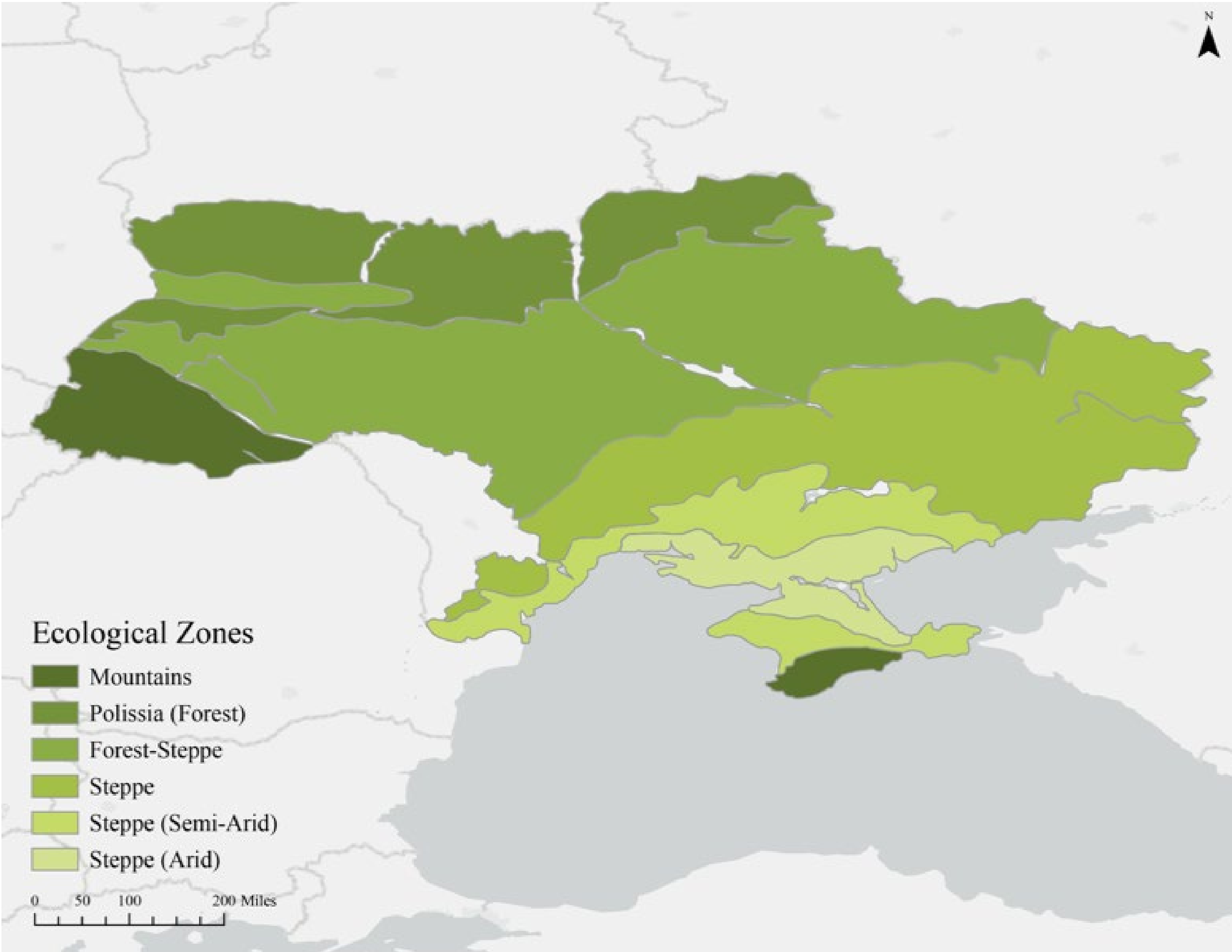

Figure 4. Ecological Zones of Ukraine. Data is from Google Maps.[46]

Ukraine has a temperate climate influenced by warm, humid air coming off the Atlantic Ocean. An exception to this is the Southern Crimea coast, which has a subtropical Mediterranean climate. Weather is considerably milder in the western regions of the country. The eastern regions of the country experience lower average temperatures in the winter and higher average temperatures in the summer. Average annual temperatures range from 42-45ºF (5.5-7ºC) in the north and 52-55º F (11-13ºC) in the

[46] "Nature-Agricultural Zoning of Ukraine," GoogleMaps (Google, March 25, 2020), https://www.google.com/maps/d/viewer?ie=UTF8&hl=ru&oe=UTF8&start=0&num=200&msa=0&ll=48.31242800000003%2C31.684570000000015&spn=13.376872%2C33.815918&t=h&z=6&mid=1MEGcqrK1pfatf6IrfkTo1lXaDEs.

south.[47] Mean summer temperatures range from 65ºF to 72ºF (18º-22ºC), while mean winter temperatures range from 23ºF to 36ºF (-4.8-2ºC).[48]

Ukraine averages between 20 and 23.5 inches of rainfall per year, with precipitation falling predominately in the summer and fall months. June and July have the highest precipitation rates,[49] while February is typically the driest month. Precipitation is highly variable depending on the region of the country. Western Ukraine, particularly the Carpathian Mountains, receives over 47 inches of precipitation while lowlands boarding the Black Sea receive less than 16 inches annually.[50]

[47].“World Bank Climate Change Knowledge Portal,” Climatology | Climate Change Knowledge Portal, accessed October 11, 2022, https://climateknowledgeportal.worldbank.org/country/ukraine/climate-data-historical#:~:text=Ukraine%20has%20a%20mostly%20temperate,months%20(May%20to%20August).

[48] “World Bank Climate Change Knowledge Portal,”.

[49] “World Bank Climate Change Knowledge Portal,”.

[50] “Ukraine,”.

2.6 Currently Known Mass Graves in Ukraine

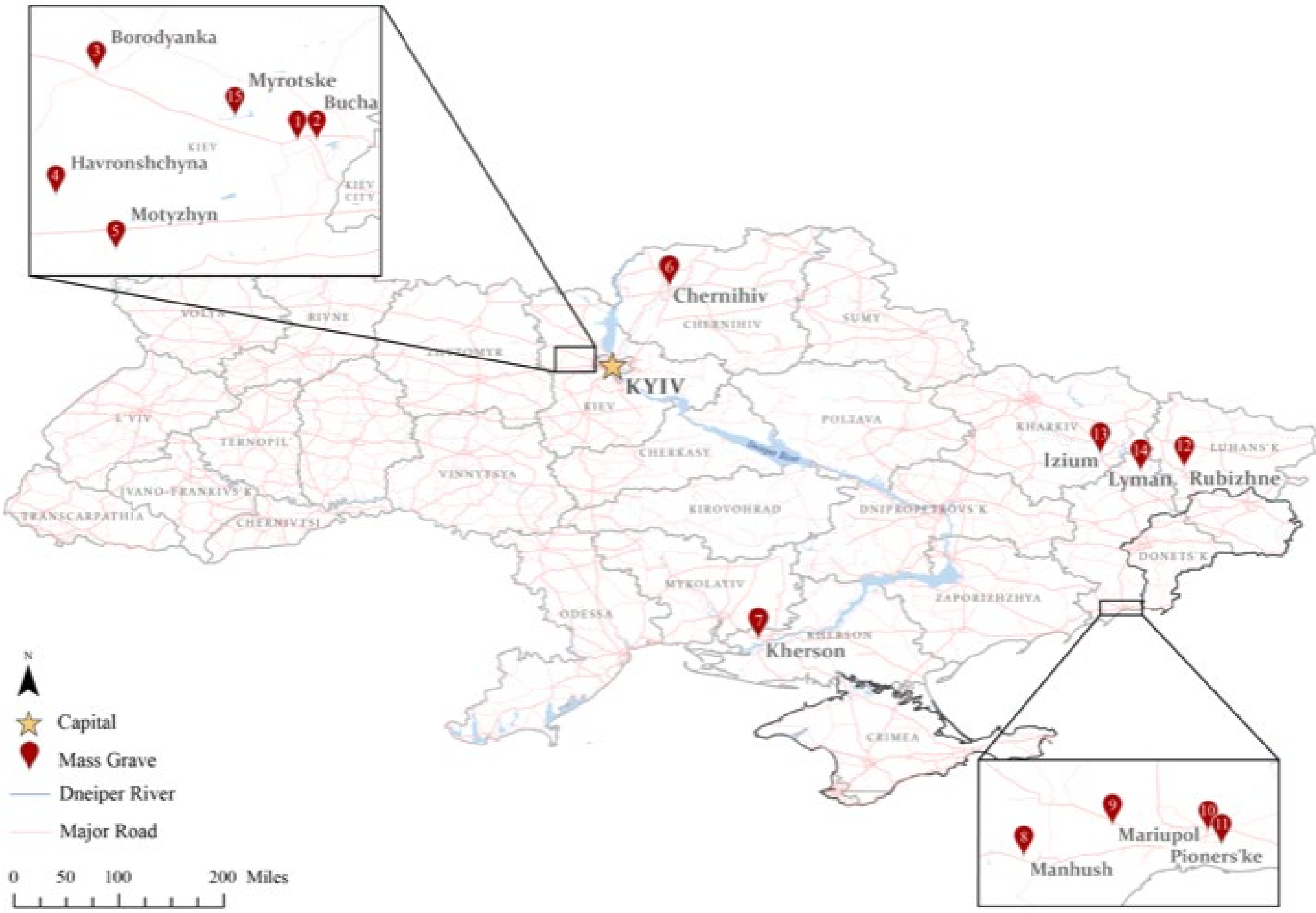

Figure 5. Mass graves in Ukraine resulting from the 2022 Russian invasion. Data obtained from the Centre for Information Resilience Eyes on Russia Project.[51] *Names of the mass graves and approximate coordinates can be found in Table 1.*

[51] Centre for Information Resilience, "Eyes on Russia: The Russia-Ukraine Monitor Map by Cen4infoRes · MapHub," The Russian-Ukraine Monitor Map (Centre for Information Resilience), accessed October 17, 2022, https://maphub.net/Cen4infoRes/russian-ukraine-monitor.

ID	Location	Coordinates
1	Church of St. Andrew and Pyervozvannoho All Saints Mass Grave Bucha, Kyiv Oblast, Ukraine	50º 32’ 54.0” N 30º 12’ 19.0” E
2	Football Field Mass Grave Bucha, Kyiv Oblast, Ukraine	50º 32’ 54.6” N 30º 13’ 55.4” E
3	Hospital Mass Grave Borodyanka, Kyiv Oblast, Ukraine	50º 38’ 39.3” N 29º 55’ 35.8” E
4	Mass Grave Near Destroyed Car Havronshchyna, Kyiv Oblast, Ukraine	50º 28’ 21.5” N 29º 52’ 13.7” E
5	Suhenko Family Mass Grave Motyzhyn, Kyiv Oblast, Ukraine	50º 23’ 47.7” N 29º 57’ 13.4” E
6	Yalivshchyna Mass Grave Chernihiv, Chernihiv Oblast, Ukraine	51º 31’ 39.4” N 31º 18’ 10.7” E
7	Kherson City Mass Grave Kherson, Kherson Oblast, Ukraine	46º 40’ 10.4” N 32º 31’ 49.5” E
8	Manhush Mass Grave Manhush, Donetsk Oblast, Ukraine	47º 04’ 23.0” N 37º 17’ 59.5” E
9	Western Mariupol Mass Grave Mariupol, Donetsk Oblast, Ukraine	47º 08’ 19.8” N 37º 29’ 08.5” E
10	Kindergarten Mass Grave Mariupol, Donetsk Oblast, Ukraine	47º 07’ 30.3” N 37º 41’ 11.1” E
11	Vynohradne Cemetery Mass Grave Pioners’ke, Donetsk Oblast, Ukraine	47º 05’ 51.6” N 37º 42’ 52.9” E
12	Rubhizhne Cemetery Mass Grave Rubhizhne, Luhansk Oblast, Ukraine	49º 02’ 05.5” N 38º 24’ 01.8” E
13	Izium Cemetery Mass Grave Izium, Kharkiv Oblast, Ukraine	49º 13’ 15.3” N 37º 14’ 40.4” E
14	Lyman Mass Grave* Lyman, Donetsk Oblast, Ukraine	48º 59’ 23.3” N 37º 48’ 18.0” E

15	Myrotske Village Mass Grave* Myrotske, Kyiv Oblast, Ukraine	50º 34’ 52” N 30º 6’ 59” E

Table 1. Index of Ukrainian Mass Graves as of 07 November 2022.
** Indicates that the mass grave’s geolocation has not been independently verified, instead the coordinates of the city or town closest to the mass grave have been used.*

3. Methodology

3.1 Primary Methods

The methodology behind this strategy focuses on fusing social media collection and HSI collection, forming a multi-modal target-centric approach. The strategy begins with social media data collection and analysis to conduct a wide-breadth search to achieve several aims: identify and keep track of discovered mass graves; retroactively search for additional potential clandestine mass graves, and prospectively search for activities that may be indicative of future or ongoing potential clandestine mass grave locations in Ukraine in areas currently under Russian control. This initial collection and analysis process serves as a tip-off point to trigger more focused HSI collection and analysis on areas that exhibit indicators of potential mass graves. These indicators include but are not limited to: video or photographic evidence of potential mass graves; written eye-witness accounts of mass graves; thinning of forests by Russian forces; expansions of currently existing cemeteries by Russian forces and the presence of a backhoe or Russian BTM-3 trenching machine; long trenches of freshly disturbed soil; frequent Russian activity at cemeteries, especially if trucks are arriving at the site; areas that have or are experiencing heavy partisan fighting, heavy artillery attacks; or areas near Russian filtration centers.

Once HSI collection is triggered, an airborne HSI sensor will be tasked to collect spectral signatures of the area(s) of interest (AOI). These collected signatures will be compared to existing vegetation spectral libraries analyzed using statistical classification methods to differentiate the signatures into discrete groups of undisturbed soil and disturbed soil. These results will be conflated with the results of social media analysis, collateral datasets, and optional secondary remote sensing methods that are briefly described in the next subsection. Clandestine graves are subtle targets and as such, it is of the utmost importance that multiple data sources are analyzed to produce statistically significant results and reduce the chances of false positives.

For irrefutable confirmation that these locations are clandestine mass graves, they will need to be excavated using archaeological methods. However, due to the current high-risk conflict environment in Ukraine, it is unlikely that archaeological excavation teams will be put on the ground within the next five years. This limitation increases the importance of identifying potential clandestine mass grave locations using this proposed multivariate geospatial strategy. Even though archaeological excavation methods are not a part of this geospatial strategy, they are briefly included here as a next step in the investigation process.

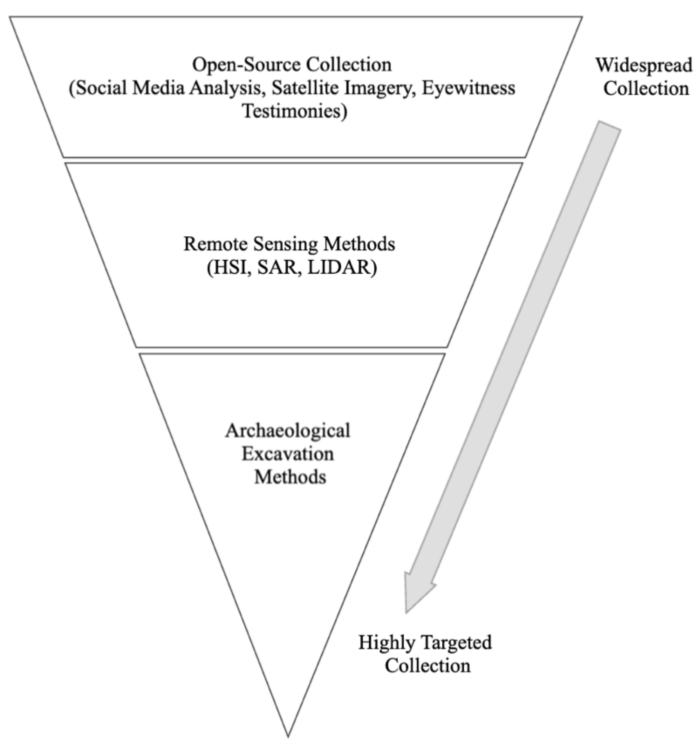

Figure 6. Methodology Graphic.

To support the primary methodology, collateral data sets are required to round out collection and analysis and provide additional datasets to corroborate social media analysis and HSI analysis results. These data sets include commercial electro-optical (EO) satellite imagery from a company such as Maxar Technologies or Planet Labs, and eyewitness testimonies separate from social media. EO satellite imagery can aid in the identification of visual indicators of clandestine mass graves and increase the confidence level of social media and HSI analyses. Maxar Technologies EO satellite imagery has a native resolution of 30 cm, a derived resolution high-definition resolution of 15 cm, positional accuracy of less than 5 m, historical imagery dating from 1999,[52] and global revisit rates of up to 15 times a day.[53] Planet Labs EO satellite imagery has a 3.7 m resolution, historical imagery dating from 2009[54], and a minimum revisit rate of twice daily at 10:30 am and 1:30 pm local time.[55] Eyewitness testimonies separate from social media can reconstruct past events and provide details about the target or perpetrators that other data sources are incapable of. While eyewitness testimonies are subject to memory biases – cognitive biases that either impair or enhance memory recall or alters the content of the memory,[56] when aggregated with multiple other sources can help identify additional indicators or AOIs to investigate.

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52 Maxar Technologies, "Optical Imagery," Earth Intelligence & Space Infrastructure (Maxar Technologies), accessed October 18, 2022, https://www.maxar.com/products/optical-imagery.

53 Carrie Drake, "From Sensor to Decision: Maxar's Combined Offerings Support next-Gen...," Maxar Blog (Maxar Technologies, September 27, 2021), https://blog.maxar.com/earth-intelligence/2021/from-sensor-to-decision-maxars-combined-offerings-support-next-gen-national-security-missions#:~:text=With%20the%20highly%20anticipated%20launch,at%2030%20cm%20class%20resolution.

54 Planet Labs, "Planet Monitoring - Satellite Imagery and Monitoring," Planet (Planet Labs), accessed October 18, 2022, https://www.planet.com/products/monitoring/.

55 James Mason, "What Is Rapid Revisit and Why Does It Matter?," Planet (Planet Labs, September 6, 2019), https://www.planet.com/pulse/what-is-rapid-revisit-and-why-does-it-matter/.

56 "Memory Bias," Memory Bias definition | Psychology Glossary | AlleyDog.com (AlleyDog), accessed October 18, 2022, https://www.alleydog.com/glossary/definition.php?term=Memory%2BBias.

Other collateral data required includes a vegetation spectral signature library with which to compare collected HSI data to. The primary signature is brighter vegetation due to elevated levels of Nitrogen. Higher Nitrogen concentrations result in higher chlorophyll production, which results in increased energy absorption and a distinct change in the solar reflected energy measured by HIS sensors. Secondary signatures include any disturbed ground resulting from crop production, construction, or domesticated animal burials that may produce false positives. The U.S. Geological Survey High Resolution Spectral Library[57] and the ECOSTRESS Spectral Library[58] are two spectral libraries that may be used to compare spectral signatures. In addition to these two publicly available spectral libraries, it is recommended that all collected spectral signatures from HSI collection are recorded in a database for future investigations.

3.2 Secondary Methods

While the following remote sensing methods are not discussed at length in this strategy, they are additional data collection methods that would be beneficial to detecting potential clandestine mass graves if the investigators have the means to employ them alongside social media and HSI collection and analysis. These methods would also provide additional datasets to check the results of social media and HIS analysis results against and provide higher confidence levels to identify potential clandestine mass grave sites.

3.2.1 SAR for Change Detection

In areas like Chernihiv and Izium, Russian forces have cleared or thinned forest land to create areas for clandestine mass graves. It is likely that forest thinning or clear-cutting in Russian-controlled areas of Ukraine is an indicator of preparing the area for the creation of a

[57] "Spectral Library," Spectral Library | U.S. Geological Survey (U.S. Geological Survey), accessed October 18, 2022, https://www.usgs.gov/labs/spectroscopy-lab/science/spectral-library.

[58] "ECOSTRESS Spectral Library - Version 1.0 - ECOSTRESS Speclib," ECOSTRESS Spectral Library (NASA), accessed October 18, 2022, https://speclib.jpl.nasa.gov/.

mass grave when the AOI is heavily forested. Forest thinning, as opposed to clear-cutting, may indicate mass graves as perpetrators need to clear the area of trees that may obstruct trenching equipment or otherwise interfere with creating a mass grave, but some canopy cover is retained to guard the site against EO satellite imagery collection. SAR imagery may complement the primary methodology and help characterize areas where environmental change is detected, allowing for proactive investigations of potential active clandestine mass graves. This is done through coherent change detection, which can detect subtle changes that do not appear in EO imagery including forest density, soil excavation, and changes in the terrain.

Coherent change detection can be done by imaging the AOI multiple times using a satellite-based SAR with the same viewing geometry, and then comparing these images during analysis. A common method for doing this is the log-ratio scaling method, which requires loading the collected SAR data into a mapping software like ArcMap and using the included Spatial Analyst Extension Raster Calculator tool to calculate the log-ratio image using the following expression:

Log10("newer image"/ "older image")

The new log-ratio image can be analyzed to determine unchanged and changed features in the image. Unchanged features are displayed as intermediate gray tones and have a gray value hovering around zero. Changed features are displayed as either bright white or dark black tones. A bright white tone indicates that the reflectivity of an object has increased while a dark black tone indicates that the reflectivity of an object has decreased.

3.2.2 LiDAR for Elevation Change Detection

When a human burial occurs, undisturbed compacted soil is replaced with loose, aerated soil and human remains. Furthermore, during stage two of human decomposition, which begins approximately three to five days after death, leaked enzymes from autolysis cause the body to produce gases that cause the body to bloat. This can cause the body to double in size.[59] These two processes subtlety alter the elevation profile of the immediate area, which can be detected and measured using LiDAR sensors. This can be used to circumvent denial and deception attempts by perpetrators, such as placing human remains in body bags or plastic to contain the decomposing remains.

The extent of elevation change depends on several factors; namely how many buried remains are present, how much soil is replaced during backfilling of the grave, how much the soil is compacted, and if any measures are taken to disguise the grave. Additionally, as time goes on, the elevation profile of the grave can change due to soil compaction from gravitational effects and the decomposition of soft tissues, causing the soil to fill in the absent areas.[60] These volumetric changes are reflected in the elevation profile of the grave.

This data can be collected using either a terrestrial tripod-mounted LiDAR scanner or an airborne LiDAR scanner mounted to an unmanned aerial vehicle (UAV) or an aircraft, depending on the level of conflict around the AOI. Depending on the chosen platform, the viewing geometry of the sensor will be different and multiple passes by the sensor may be required to acquire a satisfactory point cloud density. Regardless of the platform chosen, the analysis will follow a similar path of point cloud alignment, filtering, and visualization. However, this signature is short-lived. From approximately two days pre-burial to one-day post-burial, there is an elevation gain from the initial soil disturbance followed by elevation loss from

[59] "The Stages of Human Decomposition [Updated June 2022]: Aftermath Services," Aftermath Services | Crime Scene Clean Up & Death Cleanup Professionals (Aftermath Services, July 13, 2022), https://www.aftermath.com/content/human-decomposition/#:~:text=Stage%20two%20of%20human%20decomposition,release%20also%20cause%20skin%20discoloration.

[60] Corcoran, 207.

one-day post-burial to 108 days post-burial.[61] No further elevation changes were seen after 108 days post-burial, indicating that it would only be a reliable secondary method for approximately the first 3.5 months post-burial.

3.3 Social Media Collection

3.3.1 Operational Security

Accessing, collecting, and analyzing open source intelligence (OSINT) and its subfield, social media intelligence (SOCINT) allows access to a wealth of extremely useful information for academic, government, and intelligence investigations. When conducting investigations into illegal activities, as is dealt with in this strategy, a high level of operational security (OPSEC) is required. OPSEC should be twofold: firstly, related to all hardware, software, and networks used in the investigation; and secondly, to the behavior and actions of the investigators.[62] Security measures should mitigate risks and threats as best as possible and consider all types of harm possible. Some of the greatest vulnerabilities to guard against are associated with internet connections, IP addresses, MAC addresses, devices, and investigator behavior.

The set of minimum-security standards put forward in the Berkeley Protocol will be followed here:

1. Investigators should maintain anonymity online and avoid disclosing any identifiable elements about themselves or their organizations.[63]
2. Investigators should conduct their investigations with the expectation that such activities will be monitored and analyzed by third parties.[64]

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[61] Corcoran, 208.

[62] "The Berkeley Protocol on Digital Open Source Investigations," The Berkeley Protocol on Digital Open Source Investigations (University of California, Berkeley, School of Law), accessed October 20, 2022, https://www.ohchr.org/sites/default/files/2022-04/OHCHR_BerkeleyProtocol.pdf.

[63] "The Berkeley Protocol", 33.

[64] "The Berkeley Protocol", 33.

3. The over-exploitation of a single source may increase the risk of third-party monitoring and analysis.[65]
4. Investigators should avoid repetitive or identifiable search patterns on identifiable devices to limit the occurrence of social engineering or phishing attacks.[66]
5. Professional and personal online activities and profiles should be kept separate; personal devices should be included in this to the extent possible.[67]
6. Multiple investigations should not be intermingled during data collection, documentation, and storage.[68]
7. Hardware and software that minimizes the effect of malware or viruses should be used whenever possible.[69]

In addition to following these standards, investigators should be aware of multiple vulnerabilities in their systems and devices and take mitigating actions to prevent them. Many websites use cookies, trackers, and beacons to collect data. Their owners can use these small files to recreate an investigator's browsing habits and track their subsequent internet activities. To avoid browser tracking, cookies should be cleared regularly on devices. All devices used should be password protected, have full-disk encryption enabled, and, if applicable, employ a multifactor authentication for increased security. The content of these devices should be backed up to a secondary location regularly and the devices should be stored in a secure location when not in use. Personal devices should not be used for investigations just as investigation devices should not be used for personal use.

[65] "The Berkeley Protocol", 33.
[66] "The Berkeley Protocol", 33.
[67] "The Berkeley Protocol", 33.
[68] "The Berkeley Protocol", 34.
[69] "The Berkeley Protocol", 34.

When possible, a strong, stable, private internet connection should be used, and public Wi-Fi and semi-private networks should be avoided. A personal password-protected Wi-Fi hotspot can help ensure this. Investigators should also use secure and updated browsers to minimize data leakage from plug-ins. A device's physical (MAC) and logical (IP) addresses can uniquely identify the device and reveal where an investigator is and whom they work for. Using a virtual private network (VPN) or another proxy can mask a device's IP address to prevent the device from being linked to the investigator, as well as create an encrypted channel for all communications between the investigator's device and the VPN server[70], which provides an additional layer of security.

To camouflage the device, creating a virtual machine to conduct the investigation is recommended.[71] This essentially creates a separate computer within the computer. This virtual machine has its own MAC address and can perform all the same applications and programs as a regular computer. This is easily done by partitioning a computer's hard drive and installing the desired operating system or software. From there the virtual machine can be configured as desired.

A false identity for all online interactions and collection for the investigator can help camouflage the investigator on websites and social media platforms that require profiles to access. This can range from a simple false name and email to more complex false identities with friend lists and records.

3.3.2 Digital Landscape Assessment

Conducting a digital landscape assessment should be done prior to beginning collection to understand the digital culture of Ukraine and Russia. This will help in understanding the

[70] "The Berkeley Protocol", 39.
[71] "The Berkeley Protocol", 40.

cultural context, deciding what sources may be useful, and collecting a representative sample of the two populations. Things that should be included are the type of technology available and who uses it; and what are the most common online platforms, communication services, social media platforms, apps, relevant parties (specific communities or armed groups), relevant languages and slang, frequently used search engines, and relevant laws. Investigators should also consider how gender, age, ethnicity, religion, age, socioeconomic status, education level, geography, and membership to a linguistic, ethnic, or religious minority may impact the scope of user-generated information collected. Some of these factors can be mitigated by searching out multiple types of sources and information. The investigator must be aware of this collection bias and that the information sample collected will be inevitably skewed by these factors.

Ukraine has an approximate population of 43.3 million with 53.7% being female and 46.3% being male.[72] As of January 2022, 70% of the population lived in urban centers while 30% lived in rural areas.[73] As of January 2022, there are 31.1 million internet users in Ukraine (71.8% of the population), while 12.23 million (28.2% of the population) did not use the internet.[74] The country has 28 million social media users, about 64.6% of the total population which was an increase of 8.9% from 2021.[75]

[72] Simon Kemp, "Digital 2022: Ukraine - DataReportal – Global Digital Insights," DataReportal (DataReportal – Global Digital Insights, February 15, 2022), https://datareportal.com/reports/digital-2022-ukraine.
[73] Kemp.
[74] Kemp.
[75] Kemp.

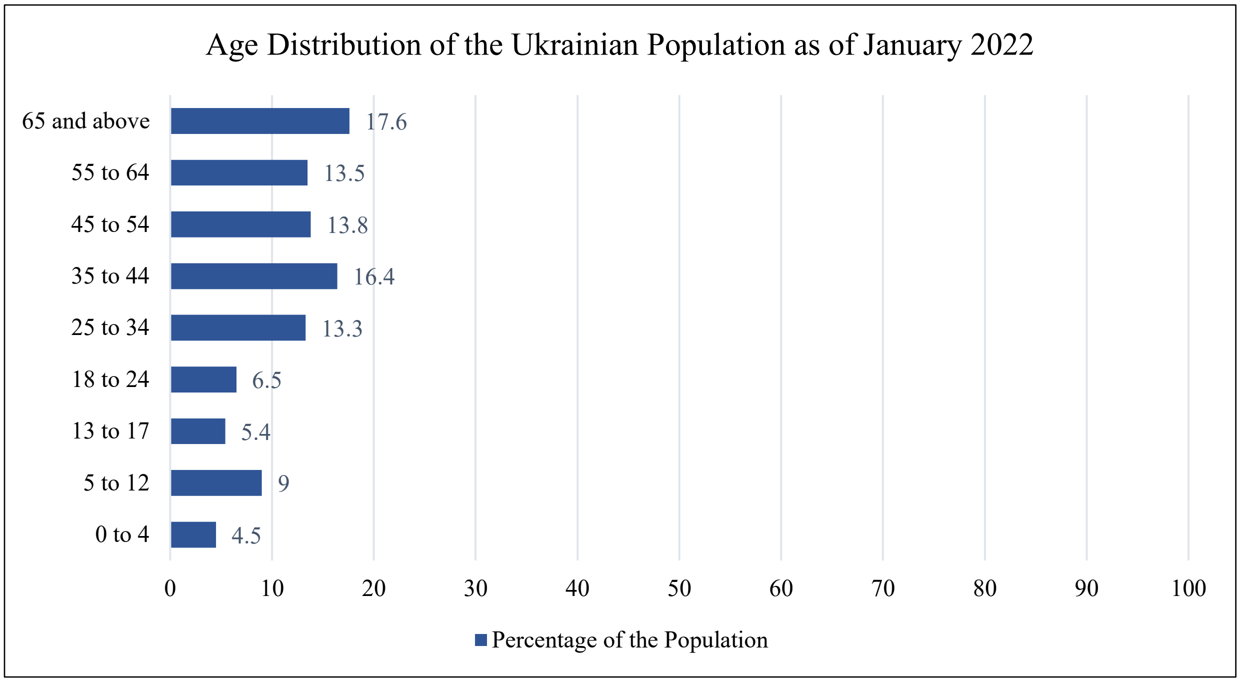

Figure 7. Graph of the age distribution of the Ukrainian Population in 2022. Data is from Datareportal.[76]

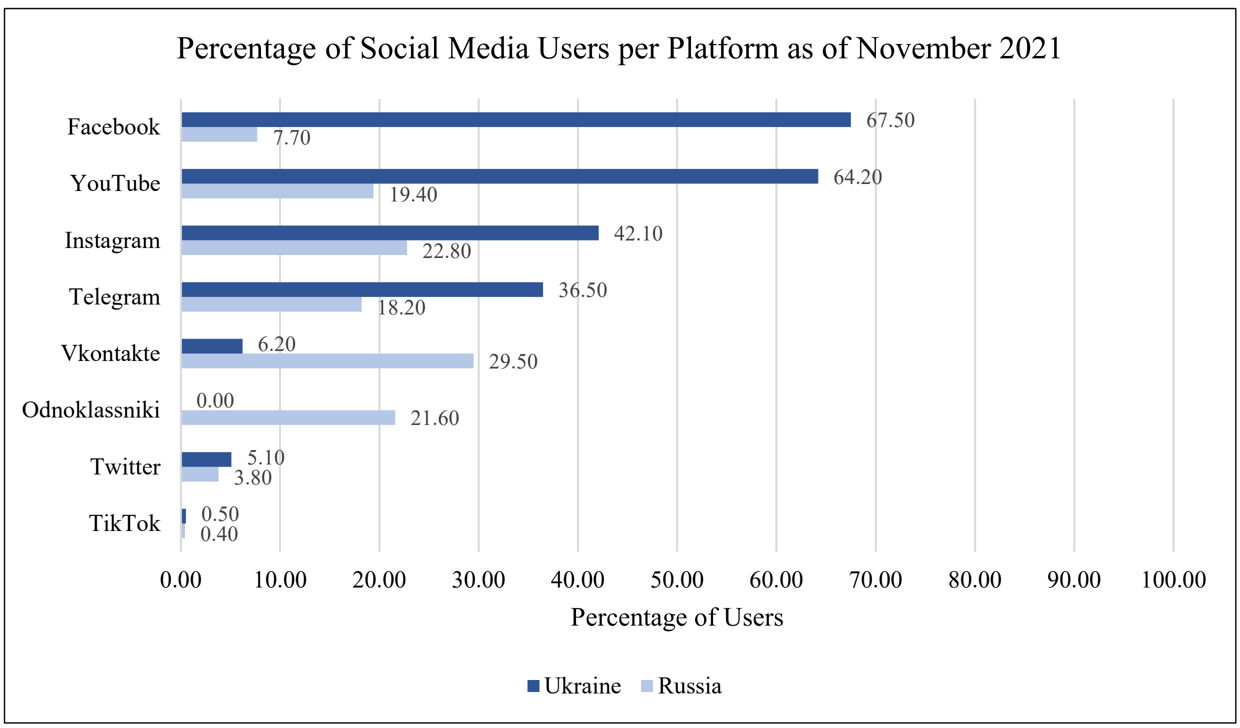

Figure 8. Graph of social media users by percentage for select social media platforms in Ukraine and Russia. Data is from Statista.[77]

[76] Kemp.
[77] S. Dixon, "Social Media Platforms Usage in Ukraine and Russia 2021," Statista (Statista, May 19, 2022), https://www.statista.com/statistics/1308258/social-media-penetration-ukraine-russia/.

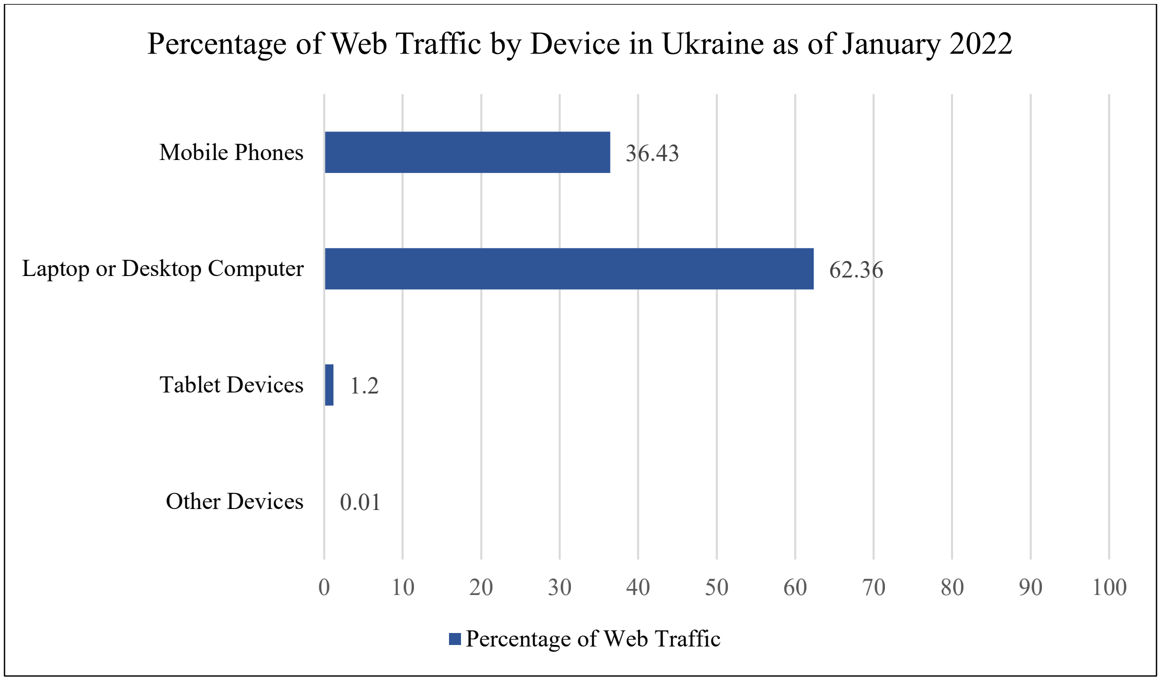

Figure 9. Graph of web traffic in Ukraine as of January 2022. Data is from Datareportal.[78]

For this strategy, Facebook, Twitter, YouTube, and Telegram have been identified as potential social media sources for social media collection, alongside blogs and newsfeeds. The Russian social media site Vkontakte has a small Ukrainian user base, but has been eliminated as a potential source due to heavy censorship and disinformation risks. While Instagram has a medium-sized user base in Ukraine, after a preliminary assessment it has also been eliminated as a potential source due to its lack of relevant content for this investigation.

3.3.3 Target Identification

As this collection plan utilizes a target-centric approach, a solid grasp of the targets is necessary. Understanding what factors in an environment increases the likelihood of a mass grave and determining if a common grave typology can be identified from mass graves that are currently being investigated is vital. The most important factors that increase the likelihood of a mass grave are wars of attrition, wars with the goal of annexation, and partisan fighting.

[78] Kemp.

According to Russian documents seized in early March, the military phase of the invasion was estimated to last 15 days[79] with little planning and supplies allotted to an extended invasion. Russian forces have made slow advances toward their goal of annexing the eastern regions of Ukraine and suffered heavy losses on all fronts, leading to a war of attrition. As established in Section 2.1, wars of annexation and wars of attrition greatly increase the likelihood of targeting civilians and mass killings[80], when coupled the likelihood is even higher. Russian forces may be targeting civilians to coerce the Ukrainian population to give up or refuse to aid partisan groups, reduce their own casualties and financial costs by launching indiscriminate shelling attacks, or as part of their policy of ethnic cleansing in Donetsk.[81,82,83] Areas with active partisan groups may also suffer disproportionate numbers of mass graves as Russian forces attack the local population indiscriminately in response to acts of sabotage and information sharing. A full list of geolocated cities, towns, villages, and settlements experiencing partisan fighting can be found in Appendix A.

Cities, towns, villages, or settlements near Russian filtration centers in Donetsk Oblast may also have a higher likelihood of having mass graves. A 17-year-old girl from Mariupol who went through a filtration center in Manhush came forward to share her experience after reaching safety. While waiting to be questioned, she overheard a conversation between two Russian soldiers stating that those who did not pass filtration were shot.[84] Visual indicators of mass

[79] Olena Roschyna, "Secret Documents of the Russians: the War Plan against Ukraine Was Calculated for 15 Days," Ukrainska Pravda (Ukrainska Pravda, March 2, 2022), https://www.pravda.com.ua/news/2022/03/2/7327539/.
[80] Downes, 53.
[81] Downes, 29.
[82] Slim.
[83] Downes, 35.
[84] Andy Heil, "'How about We Cut off Your Ear?': Ukrainian Teen Describes Family's 'Filtration' by Russian Troops," RadioFreeEurope/RadioLiberty (Radio Free Europe / Radio Liberty, May 1, 2022), https://www.rferl.org/a/ukraine-russia-filtration-violence-threats/31829588.html.

graves have already been documented in Manhush and in Olenivka, Volnovakha Raion. Additionally, the rail and transport hubs of Izium, Lyman, and Mariupol all have at least one known mass grave, indicating that key transport hubs may have a higher likelihood of mass graves as they are more strategically significant to Russian forces. Finally, three of the mass graves were located within close proximity to current or former dug-in Russian troop positions: the Myrotske Village mass grave, the Kherson City mass grave, and the Vynohradne Cemetery mass grave. A full list of geolocated and verified filtration centers in Donetsk Oblast can be found in Appendix B.

Indicators that may suggest activity linked to potential clandestine mass graves include video evidence of mass graves, photographic evidence of mass graves; written eye-witness accounts of mass graves; thinning of forests by Russian forces; expansions of currently existing cemeteries; the presence of a backhoe or Russian BTM-3 trenching machine at areas that exhibit at least one other indicator; long trenches of freshly disturbed soil; frequent Russian activity at cemeteries, especially if trucks are arriving at the site; areas that have or are experiencing heavy partisan fighting, heavy artillery attacks; or areas near Russian filtration centers.

During initial social media monitoring, two general grave typologies began to emerge. The first consists of a shallow grave, usually with up to ten victims. This typology was found in urban areas and in forested areas off the side of roads. These graves are typically either a small mass grave in the case of the Hospital mass grave in Borodyanka, the mass grave near a destroyed car in Havronshchyna, and the Suhenko family mass grave in Motyzhyn or a cluster of single burials in the case of the Football mass grave in Bucha and the Kindergarten mass grave in Mariupol. This type of grave will most likely be in a forested area and the victims will most likely not be wrapped in body bags. They may however be wrapped in cloth like the victims of the Hospital mass grave were, but this would not impact the ability of an HSI sensor to detect the grave.

The second grave typology consists of long trenches in churchyards or next to pre-existing cemeteries. These gravesites require a backhoe or trenching machine to create and can contain hundreds of victims that are usually wrapped in black plastic body bags. Examples of this typology are The Church of St Andrew and Pyervozvannoho All Saints mass graves, the Manhush mass grave, the West Mariupol mass grave, the Vynohradne Cemetery mass grave, the Rubizhne Cemetery mass grave, and the Kherson Cemetery mass grave. The Yalivshchyna Forest mass grave, Lyman mass graves, and Izium mass graves are included in this classification because a backhoe or trenching machine was used to dig trenches into which single burials were interred en mass. The Myrotske Village grave does not fit neatly into either topology. The mass grave consists of a trench containing seven remains in a forested area on the outskirts of the city. Descriptions of each mass grave, including approximate dates that the graves were created, can be found in Appendix C.

3.3.4 Online Inquiries

After a digital landscape assessment has been completed and a target list has been compiled, the online inquiry process begins. This is the process of discovering new information. To discover information relevant to retroactively identifying additional potential clandestine mass graves in Ukraine and proactively identifying areas where mass graves are likely to occur due to suspicious activity, a search and monitoring process will be used. Both retroactive and proactive searches should be structured in a systematic way, with clear research questions, search parameters, keywords, and operators. Documentation should occur at every step of the process and should be contemporaneous if possible and include the objective, research question, facts, assumptions, unknowns, search terms, keywords, searches, and search engines used. Specific times and locations can also be used to narrow down search results on social media platforms using advanced search settings. It would be best practice to search areas where at least one clandestine grave has been previously discovered, cities and towns experiencing partisan fighting, and cities and towns with a high certainty of having Russian filtration centers using these advanced settings. For this investigation, the dates of interest are 24 February 2022 – ongoing.

An example of an initial list of keywords and hashtags can be seen in Table 2 and a list of search operators and their functions in Table 3. Tools like Social-searcher, Hashatit, and Intelligence x: TG can search hashtags and usernames across multiple platforms, while Geogramint locates Telegram groups at specified geographic locations making initial online inquiries more efficient.

Keywords	**Hashtags**
Ukraine	#standwithukraine
Russia	#Ukraine
Russian Federation	#Russia
Izium/Izyum	#nowar
Bucha	#UkraineRussiaWar
Mariupol	#StopRussianAgression
Melitpol	#StopRussia
Kharkiv	#StopPutin
Kherson	#humanrights

Donetsk	#Ukrainiangenocide
Volodymyr Zelensky	#kharkiv
Putin	#donetsk
Genocide	#kherson
Massacre	#zelenskyi
Atrocities	#RussiaWarCrimes
Exhumation	#russianarmy
'Clandestine grave'	#fellas
'Mass grave'	#kyiv
'Mass burial'	#putinwarcrimes
'Human rights violation'	#izyummassacare
'Crimes against humanity'	#путин
'Armed conflict'	#чернигов
'War crimes'	#украина
'Russian invasion of Ukraine'	#Маріу́поль
'Russian filtration centers'	#киев
'Russian filtration camps'	#харьков
'Registration Camp'	
'Detention Camp'	
'Holding Camp'	

Table 2. An example list of initial search keywords and hashtags.

Operator	Function	Example
‘ ’	This links words together as a phrase	‘mass grave’ or ‘human rights violation’
OR	This finds optional keywords, phrases, spellings, etc.	Izium OR Izyum
site:	This specifies a domain name and/or type	site:edu OR site:ua
AROUND(n)	This specifies the proximity between two words or phrases where n is the possible number of words between terms.	Russia AROUND(3) ‘war crimes’
..	This specifies a number range to search	Ukraine 2021..2022
intitle:	This finds a single search term in the title of a webpage.	intitle:‘mass grave’ site:ua
allintitle:	This finds more than one search term in the title of a webpage	alltitle:‘mass grave’ site:ua
anurl:	This finds a keyword or phrase in a site’s address	inurl:Kherson
allinurl:	This finds more than one keyword in a site’s address	allinurl: Izium massacre OR Izyum massazre
Filetype:	This specifies the format the document being searched for.	Ukrainian genocide filetype:PDF
AND	This searches for two keywords	Mariupol AND Kharkiv
-	This excludes a term or phrase from results	‘armed conflict’ - Rohingya

Table 3. Summary of Google search operators.

The locations in Table 1 and Appendix A also provide a basis for defined targets for ongoing monitoring. Using lists of vetted websites, social media accounts, hashtags, and keywords, search queries can be run against these targets on an ongoing basis daily or weekly. This can track changing information in these areas using secured and verified sources. While this may be done manually, it is recommended that this monitoring be automated using either a script or tool. Many automation scripts are available for free on Github such as Data Sploit, SpiderFoot, Omnibus, Photon, and OSRFramework, while other independent tools like Phantombuster are available for a fee.

3.3.5 Preliminary Assessment

After any information has been discovered, a preliminary assessment determines if it is relevant enough to the investigation to warrant collection. If done correctly, this step should help prevent over-collection. This should determine if the information is (1) relevant, (2) reliable, (3) likely to be removed from public access or the internet, and (4) safe to collect. Information relevance will depend on the information's source, context, and content and the objectives of the collection. Reliability will depend on checking the embedded metadata, linked information, and investigating the original source of the information. This step may require tracing the original creator, author, or uploader through several sources to determine the information's provenance. Removal risk can be determined by the content of the information. If the information has graphic or offensive content, it is likely to be removed for violating a platform's terms of service. If the risk of removal is assessed to be high, the information should be collected immediately, regardless of ongoing verification of the information. Safety of information will depend on an assessment of the information to determine if the information is likely to have any corrupted files, malware, or other malicious software that may cause damage to the devices, hardware, and software being used for information collection.

3.3.6 Social Media Collection

The social media phase of this collection plan has three aims. First, to identify and record all discovered mass graves. Second, to retroactively search for additional potential mass graves that have already been created. Third, to proactively search for activities that may be indicative of activity related to the creation or use of potential clandestine mass graves in Russian-controlled areas of Ukraine. All three of these aims require a target-centric investigative approach to collection. This type of collection requires more agility and a wider variety of tools, methods, and sources as it seeks to discover everything about the topic rather than a monitoring approach, which is more passive. Investigative collection, however, will require multiple iterations of collection and analysis as new information is discovered.

Information should be collected on sight whenever possible and in its native format, or as close to its native format as possible. The current best practice is to collect the uniform resource locator (URL), Hypertext Markup Language (HTML) source code, and a full-page screen capture of the content with the date and time of collection visible at a minimum.[85] FRAPS, ShareX, and Greenshot are all open-source tools for screen capture. Embedded media files, embedded metadata, contextual data, and collector data should be collected whenever possible. Information such as uploader identifiers, hashtags, geolocation tags, and comments may fall into both the embedded metadata and contextual data categories.

The actual method of collection can range from screenshotting a piece of information to forensically downloading information and can be done manually or automatically through special tools. The process used to capture and collect the information will depend on whether the collection and larger investigation have the potential of being used as evidence within judicial proceedings. Screenshotting may be a sufficient collection method in simpler cases like internal reporting. In this case, the collection should use a cryptographic forensic download tool such as Forensic Toolkit, Forensically, or Autopsy since information on clandestine mass graves may be used at international criminal court proceedings for war crimes and crimes against humanity in the future. These forensic collection tools assign each piece of data a hash value. A hash value is a deterministic electronic numeric signature, usually 32 to 64 characters long, that uniquely identifies the data and remains unchanged unless the data file is altered in some way. This allows for data authentication during the collection and analysis process.

[85] "The Berkeley Protocol", 59.

As collection is occurring across multiple social media platforms, free tools like Tweetdeck and Hootsuite can help manage multiple social media feeds during collection by creating dashboards for specific content, keywords, hashtags, geographic locations, languages, dates, and engagement levels set in the tool's advanced settings. Tweetdeck allows investigators to manage an unlimited number of Twitter accounts, while the free version of Hootsuite allows investigators to manage three different social media accounts across multiple social media platforms. Tools like Phantombuster, Facebook Video Downloader, TGstat, Twitter Video Downloader, twint, and Twlets provide automatic data extraction and downloading options for various social media platforms and may also aid in collection. Both Hunch.ly and DMCA automate the collection of all visited sites to a local drive.

As the goals of this social media collection are large and the conflict environment in Ukraine is fluid, manually searching for information is too time-consuming and inefficient. Setting up web crawlers to automate the process of looking for information when possible should be done to manage attention resources under the theory of attention economics.[86] A web crawler's behavior is dictated by four policies set by the investigator. A selection policy that indicates what pages to download, a re-visit policy that indicates how frequently a page should be re-visited, a politeness policy that dictates how to avoid overloading the servers of the pages being crawled, and a parallelization policy to avoid repeated page downloads if multiple web crawlers are being used. Once a web crawler is set up with a specified number of seed URLs, the crawler scans each page, downloads any required content, identifies new URL links, and then navigates to the new page, and repeats the process. Common open-source web crawlers include Scrapy, Heritrix, Web-Harvest, and MechanicalSoup.

[86] Richard A. Lanham, *The Economics of Attention: Style and Substance in the Age of Information* (Chicago, IL: University of Chicago Press, 2007).

Once these pages have been located, the context of these sites can be extracted through a process called main body extraction, which utilizes natural language processing. This process extracts a page's HTML structure from the main body text, excluding surrounding web elements using tools like Flipboard, Goose, and the AlchemyAPI. Doing so prevents erroneous information or advertisements from being included in the collection, which may negatively influence later analysis. Named entity recognition can also be run to identify names, organizations, places, dates, times, and URLs within a page's main text. This process can be done using linguistic, pattern, or statistical machine-learning methods, however, their effectiveness depends on the source of training data used to train the algorithm. Algorithms will perform better when they are used against information that is the same information type that they were trained with. Popular named entity recognition tools include AlchemyAPI, and Aylien.

3.3.7 Archival

After social media and open source information has been collected, the information must then be archived within a database. This will create a digital collection of all evidence and information collected on the topic of clandestine mass graves in Ukraine and its associated documentation. When archived, the original copy should be preserved as it was captured as an evidentiary copy. This copy should never be altered or changed. For any analysis or visualization, working copies should be created and stored separately from the evidentiary copy. This database will aid in future analysis by providing a controlled environment where data exploitation tools can be tailor-made and provide data for large-scale temporal and statistical analysis. This can help combat overcollection and big data problems associated with this part of the geospatial strategy.

Archival includes permanent storage for all collected information, as well as hierarchy management, fixity checking, disaster recovery, and information retrieval.[87] Storage options include a local hard drive or a networked drive on a local, remote, or cloud network. At least three different copies of data on two different networks in two separate geographic locations are recommended in case of data loss or data errors.[88] The exact database software and storage solution used for this will vary depending on the investigator's personal or professional preferences.

3.4 Social Media Analysis

3.4.1 Data Verification

The first step of social media analysis is to verify the information. Verification refers to the process of establishing the validity of a piece of information that has been collected. This process can be broken down into three analytic groups: source, technical, and content. Source analysis evaluates the credibility of the source of the information, this will most likely be an author of an article, post, blog, or the creator of a photo or video. The first step in source analysis is to back-trace the piece of information to its original source. This is sometimes called attribution analysis. There may be difficulties locating the original source or sources of a piece of information if the source uses a pseudonym or remains anonymous, which may be done to protect both the author/creator and those close to them. While this step is not always possible and not essential to establish a piece of information's credibility and authenticity, it is advantageous.

In addition to attribution analysis, an information source's criteria should be evaluated on its credibility, independence, impartiality, specificity, and attenuation.[89] Credibility can be

[87] "The Berkeley Protocol", 61.
[88] "The Berkeley Protocol", 62.
[89] "The Berkeley Protocol", 63.

assessed by examining a source's posting history, online footprint, and online activity. Does the source's posting history suggest the author/creator is in the same geographic location they are posting about? Does the source have a post history indicating they post frequently about the same topic, or is this piece of information a one-off? What is the age of the source in question? Who is in the source's network and who follows the source? All these questions are helpful in assessing the credibility of a source.

Independence can be assessed in a similar way by looking at the source's network. This may show if they are associated with any political parties, organizations, or ideological groups that may influence their information. This will help identify any connections the source has to relevant Ukrainian or Russian entities involved in the Russo-Ukrainian war that may have underlying motivations to influence the source's accuracy. Specificity can be assessed by examining how specific the source is, vague claims are difficult to analytically assess. The more detailed claims are easier to verify or denounce as false. Finally, attenuation can be assessed by examining when the information was created. Information created contemporaneously with the events they discuss or show is characteristically seen as more reliable than information created subsequently. However, this criterion can pose a challenge to investigators if a piece of digital information lacks a time stamp or publication date.

Once a source has been verified, a technical analysis of the piece of information is necessary. This digital investigative analysis tests the integrity of the document, video, or image file to see if it has been digitally altered or manipulated. This is typically done through a digital forensic investigation and assesses the file's metadata, exchangeable image file format data, and source code.[90] A file's metadata may include the creator, date of creation, upload data, file size,

[90] "The Berkeley Protocol", 64.

geographic data, and modifications to the file. Typically, this data is embedded into the file, but some metadata may be stripped during the file's uploading to social media platforms to optimize the file for online viewing and sharing. Exchangeable image file format data is associated specifically with image and sound files created with digital cameras and is used to embed technical metadata within image files. Examining a page's source code can reveal hidden or modified content, link structures, and broken links within the page. There are many tools to help with viewing a page's source code, but in the Google Chrome browser, simply go to the browser toolbar, go to the View tab and down to Developer, and then select View Source.

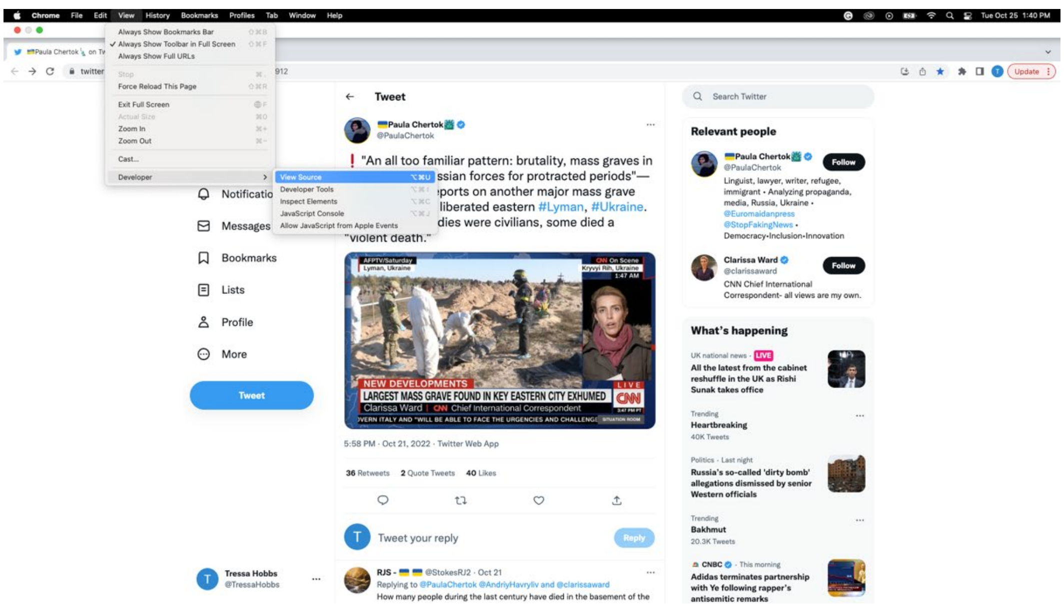

Figure 10. Screenshot showing how to access a website's source code using Google Chrome.

Once the digital investigative analysis has been completed, the last step is content analysis. This is the process of verifying the actual content of a document, image, video, or another piece of information. This analysis focuses heavily on visual clues to verify the validity of the content and may include multiple verification methods depending on the information's file type. Due to the nature of the internet, this type of analysis is frequently subject to circular reporting, decontextualization, and misinterpretation, which can heavily influence information's validity and perceived validity.[91] An investigator may seek out unique identifying features in buildings, signs, symbols, flora, fauna, and people in a video or image to help them verify the information's geographic location and time of creation. These two types of analysis are commonly referred to as geolocation and chronolocation.

Geolocation is the process of analyzing images and videos for identifying landmarks or features to identify the approximate location of an object, activity, or event.[92] For recycled material from other events, geolocation will provide a way of debunking the information while being one of the fastest ways of establishing a higher confidence level in the validity of genuine information. The content's unique identifying features are cross-referenced with satellite imagery, street-view photography, historical imagery, other geo-tagged images and videos from social media platforms, and weather reports to confirm the approximate location. Useful street-view tools for geolocation in Ukraine include Google Maps Street View and Yandex Panorama, while Google Earth is the most useful free tool for satellite and historic imagery. DigitalGlobe and Planet both offer commercial satellite imagery for a fee, while Wikimapia hosts a collection of satellite imagery from Yandex Maps, Bing Maps, and other services and allows the user to view satellite imagery from multiple sources overlaid onto a single map. Wikimapia has an extensive database of user-submitted locations, allowing geolocation with limited information. However, this service operates similarly to Wikipedia, relying on users to submit, edit, and classify information, and should be used carefully to supplement other tools.

[91] "The Berkeley Protocol", 64.
[92] Sam Dubberley, Alexa Koenig, and Daragh Murray, *Digital Witness: Using Open Source Information for Human Rights Investigation, Documentation, and Accountability* (Oxford: Oxford University press, 2020).

Chronolocation or determining the time when a piece of information or content was created often accompanies geolocation. Outside of a visible clock in an image or video, this can be difficult to assess, but a few methods can help approximate the time. If the geographic location and supposed date are known, weather reports can help determine the time. Wolfram Alpha can provide hour-by-hour historical weather data, as well as cloud conditions, precipitation rates, temperature, and wind speeds. This can narrow down the possible time frame in which a piece of content was created. Temporary visual details such as construction and advertisements can provide wider insights into the timeframe in question. Finally, using observable shadows to determine the approximate time of creation can provide a more accurate estimate than either weather or temporary features. While the naked eye can make basic determinations of the time based on the length of the shadows, the website SunCalc.org can provide accurate data for the sun if the correct geographic location and date are entered into the website. This provides an approximate timeframe in which the shadows would have appeared in a similar fashion to what is seen in the image or video.

Other components of content analysis include assessing the completeness of each piece of information. It is important to collect a full file and, when necessary, its surrounding context. Context can be misrepresented, and imagery in particular can be used to give a false interpretation of events, while image and video framing, cropping, or editing can easily mislead people. To ensure imagery hasn't been reused from other events, a reverse image search can be used to see if imagery has been published online previously. Google, Bing, TinEye, and Yandex all have versions of free reverse image search tools that can be used for this. If an image has been cropped or horizontally flipped, a reverse image search may not identify previous versions of the image. Searching for visually similar results for cropped images may help identify the cropped images. If it is suspected that an image has been flipped, a photo manipulator such as Lightroom can be used to flip the photo, and then a reverse image search can be run on the flipped image. There are no current tools to reverse-search videos, but video thumbnails and frames can be extracted and reverse-searched. Amnesty International's DataViewer is one tool that extracts thumbnails of videos and reverse searches them as well as providing the video's exact upload time. Finally, externally corroborating the piece of information being analyzed with outside data that coincides, confirms, or otherwise supports the content of the information is incredibly important and should always be done.

3.4.2 Data Analysis and Visualization

After collected information has been verified, the working copies of the data can be used in investigative data analysis and visualization. Before investigative data analysis is started, any data processing, data reformatting, language translation, and data aggregation should be completed. Various types of analysis can be performed, but of specific interest here are image/video comparison analysis, image/video interpretation analysis, spatial analysis, network analysis, and incident mapping.

Image/video comparison analysis consists of comparing structures, objects, locations, and people from one image or video to unknown or known items in another image. This compares the content of the image or video, its quality, perspective, lighting, and other visual settings.[93] This will help identify different videos or images taken in the same location or identify objects, people, or signatures identified across multiple geographic locations. This would help establish higher confidence levels for indicators of potential mass graves. NVIDIA Technologies' Image Comparison Analysis Tool is an open-source tool for this type of analysis. Image/video

[93] "The Berkeley Protocol", 66.

interpretation analysis is similar to image/video comparison analysis; however, this analysis focuses on identifying objects within images and videos. This type of analysis will be used to assess Russian military assets located near identified gravesites and discovered clandestine mass graves to identify grave typologies and potential indicators.

Spatial analysis will include generating and maintaining geospatial databases for all geographically referenced data. All known mass graves, areas of partisan fighting, heavy fighting, key locations for Russian forces, and Russian filtration centers should be mapped using a geographic information system such as ArcGIS Pro. This will allow for data visualization, geospatial statistical analysis, big data analysis, and spatial analysis to discover patterns and relationships within the data. This will aid actor mapping and multivariate network analysis to understand which Russian military units were present at which mass grave locations, understand power influence and key relationships within the Russian military regarding the clandestine mass graves, identify key locations to the Russians, and identify if there is a pattern to the units committing these atrocities or if the phenomena are more randomly dispersed. Finally, incident mapping will help establish temporal and/or geographical relationships between current clandestine mass graves, potential clandestine mass graves, and areas with activity that may indicate the creation or use of a clandestine mass grave. This type of analysis may also include mapping relevant events such as Russian filtration and detention centers, and areas on the front lines experiencing heavy fighting between Russian and Ukrainian forces.

3.5 Social Media Analysis Product Generation

The results of social media analysis may be reported in several ways. The most common is a written intelligence report. This type of product may be used for internal reporting, reports for clients, and publicly available reports. This report should include the investigation objectives;

research questions; the data and sources used; detailed research methodology; documentation of the collection that was performed; processing, and analyses; any gaps, uncertainties, or unknowns in the data; the results of any analysis performed and associated visuals, graphs, charts, and maps; and future recommendations. Oral reporting may be required later within the context of a criminal court investigation or a presentation and should include the same sections as a written report. When deciding on the format of a social media analysis report, consideration should be given to the audience's familiarity with certain formats and how it will impact their ability to understand the intelligence. As social media collection and analysis are reiterative processes, it is expected that this report will trigger additional collection and analysis in a feedback loop to consistently refine the geospatial strategy. It is also expected that the ongoing results of this social media collection and analysis will act as triggers for targeted HSI collection and analysis in areas that exhibit indicators of potential clandestine mass graves.

3.6 Hyperspectral Imagery Collection

3.6.1 Understanding the Influence of Soil and Climate on Decomposition Rates

Before collection occurs, it is important to understand how different geographic and climactic factors influence the rate of human decomposition, as this can change the temporal window in which anomalies may be detected. Five stages of decomposition are recognized in vertebrates: fresh, bloat, active decay, advanced decay, and skeletonized. The rate that a body passes through these stages varies heavily based on environmental factors including temperature, precipitation, humidity, soil salinity, and oxygen availability.

Higher temperatures will accelerate the decomposition rate, while cooler temperatures will slow down the decomposition rate. Similarly, the more humid the environment is, the faster a body will decompose. However, high rates of precipitation will slow down decomposition since it reduces a body's exposure to air, creating a semi-anaerobic environment where microorganism growth slows down. Saline soils with a pH between 7 and 8.5 increase the rate of decomposition, while acidic soils with a pH below 7 tend to slow down this process.[94]

The southern and eastern regions of Ukraine experience warmer summers and colder winters than the rest of the country. This will increase the rate of decomposition in the summer and slow it down in the winter. The regions receive little precipitation compared to the rest of the country and are not remarkably humid. Unless heavier than average rainfalls are seen, it is unlikely that the rate of precipitation will influence the standard rate of decomposition in the climate significantly. The regions have a mix of gray forest soil, podzolized black earth soil, chernozems, and chestnut saline soils. Gray forest soil and podzolized soils are typically acidic with pH ranges of 5.3 to 5.4 and 3.5 to 4.5 respectively, and bodies will decompose slower in these types of soils.[95] Chernozems have a neutral pH range and do not remarkably change the rate of decomposition. Chestnut saline soils are acidic with a pH range of 7 to 8.5 and bodies may decompose at a faster rate.[96]

In addition to these environmental factors, how the bodies are buried may also influence the rate of decomposition. A grave with exposed bodies will decompose faster than one with even a thin covering of soil. This is because scavengers and microorganisms have easier access to the bodies. Containers like coffins, caskets, or body bags drastically reduce the amount of oxygen available to the body and prevent insects from accessing the bodies, slowing down decomposition. These containers also prevent the body's nutrients from leeching into the

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[94] Darlington Nnamdi Onyejike et al., "Factors That Influence Decomposition Timeline Estimation in Anambra State, Nigeria," *Egyptian Journal of Forensic Sciences* 12, no. 1 (June 20, 2022), https://doi.org/10.1186/s41935-022-00281-7.
[95] Darlington.
[96] Petra Marschner et al., "Adaptation of Plants to Adverse Chemical Soil Conditions," in *Marschner's Mineral Nutrition of Higher Plants* (Amsterdam: Elsevier/Academic Press, 2012), https://www.sciencedirect.com/science/article/pii/B9780123849052000170.

surrounding soil unless there are cracks or tears in the containers. In cases like these, soil disturbance can still be identified through an increased level of Nitrogen in the soil due to increased organic matter in the churned soil.

3.6.2 Hyperspectral Imagery Sensor Payload and Platform

The geophysical portion of this strategy is focused on airborne HSI collection, preferably using a UAV due to the ongoing war in Ukraine. A manned aircraft may be used as a last resort in cases where Ukrainian drone laws conflict with the mission requirements and special permission cannot be granted, and when a risk assessment determines there is a low likelihood of pilot injury. The platform should be small, lightweight, and have a lower power consumption to extend flight times and make the platform less noticeable. In addition to carrying the HSI payload, the platform should also carry a global positioning device (GPS), an inertial measurement unit (IMU), and an active stabilizing gimbal. These devices will help georeference the collected data and account for the effects of pitch, roll, and yaw on the platform and data.

Hyperspectral sensors collect hundreds or thousands of spectral images at a time in narrow contiguous wavelengths, giving them an extremely high spectral resolution. The specific HSI payload will be determined by the investigator. Ideally, it should be small, lightweight, and rugged with a low signal-to-noise ratio and high spectral and spatial resolution. Airborne-collected HSI is influenced by atmospheric absorption, various types of scattering, sensor calibration, and sensor-target illumination geometry, which should be taken into consideration when choosing and calibrating the payload.

The payload will most likely be a pushbroom scanner, this can also be called an along-track scanner. This type of sensor uses a linear array of detectors at the focal plane that moves along the flight path in a forward motion. This motion allows the imager to collect energy and create a 2-D image of the area of interest in successive strips perpendicular to the flight direction. Each detector simultaneously collects spectral data from a single ground-resolution cell, so the number of detectors in the sensor determines the pixel size of the image. While other sensor configurations may be used, a pushbroom style sensor has no moving parts so the sensor's scanning speed can be increased, leading to a longer dwell time and a stronger spectral signal strength. There is also less risk of machinery malfunctioning.

The spatial resolution of the sensor is significantly influenced by the altitude the platform is flying. Other factors that impact the spatial resolution are the viewing geometry and the sensor's configuration. Due to this, the platform should be flown as low as safely possible to increase the spatial resolution, but this altitude should be kept consistent throughout the entire collection process. A common trade-off with HSI sensors is resolution versus coverage. Fine resolution is essential in this application; however, the coverage tradeoff is partially solved by using social media collection and analysis to narrow down the potential areas of interest requiring HSI collection. This method of tasking helps conserve limited resources.

3.6.3 Flight Planning

The aircraft or UAV will follow a pre-determined programmed flight path that optimizes the collection of all target packages. The exact flight path will vary depending on the number and locations of target packages included on each sortie, fluctuating lines of engagement, shelling activity, and weather. Flight planning should be done to determine the exact coordinates within the platform that will collect data to save hard drive storage, conserve fuel or battery life, and reduce the amount of data requiring processing, analysis, and storage in the future. Flight planning may also include mission planning, overlap, best collection times, and calibrating reflectance panels.

Collection should extend past the AOI on all sides to ensure that data is collected all the way to the edge of the area and should follow a grid pattern with an extra flight track on either end of the AOI. In addition to ensuring sufficient data collection, this will help the platform re-align with the flight path at the end of each track. The frontlap and sidelap should be configured in such a way that there is approximately a 75% overlap for both. If the overlap is too small, artifacts or alignment errors may occur. The sensor should be pointing at nadir or as close to nadir as possible during imaging.

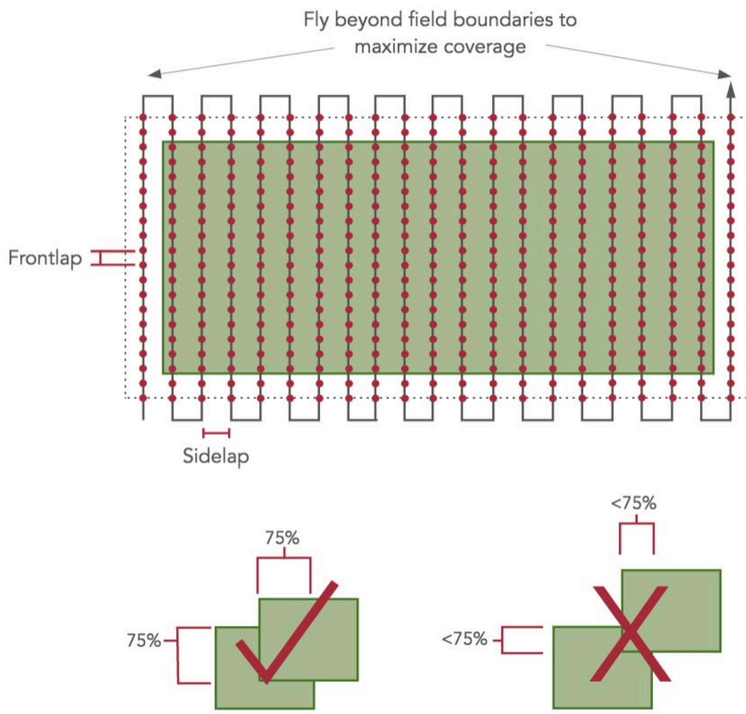

Figure 11. Image showing the proper overflight and overlap of a collection area according to best practices. The image is from MicaSensor.[97]

The collection should be scheduled within two and a half hours of solar noon to minimize shadows[98] which may influence vegetation indices results that will be used during analysis. Very

[97] "Best Practices: Collecting Data with MicaSense Sensors," MicaSense (MicaSense, October 27, 2022), https://support.micasense.com/hc/en-us/articles/224893167-Best-practices-Collecting-Data-with-MicaSense-Sensors.
[98] "Best Practices: Collecting Data".

overcast or sunny days may impact collection. On overcast days the lack of illumination may result in deep shadows that can significantly alter spectral signals, while collection on extremely sunny days can result in sunspots in the data.

In addition to flying at a specific time to reduce shadows, timing collection with the seasons will ensure maximum collection. Since most AOIs are in forested areas, collecting during the off-leaf seasons of spring and autumn when deciduous trees lack their leaves will reduce the level of canopy interference and allow a clearer path to the vegetation on the ground. Unfortunately, this seasonal collection will not help with conifer forests or undergrowth, which keep their needles year-round and may still block the sensor from collecting an accurate spectral signature from ground vegetation. If a choice is available between collecting during spring or autumn, autumn should be chosen as experimental studies show that spectra collected in autumn have a higher degree of separability than those collected in the spring[99], however, this may also be attributed to a longer decomposition time at the time of the autumn collection in the study, at approximately 20 months post-burial. Collection in winter should be avoided due to snow cover and the sun's low altitude, which may be insufficient to provide the direct solar illumination required for accurate data collection.

Immediately before and after every collection sortie, an image of a calibrated reflectance panel should be taken. This ensures the panel images will have accurate location and time information for pre-processing. The calibration reflectance panel should be far away from any objects that may influence its illumination by the sun and no shadows should be present on the panel. This allows for an object with known reflectance characteristics to be imaged so image

[99] Corcoran, 199.

pixels can be converted to reflectance during pre-processing. An airport tarmac or runway would work as a location for a calibrated reflector panel.

The platform can be launched from a variety of airports, airfields, and airstrips depending on the AOIs requiring collection. Before selecting an airport as a launching point for collection, it is important to check if the airport, airfield, or airstrip has been bombed or shelled by Russian forces. At least 15 airports have been destroyed since the start of the invasion[100] including the Dnipro Airport, the Antonov International Airport northwest of Kyiv, and the Odesa International Airport.

Launching points in friendly NATO countries may also be a possibility, depending on how damaged Ukrainian launching points are and the scope of collaboration between States and intergovernmental organizations. Airports or airfields in eastern Poland may be potential launching locations but platforms will have to cross the entirety of western Ukraine before reaching the AOIs, which may reduce the total possible collection time. Romania presents another potential launching point closer to Ukraine's southern and eastern regions.

As the platform makes its way along the flight path, the sensor will collect spectral data from the AOIs. Collection may be triggered manually by the pilot or be pre-programmed. If there is an internal hard drive for the payload, this data will be stored there and will be removed upon landing after a completed sortie and uploaded to the system being used for pre-processing, processing, and analytics. While a laptop may be used for this, a desktop computer in a secure location is recommended.

[100] Dmitri Chirciu, "Russian Forces Have Destroyed 15 Ukrainian Airports since Start of War: Kyiv," Anadolu Ajansı (Anadolu Ajansı, April 1, 2022), https://www.aa.com.tr/en/russia-ukraine-war/russian-forces-have-destroyed-15-ukrainian-airports-since-start-of-war-kyiv/2552017.

The potential AOIs are extremely large, especially the area of partisan fighting surrounding the city of Melitopol. Partisan fighting has been historically linked to higher levels of indiscriminate attacks on civilians and so this area should be carefully investigated. However, this area alone has an approximate area of 1,869.4 km^2 and it is highly unrealistic to image, process, and analyze the entire area using HSI. Therefore, narrowing down potential AOIs by using multiple data sets is key to the collection's success.

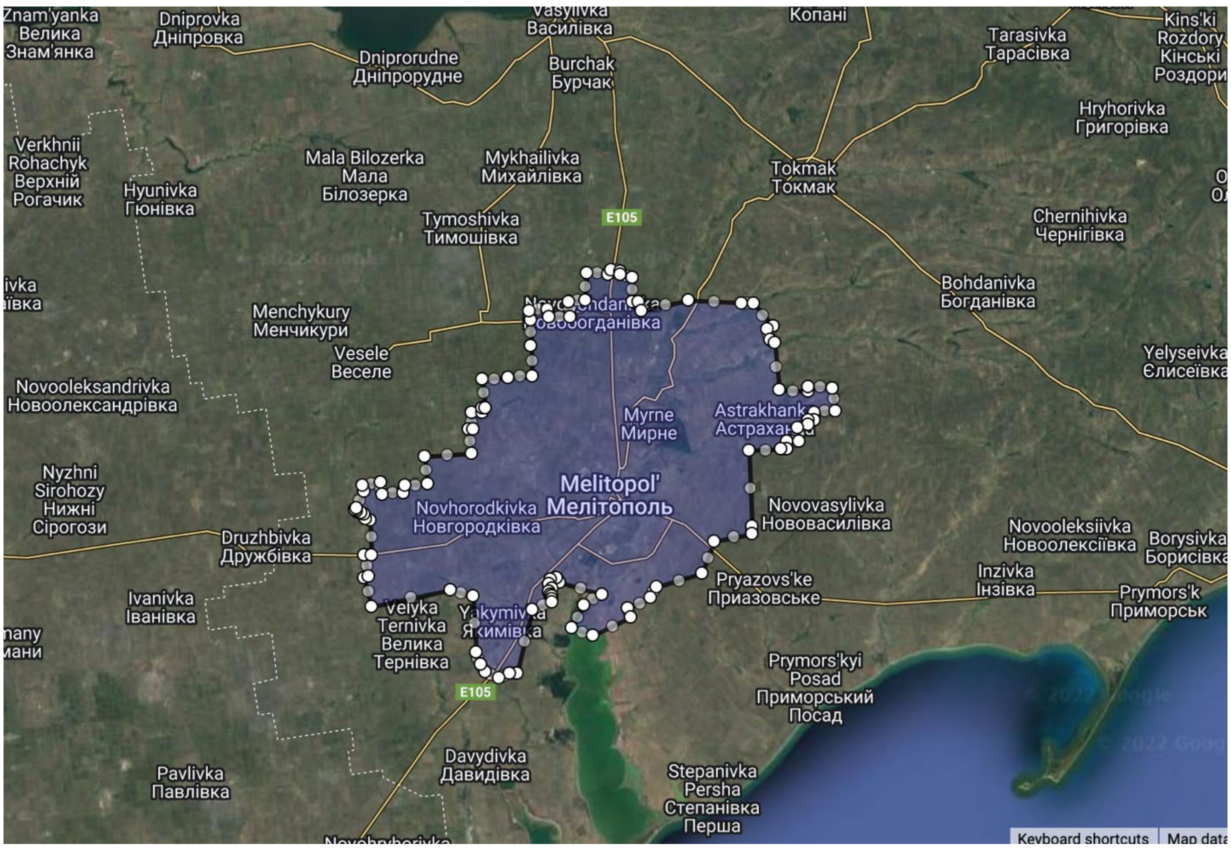

Figure 12. Image showing the approximate area of partisan fighting around Melitopol, Zaporizhzhia Oblast. The image is based on the Institute for the Study of War's interactive map of Ukraine.[101]

Using the known mass grave at Manhush as a targeted example, the time it takes to collect HSI using a UAV for an AOIs of similar size can be determined. The Manhush mass grave was chosen due to its unobstructed imagery and size. It is one of the larger mass graves

[101] Barros, Stepanenko, and Bergeron.

that have been discovered. The approximate length of the AOI is 425 m and the approximate width is 90 m. This gives the AOI an approximate area of 0.038 km^2. A UAV carrying a Nano-Hyperspec lens HSI sensor with a 12 mm focal length at an altitude of 20 m will have a spatial pixel size of 12.33 mm and a swath width of 7.89 m. With a 75% overlap and a line spacing of 1.97 m, it would take approximately 1.5 hours and 46 flight lines to image the AOI. The time it takes to image an AOI will be highly dependent on the payload and platform used and what altitudes, spatial pixel size, and swath width are optimal for the collection package. Based on this timing, multiple AOIs can be collected each day.

Figure 13. The top image is taken from Headwall Photonics' Flight Planning polygon software used to aid in defining data collection coordinates. It shows the collection coordinates and area of the Manhush mass grave search area as an example of HSI collection for clandestine mass graves. The bottom image is Planet satellite imagery from 8 May 2022 showing activity at the mass gravesite in Manhush.[102]

3.6.4 Collection Bands

An electromagnetic signature is created when electromagnetic energy from the sun or an active sensor interacts with matter.[103] This emitted or reflected signature is collected by HSI sensors. This specific application is focused on the positive relationship between higher levels of Nitrogen and elevated chlorophyll levels in vegetation leading to less reflected solar energy as a proxy for potential clandestine mass graves. As such, any anomaly indicating an unusually high or low spectral reflectance value for a plant species with a known spectral reflectance curve may indicate a ground disturbance that has the potential to be a clandestine mass grave. Elevated chlorophyll levels from Nitrogen released during human decomposition and increased decomposing organic matter in the soil from soil mixing during digging and backfilling can be detected in the visible red and NIR regions of the electromagnetic spectrum and be used to detect these areas of disturbed earth.[104] Focusing collection within the visible and NIR portion of the electromagnetic spectrum will optimize this collection and reduce noise.

While the SWIR is also a part of the reflective band, signals from this portion of the electromagnetic spectrum will be too noisy and weak to be of much use. Using a sensor that has been designed to only collect radiation within these specific bands will help with this. Using an image intensifier to help amplify weaker signals in low-light conditions when collecting in the NIR may be used if necessary.[105]

3.6.5 Revisit Rate

[102] Centre for Information Resilience, 52.
[103] Robert M. Clark, *Intelligence Collection* (Los Angeles, CA: Sage, 2014), 180.
[104] Corcoran, 195.
[105] Clark, 250.

To monitor this issue, a revisit rate of every two weeks during the spring and autumn seasons is ideal, but a revisit rate of once a month is also feasible. There is a waiting period between the time of burial and when detection and spectral separability is possible, this is most likely due to the decomposition process. As the rate of decomposition is highly variable depending on location, this waiting period will change from grave to grave. However, it can be assumed that the waiting time will be at minimum 3.5 to 4 months long as that is the earliest an experimental study has been able to detect clandestine graves using HSI.[106]

A longer revisit rate will accommodate this waiting period by allowing a sufficient period between each collection to increase the likelihood of minute changes in vegetation reflectance being captured while reducing unnecessary expenditures. The age at which the disparity of spectral signatures associated with disturbed earth and potential clandestine mass graves decreases is unknown. The longest experimental study successfully collected spectrally separable signatures at 27 months post-burial.[107] Since the earliest mass graves were created in late February and early March, this waiting period has either already ended or will be ending soon, allowing for the spectral separability of these graves from the surrounding soil.

3.7 Hyperspectral Image Processing and Analysis

3.7.1 Pre-processing

After the HSI collection stage, the data must go through pre-processing to extract information from the pixels. This involves making radiometric and geometric corrections to the images before further information can be extracted. The need for atmospheric corrections is limited as the data is being collected by a UAV. Atmospheric effects are less significant in UAV collection due to the altitude at which the data is collected rather than if the data was collected by

[106] Silván-Cárdenas, 15.
[107] Corcoran, vii.

an aircraft or satellite at a high altitude. However, using a UAV will make radiometric corrections, geometric corrections, and spectral calibration more difficult due to the low altitude and less stable movement.

Radiometric and geometric corrections can be done using a range of software tools that are commonly provided by the sensor's manufacturer. This process includes converting the data from raw digital numbers to calibrated radiance units, georegistering the data, ortho-rectification, correcting any geometric distortions caused by viewing geometry. At this time, the signal-to-noise ratio should also be quantitively evaluated to determine the quality of the data. A high signal-to-noise ratio is desired and any data with a low signal-to-noise ratio should be removed at this stage of processing.

3.7.2 Processing

Pre-processing should be followed by dimension reduction and band selection operations to make handling the data more efficient. This reduces the amount of data the software needs to process during analysis and removes redundant data to increase target detection accuracy in classification. Dimensionality reduction applies a mathematical transformation to the data and creates a new dataset by linearly combining the input bands. The resulting new bands contain the image's unique information while bands containing redundant data are removed. Band selection selects a discrete set of the most important bands to use in target classification either manually or by using ENVI software. Bands surrounding 1400 nm and 1900 nm should be removed as they are linked with spectral noise and atmospheric scattering. Once this is done, the spectral signatures should be stored as signature libraries before analysis begins.

3.7.3 Analysis

The relationship between Nitrogen and chlorophyll is of chief importance in this proposal. The impact of buried remains on the surrounding soil and vegetation is dependent on the relationship between Nitrogen and chlorophyll. Nitrogen is a major component of the photosynthesis process in vegetation. During photosynthesis, vegetation transforms solar energy into chemical energy by converting water, carbon dioxide, and minerals into oxygen and glucose compounds. This process takes place in a plant's chloroplasts where the pigment chlorophyll absorbs visible red and blue light and reflects visible green light. The chlorophyll concentration of vegetation is curvilinearly related to Nitrogen content where a higher concentration of Nitrogen results in a higher concentration of chlorophyll within the plant.[108, 109] Based on this logic, the Nitrogen that is released from decomposing human remains and organic matter and dispersed in the surrounding soil should be absorbed by the surrounding vegetation and show elevated chlorophyll levels that can be detected. Analysis using statistical models and vegetation indices can identify statistically significant anomalies that may indicate the presence of a clandestine mass grave.

Using the proposed collection method, these small fluctuations should be detectable with an overhead platform and sensor with a fine spectral resolution. Multiple data sets including HSI imagery, social media analysis, and satellite imagery should be used to corroborate and increase the statistical significance of any results found. HSI alone does not provide strong enough evidence to say an anomaly is a clandestine mass grave with a high confidence level due to the lack of real-world applications of this approach. It should be noted that animal burials, most

[108] L. Ercoli et al., "Relationship between Nitrogen and Chlorophyll Content and Spectral Properties in Maize Leaves," *European Journal of Agronomy* 2, no. 2 (1993): pp. 113-117, https://doi.org/10.1016/s1161-0301(14)80141-x.

[109] Yuan Wang et al., "Estimating Rice Chlorophyll Content and Leaf Nitrogen Concentration with a Digital Still Color Camera under Natural Light," *Plant Methods* 10, no. 1 (2014): p. 36, https://doi.org/10.1186/1746-4811-10-36.

likely livestock, could also increase the Nitrogen content of the soil and produce a false positive. However, only the plants directly above the grave will experience an increase of Nitrogen once regrowth occurs so the size of the anomaly should help distinguish livestock burials from mass graves. Visual indicators from satellite imagery and social media will continue to play an important role in separating livestock burials and non-burial disturbed earth from mass graves when spectral signatures cannot distinguish them.

Spectral signature collection forms the basis of the HSI analysis portion of this strategy. Every object has a unique spectral signature that can be compared to existing spectral libraries to identify the object. This process depends heavily on computer algorithms and many commercial software packages exist that help with this. If any secondary methods are used in addition to the primary method ENVI image analysis software is recommended. ENVI image analysis software is tightly integrated with ESRI's ArcGIS mapping platform and supports hyperspectral, LiDAR, and SAR imagery.[110]

Whichever commercial software is chosen, it will use algorithms to separate spectral signatures for identification, statistical analysis, and classification. Publicly available spectral libraries from the United States Geological Survey, Johns Hopkins University Applied Physics Laboratory, or NASA Jet Propulsion Laboratory should be used as controls to compare the collected vegetation spectra. To help with classification, statistical methods like binary logistic regression modeling, discriminant function analysis, and multivariate analysis should be used to create predictive models for classification modeling based on membership to discrete groups for target identification.[111] Calculating vegetation indices will also help analysts identify vegetation

[110] "ENVI," Software & Technology (L3Harris Geospatial), accessed November 7, 2022, https://www.l3harrisgeospatial.com/Software-Technology/ENVI.
[111] Corcoran, 84.

anomalies, with a number being developed to monitor leaf pigment and health for agricultural monitoring. A few of these indices can be applied to HSI and can be found in Table 4. Analysts may run into an issue with target material mixing with background material within the pixels resulting in a composite spectrum. This composite spectrum will need to be resolved into its individual components so that it faithfully resembles the target spectra.

Index	**Estimates**
Normalized Difference Vegetation Index (NDVI)	Vegetation Health
Red Edge NDVI (RENDVI)	Vegetation Health
Modified Red Edge Simple Ratio Index (MRESRI)	Vegetation Health
Modified Red Edge NDVI (MRENDVI)	Vegetation Health
Sum Green Index (SGI)	Vegetation Pigment
Red Edge Position Index (REPI)	Chlorophyll Concentration
Green Chlorophyll Index (GCI)	Chlorophyll Concentration
Transformed Chlorophyll Absorption Reflectance Index (TCARI)	Chlorophyll Concentration
Green Normalized Difference Vegetation Index (GNDVI)	Photosynthetic Activity

Table 4. List of different vegetation indices that may be helpful for assessing vegetation anomalies.

3.8 Hyperspectral Imagery Product Generation

HIS analysis will produce a written report and an annotated graph of any spectral reflectance curves of the target. The report should include any relevant information about the target including the results of statistical testing, classification, and vegetation indices analysis, a confidence level associated with the likelihood the target is a clandestine mass grave, geographic coordinates for the target, and relevant sensor and software information. The annotated graph should show spectra reflectance curves for the targets compared with control spectra curves with any significant details and coordinates noted with the annotations. False color composites of the imagery should also be included showing the AOI's elevated chlorophyll content if deemed necessary. This report should be combined with the results of social media analysis that tipped off collection for the AOI being reported, relevant satellite imagery and collateral data, and the results of any secondary methods used to create a complete report on the AOI.

3.9 Dissemination

This strategy assumes a policy of unrestricted information sharing and uses commercial tools for product dissemination. Even though a policy of unrestricted information sharing is assumed, this only applies to those who would not misuse this information such as the Ukrainian government, allies of the Ukrainian government, international criminal courts, and humanitarian organizations. This information should not be shared with any entity that has an affiliation with the Russian government.

Web publications should be the primary means of public dissemination. These reports should be shared as soon as they have been verified. A database and mapping project may also be used to track mass graves as they are discovered and be available to humanitarian organizations and think tanks to promote information sharing and collaboration.

4. Limitations

4.1 Sampling Bias in Social Media

While social media presents a large opportunity for open source intelligence exploitation, a significant sampling bias occurs when conducting social media collection. Collection only occurs against targets that use the social media platform or platforms being collected from. These sample populations are almost never representative samples of the population. Additionally, social media platforms function differently and attract different user bases. To mitigate this limitation, collection should be based on multiple social media platforms and a digital landscape assessment should be done prior to collection.

In Ukraine, understanding where and to what extent internet connectivity has been limited or cut off is important. In occupied cities like Kherson, Melitopol, and Mariupol internet traffic has been diverted through Russian networks in Crimea since June[112] and censored. Social media platforms Facebook, Instagram, and Twitter were among the websites blocked in these cities, effectively restricting local residents' access to the internet.

4.2 Expectations of Privacy Online

When conducting an online investigation, abiding by the data privacy laws of the country or countries in which collection is occurring is non-negotiable. While Ukraine is currently not a member of the European Union (EU), the country committed to updating its data protection laws to comply with the EU's General Data Protection Regulation (GDPR) by 25 May 2018[113] in all terminology and data subjects' rights. This means that all online collection, processing, and storage of personal data must comply with the GDPR guidelines, even if the online investigation is physically occurring within the United States.

4.3 Big Data Issues

Both social media and HSI collection and analysis discover and generate enormous quantities of data. These large quantities of data create several challenges, most notably volume, velocity, and variety. Big data requires enormous volumes of storage and analytic capabilities to

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[112] Adam Satariano and Scott Reinhard, "How Russia Took over Ukraine's Internet in Occupied Territories," The New York Times (The New York Times, August 9, 2022), https://www.nytimes.com/interactive/2022/08/09/technology/ukraine-internet-russia-censorship.html.

[113] Olga Belyakova, "Ukraine - Data Protection Overview," DataGuidance, October 20, 2022, https://www.dataguidance.com/notes/ukraine-data-protection-overview#:~:text=Given%20Ukraine%20is%20not%20a,directly%20apply%20in%20its%20territory.

make use of the information collected. Most photos, videos, and documents collected will be considered unstructured data, making these pieces of data difficult to search for and analyze, and incompatible with traditional relational databases.[114]

The velocity of data exploitation also needs to be at such a rate that real-time decisions can be made with the data. Increasing analytic efficiency can be done through a myriad of emerging ETL and analytic tools and recruiting and retaining big data engineers who have the skills to exploit these tools to their full potential.

Similarly, integration tools can help mitigate the challenges of data variety by integrating distinct data types into actionable reports. These challenges are accompanied by upfront costs for infrastructure and ongoing costs of management, maintenance, human capital, and other miscellaneous expenses which vary depending on the skill level required, the scope of the project, and the geographic location. However, unique big data storage and analytic solutions are becoming more financially accessible due to increased market demand.

4.4 Denial and Deception

Investigators should take into account that there is a possibility that the evidence collected has been deliberately shaped by the perpetrators through denial and deception. For this reason, all major hypotheses, analytic conclusions, and assumptions should be checked. Deception may take the form of placing a mass grave next to a farm or an existing livestock burial to disguise the true purpose of the grave. Graves may also be located in agricultural fields to mask the hyperspectral signatures of the disturbed earth and elevated Nitrogen content with agricultural activity and fertilizer.

[114] Cynthia Harvey, "Top Challenges of Big Data & How to Overcome Them," Datamation (Datamation, June 20, 2022), https://www.datamation.com/big-data/big-data-challenges/.

Another factor to be aware of is that Russia commonly runs disinformation and mal-information campaigns as a part of its propaganda apparatus. Frequent narratives seen since the beginning of the Russo-Ukrainian War include "Russia as an innocent victim responding to the West's aggressive actions" and historical revisionism[115] and collectors and analysts should be aware of these common campaign types and their defining characteristics and behaviors. Disinformation is information that has been falsely created with the intent of harm, while mal-information is information based on reality and truth but is often exaggerated and misleading with the intent of causing harm. Misinformation is similarly considered fake news, but this type of false information is not created maliciously and, in most cases, done accidentally.

[115] "Russia's Top Five Persistent Disinformation Narratives - United States Department of State," U.S. Department of State (U.S. Department of State, January 21, 2022), https://www.state.gov/russias-top-five-persistent-disinformation-narratives/.

Appendix A

Areas in Russian-controlled Ukraine experiencing partisan fighting as of 07 November 2022. Here partisan fighting refers to any member of an irregular or guerilla local force resisting a foreign occupation.

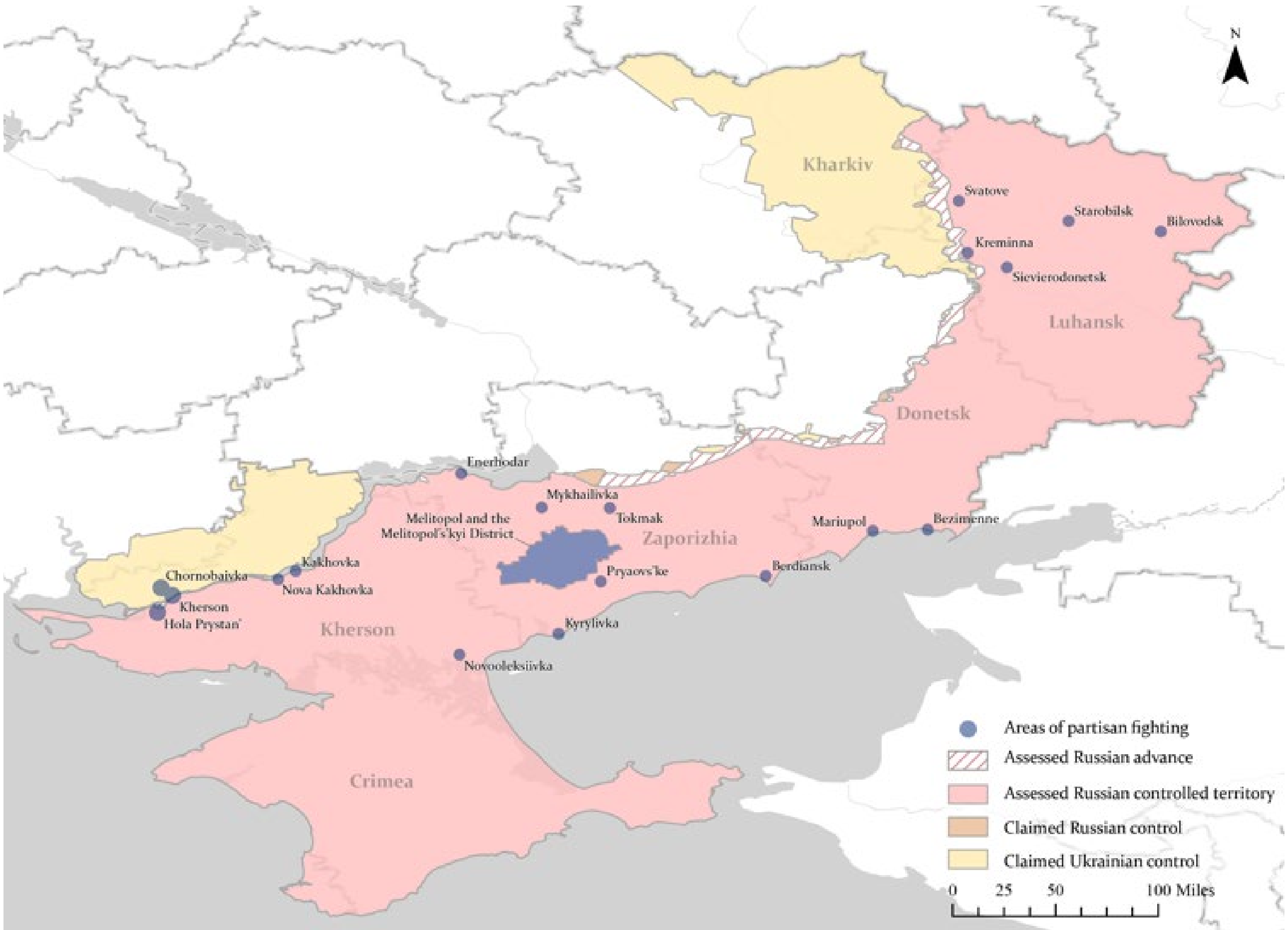

Figure 14. Map showing locations of partisan fighting in Russian-controlled territories as of 07 November 2022. Areas of control are as of 14 November 2022. Data is from the Institute for the Study of War's Interactive Map: Russia's Invasion of Ukraine.[116] *Due to the high number of partisan activities around the city of Melitopol, a polygon of the Melitopol's'kyi district is used instead of individual points. Town names and coordinates can be found in Table 5.*

[116] George Barros, Kateryna Stepanenko, and Thomas Bergeron, "Interactive Map: Russia's Invasion of Ukraine," Interactive Map: Russia's Invasion of Ukraine (Esri, October 26, 2022), https://storymaps.arcgis.com/stories/36a7f6a6f5a9448496de641cf64bd375.

Location Name	Oblast	Coordinates
Svatove	Luhansk	49° 24′ 54″ N, 38° 9′ 18″ E
Starobilsk	Luhansk	49° 16′ 24.3″ N, 38° 55′ 36.1″ E
Bilovodsk	Luhansk	49° 12′ 0″ N, 39° 34′ 32″ E
Kreminna	Luhansk	49° 3′ 0″ N, 38° 13′ 0.12″ E
Sievierodonetsk	Luhansk	48° 56′ 53″ N, 38° 29′ 36 E
Mykhailivka	Zaporizhzhia	47° 15′ 38.0″ N, 35° 13′ 21.0″ E
Enerhodar	Zaporizhzhia	47° 29′ 56″ N, 34° 39′ 21″ E
Tokmak	Zaporizhzhia	47° 15' 24.2" N, 35° 42' 00.8" E
Melitopol	Zaporizhzhia	46° 50′ 56″ N, 35° 22′ 3″ E
Mordvynivka	Zaporizhzhia	46° 44' 46" N, 35° 21' 59" E
Danylo-Ivanivka	Zaporizhzhia	46° 45' 4" N, 35° 16' 49" E
Novens’ka	Zaporizhzhia	46º 46’ 57.4”N, 35º16’45.8” E
Dolynske	Zaporizhzhia	46° 47' 09.7" N, 35° 12' 27.8" E
Kyrpychne	Zaporizhzhia	46° 45′ 0″ N, 35° 12′ 0″ E
Yakymivka	Zaporizhzhia	46° 42′ 0″ N, 35° 10′ 0″ E
Udachne	Zaporizhzhia	46° 49' 12.9" N, 35° 14' 32.7" E
Novhorodkivka	Zaporizhzhia	46° 49′ 40.16″ N, 35° 7′ 8.75″ E
Sadove	Zaporizhzhia	46° 46' 54" N, 35° 21' 58" E
Kostyantynivka	Zaporizhzhia	46° 49′ 9.91″ N, 35° 25′ 19.87″ E
Stepne	Zaporizhzhia	46° 48′ 45.3″ N, 35° 03′ 36.4″ E
Mar’ivka	Zaporizhzhia	46º 46’ 25.0″ N, 35º 04’ 01.1″ E
Polianivka	Zaporizhzhia	46° 44′ 35.4″ N, 35° 5′ 0.51″ E

Verkhovyna	Zaporizhzhia	46° 44′ 26.27″ N, 34° 58′ 2.42″ E
Lazurne	Zaporizhzhia	46° 46' 1" N, 34° 59' 47" E
Vysoke	Zaporizhzhia	46° 48' 38.5" N, 34° 58' 32.9" E
Novoiakymivka	Zaporizhzhia	46° 50' 44.4" N, 34° 55' 40.7" E
Malyi Utliuh	Zaporizhzhia	46° 51' 23.1" N, 35° 01' 53.3" E
Novohorodkivka	Zaporizhzhia	46° 49' 39.3" N, 35° 07' 09.2" E
Maiak	Zaporizhzhia	46° 52' 41.9" N, 35° 06' 41.8" E
Zelenchuk	Zaporizhzhia	46° 54' 09.1" N, 35° 06' 17.1" E
Noromykolaivka	Zaporizhzhia	46° 54' 01.3" N, 35° 11' 41.8" E
Skhidne	Zaporizhzhia	46° 56' 02.9" N, 35° 14' 06.0" E
Trudove	Zaporizhzhia	46° 57' 19.4" N, 35° 09' 58.3" E
Pivdenne	Zaporizhzhia	46° 58' 05.6" N, 35° 12' 32.4" E
Pershotravneve	Zaporizhzhia	46° 58' 24.2" N, 35° 09' 17.6" E
Fedorivka	Zaporizhzhia	46° 59' 39.5" N, 35° 16' 10.5" E
Obil’ne	Zaporizhzhia	46° 55' 19.5" N, 35° 19' 05.4" E
Vidrodzhennya	Zaporizhzhia	47° 04' 46.8" N, 35° 14' 23.7" E
Novobohdanivka	Zaporizhzhia	47° 04' 45.3" N, 35° 19' 37.9" E
Spas’ke	Zaporizhzhia	47° 01' 10.2" N, 35° 23' 19.1" E
Pivnichne	Zaporizhzhia	46° 56' 54.9" N, 35° 23' 11.1" E
Myrne	Zaporizhzhia	46° 56' 39.1" N, 35° 25' 43.7" E
Terpinnia	Zaporizhzhia	46° 58' 48.7" N, 35° 25' 22.7" E
Troits’ke	Zaporizhzhia	47° 03' 34.1" N, 35° 27' 09.9" E
Prylukivka	Zaporizhzhia	47° 02' 55.3" N, 35° 28' 24.4" E

Travneve	Zaporizhzhia	47° 00' 46.4" N, 35° 28' 12.6" E
Zarichne	Zaporizhzhia	46° 59' 25.9" N, 35° 27' 51.1" E
Pryvilne (Novobohdanivska)	Zaporizhzhia	47° 04' 50.7" N, 35° 19' 26.2" E
Novopylypivka	Zaporizhzhia	46° 57' 20.2" N, 35° 29' 17.6" E
Sosnivka	Zaporizhzhia	46° 56' 14.3" N, 35° 29' 03.2" E
Kam'yans'ke	Zaporizhzhia	47° 03' 55.9" N, 35° 29' 51.6" E
Orlove	Zaporizhzhia	47° 03' 54.6" N, 35° 34' 06.2" E
Berehove	Zaporizhzhia	47° 00' 02.8" N, 35° 31' 14.7" E
Promin'	Zaporizhzhia	47° 00' 12.3" N, 35° 33' 47.9" E
Shyrokyi Lan	Zaporizhzhia	47° 00' 40.7" N, 35° 36' 20.6" E
Ukrains'ke	Zaporizhzhia	47° 01' 50.1" N, 35° 37' 32.6" E
Yasne	Zaporizhzhia	47° 01' 40.9" N, 35° 38' 52.9" E
Voloshkove	Zaporizhzhia	47° 02' 42.7" N, 35° 39' 50.2" E
Olenivka	Zaporizhzhia	46° 56' 46.2" N, 35° 34' 25.7" E
Tykhonivka	Zaporizhzhia	46° 55' 25.3" N, 35° 33' 01.8" E
Borysivka	Zaporizhzhia	46° 56' 42.8" N, 35° 37' 28.0" E
Astrakhanka	Zaporizhzhia	46° 56' 56.7" N, 35° 38' 27.4" E
Svobodne	Zaporizhzhia	46° 57' 30.5" N, 35° 42' 36.3" E
Arabka	Zaporizhzhia	46° 58' 15.5" N, 35° 44' 20.7" E
Rivne	Zaporizhzhia	46° 55' 53.6" N, 35° 23' 47.8" E
Semenivka	Zaporizhzhia	46° 53' 45.0" N, 35° 24' 33.8" E
Voznesenka	Zaporizhzhia	46° 52' 49.3" N, 35° 27' 39.4" E
Pryazovs'ke	Zaporizhzhia	46° 44' 22.6" N, 35° 38' 13.7" E

Kyrylivka	Zaporizhzhia	46° 22' 21.1" N, 35° 20' 25.1" E
Berdiansk	Zaporizhzhia	46° 46' 43.3" N, 36° 47' 52.8" E
Mariupol	Donetsk	47° 5′ 45″ N, 37° 32′ 58″ E
Bezimenne	Donetsk	47° 06' 20.0" N, 37° 56' 08.9" E
Kherson	Kherson	46° 38′ 33″ N, 32° 37′ 30″ E
Hola Prystan’	Kherson	46° 31' 19.3" N, 32° 31' 10.3" E
Nova Kakhovka	Kherson	46° 45' 16.1" N, 33° 22' 04.2" E
Kakhovka	Kherson	46° 48' 46.7" N, 33° 29' 17.2" E
Novooleksiivka	Kherson	46° 13' 32.6" N, 34° 38' 35.6" E
Chornobaivka	Kherson	46° 41' 44.4" N, 32° 32' 39.4" E

Table 5. Areas in Russian-controlled Ukraine experiencing partisan fighting as of 07 November 2022. Data is from the Institute of the Study of War.[117]

[117] Barros, Stepanenko, and Bergeron.

Appendix B

Russian filtration centers in Donetsk and Zaporizhzhia Oblasts. These locations have been assessed with a high confidence level to contain at least one Russian filtration center. This filtration system has been present in Donetsk Oblast since early March of 2022 and is defined by the Conflict Observatory as "the multi-step system Russia and its proxies have deployed in territory they currently occupy within Ukraine to register, interrogate, and, in some cases, indefinitely detain people residing there".[118] As of 25 August 2022, at least 21 distinct locations have been identified with a high confidence level containing one or more Russian filtration facilities.

[118] "System of Filtration: Mapping Russia's Detention Operations in Donetsk Oblast" (Yale School of Public Health Humanitarian Research Lab, August 25, 2022), https://hub.conflictobservatory.org/portal/sharing/rest/content/items/7d1c90eb89d3446f9e708b87b69ad0d8/data, 5.

Figure 15. Map showing the cities, towns, and villages in the Russian filtration system in Donetsk and Zaporizhzhia Oblasts. Data is from the Conflict Observatory and the Yale School of Public Health Humanitarian Research Lab.[119] The centers have been split into 4 purposes, with some filtration centers serving multiple purposes. More detailed information on each filtration center can be found in Table 6.
**Designates that the city, town, or village has more than 1 filtration center.*

ID	Raion, City, Town, or Village	Location Name	Center Use	Presence of Visual Characteristics of Mass Graves
1	Bezimenne	Filtration Post "Bezimenne"	Registration, Holding & Secondary Interrogation	No
2	Bezimenne	Bezimenne School	Holding	No
3	Dokuchaievsk	Dokuchaievsk Department of Ministry of Internal Affairs	Registration	No
4	Dokuchaievsk	Dokuchaievsk Center of Culture and Leisure	Holding & Registration	No
5	Kozatske	Chelyuskinska School	Holding & Registration	No
6	Manhush	Manhush District Department of the Ministry of Internal Affairs	Registration, Secondary Interrogation, & Detention	Yes
7	Manhush	Filtration Post "Manhush"	Registration	Yes
8	Nikolske	Nikolske Police Department/Volodarskoe District Department of Internal Affairs	Registration & Secondary Interrogation	No
9	Nikolske	Nikolske School No. 1	Holding	No
10	Donetsk	Donetsk Headquarters of the Ministry of Internal Affairs	Registration	No

[119] "System of Filtration".

11	Donetsk	Donetsk Pre-Trial Detention Center	Detention	No
12	Donetsk	Izolyatsia Prison	Detention	No
13	Donetsk	Directorate for Combating Organized Crime	Registration, Secondary Interrogation, & Detention	No
14	Makiivka**	Makiivka Correctional Colony No. 32 OR Western Correctional Colony No. 97	Detention	No
15	Novoazovsk	Novoazovsk District Department of the Ministry of Internal Affairs	Registration	No
16	Novoazovsk**	Novoazovsk School No. 1 OR Novoazovsk School No. 2 OR Novoazovsk School No. 3	Holding	No
17	Starobesheve	Starobesheve Department of the Ministry of Internal Affairs	Registration	No
18	Buhas	Buhas Village Administration	Registration	No
19	Olenivka | Bahkmut Raion	Yenakiieve Correctional Colony No. 52	Detention	No
20	Olenivka | Volnovakha Raion	Volnovakha Correctional Colony No. 120	Detention	Yes
21	Vasylivka***	Vasylivka Highway Checkpoint	Registration	No

Table 6. Russian filtration centers in Donetsk and Zaporizhzhia Oblasts. Data is from the Conflict Observatory and Yale's Humanitarian Research Lab.[120]
**Town or village coordinates are used here instead of approximate building coordinates as some locations have been geolocated to multiple potential locations.*
***These filtration centers have been geolocated to more than one potential location.*
****Vasylivka Highway Checkpoint is in Zaporizhzhia Oblast but is included here because it functions the same as the Donetsk Oblast filtration system, which all other entries are a part of.*
*****Potential filtration sites that did not meet the required confidence level were found at Anadol, Amvrosiivka, Mykilske, Sartana, Siedove, Stepanivka, and Yalta. Checkpoints in Mariupol were not included in this assessment.*

[120] "Mapping the Filtration System in Donetsk Oblast," Conflict Observatory Publication Portal Redirection (The Conflict Observatory), accessed October 26, 2022, https://hub.conflictobservatory.org/portal/apps/sites/#/home/pages/filtration-1.

Appendix C

The following appendix contains descriptions of mass graves in Ukraine. No images are included in this appendix, but the sources may be examined to find imagery of the graves. Caution should be taken as some images are explicit graphic images of the deceased.

Kyiv Oblast

The Church of St Andrew and Pyervozvannoho All Saints mass grave, Bucha

Bucha had been captured and occupied twice by Russian forces during the Battle of Kyiv Oblast. First on 27 February through 12 March and again from 29 March to 31 March.[121] Hundreds of bodies have been exhumed from a mass grave in the churchyard of the Church of St Andrew and Pyervozvannoho All Saints in the city center. Trenches approximately 14 m long in the churchyard are visible on Google Earth imagery starting from 12 March.[122]

Football field mass grave, Bucha

A photo published by Reuters on 06 April showed a cluster of shallow single burials in what appeared to be a football field 2.5 km away from the Church of St. Andrew and Pyervozvannoho All Saints mass grave. It appears that there were at least 8 civilians buried here. This grave was created between 27 February and 31 March and is likely tied to violence that was committed against civilians at 144 Yablunska St. by the 76th Guards Airborne Assault Division.[123]

Hospital mass grave, Borodyanka

[121] "Bucha Liberated, Says Mayor.," The Kyiv Independent (The Kyiv Independent, June 23, 2022), https://kyivindependent.com/uncategorized/bucha-liberated-by-ukraine-says-mayor.

[122] El-Sherbiny, Eman, and Benjamin den Braber, 26.

[123] Erika Kinetz, Oleksandr Stashevskyi, and Vasilisa Stepanenko, "How Russian Soldiers Ran a 'Cleansing' Operation in Bucha," ABC News (ABC News Network, November 3, 2022), https://abcnews.go.com/Politics/wireStory/russian-soldiers-ran-cleansing-operation-bucha-92596630.

Borodyanka fell along the main Russian advance toward Kyiv and was occupied from the earliest days of the "special military operation" until 30 March when Russian forces withdrew from the region. The mass grave sits on the grounds of a hospital that had to close its morgue due to power outages. While the total number of victims is unclear, at least 9 bodies have been exhumed from the mass grave wrapped in blankets or body bags.[124] No visible grave additives could be seen on the video.

Mass grave near a destroyed car, Havronshchyna

Photos and video on the UNIAN Telegram channel from 12 April show a shallow grave in a wooded area off the side of a road. According to residents and local law enforcement, the civilians were killed by Russian forces as they were attempting to flee in mid-March.[125] The 5 victims did not appear to be wrapped in any way and there were no visible signs of any grave additives.

Suhenko Family Mass Grave, Motyzhyn

A Reuters article from 04 April shows an image of the shallow mass grave of the Suhenko family in a forested area outside the village of Motyzhyn near a destroyed farm. 4 civilians were partially covered by sand and a burnt-out tractor could be seen nearby in images released from the site. No other grave additives or body wrappings were seen. A family friend told Reuters that the family had been taken into custody by Russian forces on 23 March[126] and most likely killed soon after.

Myrotske Village mass grave, Myrotske

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[124] Mathias Bölinger, "Mass Graves Exhumed in Urkaine," dw.com (DWNews, May 14, 2022), https://www.dw.com/en/ukraine-corpses-exhumed-from-mass-graves/video-61530878.

[125] UNIAN (@УНИАН) "В Киевской области россияне расстреляли из БМП семью, которая пыталась эвакуироваться", Telegram post, April 12, 2022, https://t.me/uniannet/46246.

[126] Marko Djurica, "Ukrainian Village Leader and Family Found Buried in Shallow Grave," Reuters (Thomson Reuters, April 5, 2022), https://www.reuters.com/world/europe/village-leader-family-found-buried-shallow-grave-outside-ukrainian-capital-2022-04-04/.

In late April, a shallow grave containing the bodies of 7 civilians were discovered in Myrotske Village northwest of Bucha. The shallow grave was in a wooded area close to an abandoned Russian military position.[127] It did not appear that the bodies were wrapped in any material or that anything had been added to the grave. The area was occupied by Russian forces from approximately 28 February to 02 March and again from 15 March to 22 March, leaving two small windows for the creation of the grave.

<u>Chernihiv Oblast</u>

Yalivshchyna Forest mass graves, Chernihiv

Between 26 February and 06 March, a series of three mass graves appeared on satellite imagery of the Yalivshchyna Forest north of Chernihiv. These mass graves continued to expand during the month of March.[128] It is unclear if the burials are grouped as single-burials or multi-burials, but initial single-burial estimates place the number of victims at 323-381. Imagery of the site shows trenches with what appears many single burials with identification cards. The bodies were contained in caskets. This mass grave is an extension of the existing Yalovshchyna Cemetery.

<u>Kherson Oblast</u>

Kherson City mass grave, Kherson

On 02 March, the city of Kherson fell to Russian forces and at the time of writing is still under Russian control. The mass grave appeared on satellite imagery on 28 February and trenches are still being added to the site.[129] The mass grave discovered in Kherson is an

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127 Pavel Polityuk, "Kyiv Police Find Three Bound Men They Say Were Executed by Russian Occupiers," Reuters (Thomson Reuters, April 30, 2022), https://www.reuters.com/world/europe/kyiv-police-find-three-bound-men-they-say-were-executed-by-russian-occupiers-2022-04-30/.
128 El-Sherbiny, Eman, and Benjamin den Braber, 6.
129 El-Sherbiny, Eman, and Benjamin den Braber, 22.

extension of the city's main cemetery. The grave is also located nearby the Kherson International airport, a location that Russian forces have heavily fortified and are using as a base. It has been speculated that the high number of anti-Russian occupation protests occurring in the city has increased the level of violence against civilians by Russian forces. An estimated 824 grave plots have been created by this mass grave since the beginning of the Russian occupation.[130] However, since the city is still under Russian control, this estimate cannot be confirmed. Higher-resolution images that would allow for more grave details to be seen are also unavailable at this time.

Donetsk Oblast

Western Mariupol mass grave, Mariupol

The Western Mariupol mass grave is also referred to as the Starokrymske Cemetery mass grave and the Staryi Krym mass grave. The Siege of Mariupol began on 24 February until 20 May, when Russian forces assumed control of the city. At the time of this writing the port city of Mariupol and its suburbs remain under Russian occupation. Satellite imagery shows an extension on the southern end of the cemetery beginning in mid-March. Drone footage posted to Twitter on 30 May by a German journalist shows a backhoe digging trenches for additional graves.[131] It is estimated that over 1,000 graves have been added from mid-March to the end of May.[132] It is unknown how many more graves have been added since then.

Kindergarten mass grave, Mariupol

Images from the Telegram channel Мариуполь сейчас on 08 April show what appears to be a cluster of at least 5 shallow graves in front of a kindergarten in eastern Mariupol.[133] The

[130] El-Sherbiny, Eman, and Benjamin den Braber, 22.
[131] Röpcke, Julian (@JulianRoepcke). 2022. "Das Video dazu…". Twitter, May 30, 2022. https://twitter.com/JulianRoepcke/status/1531227775029346304
[132] El-Sherbiny, Eman, and Benjamin den Braber, 40.
[133] El-Sherbiny, Eman, and Benjamin den Braber, 39.

graves have a similar design to the football field mass grave in Bucha. As Mariupol is still under Russian control, information on this and other mass graves is limited. A broad window is possible for the creation of this gravesite, from 24 February to 07 April, but unfortunately a more detailed temporal assessment is not currently possible.

Manhush mass grave, Manhush

On 21 April, the mayor of Mariupol Vadym Boychenko revealed the existence of a new 30 m long mass grave in Manhush extending off the local cemetery. This grave first appears on satellite imagery on 23 March[134] The mass grave at Manhush was dug to accommodate the influx of dead from Mariupol who were brought to the grave by Russian trucks. A 25 April estimate puts the victims buried in the grave between 3,000 and 9,000[135], however, this number is most likely far higher at the time of writing. It is unknown if the bodies are wrapped in cloth, body bags, or are otherwise contained in caskets at this time. Manhush is also home to Russian registration, secondary interrogation, and detention centers which may also be a source of victims.

Vynohradne Cemetery mass grave, Pioners'ke

Like Manhush, the Vynohradne Cemetery mass grave was created in part to bury the dead from Mariupol. A Telegram message from 22 April from Mariupol's mayor Vadym Boychenko publicly acknowledged the mass grave and estimated that over 1,000 victims were buried in the 45 m by 25 m grave.[136] The trenches are approximately 43 m long. The grave appeared on satellite imagery starting on 20 April. Imagery from 28 April and 12 May shows an

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[134] "Russian Invaders Disguising Mass Grave in Manhush, Says Mariupol City Council," The New Voice of Ukraine (The New Voice of Ukraine, April 25, 2022), https://english.nv.ua/nation/russian-invaders-disguising-mass-grave-in-manhush-says-mariupol-city-council-50236812.html.

[135] El-Sherbiny, Eman, and Benjamin den Braber, 51.

[136] Маріупольська міська рада (@mariupolrada) "Ще одну величезну братську могилу виявлено на околиці Маріуполя – у селищі Виноградне.", Telegram post, April 22, 2022. https://t.me/mariupolrada/9332/

expansion to the grave. Small black shapes can be seen on imagery from multiple dates and are assumed to be body bags.

Lyman mass grave, Lyman

The city of Lyman experienced heavy military activity from 23 May to 27 May during the First Battle of Lyman in which Russian forces were victorious, gaining control of the strategic rail and transit hub. The city was under Russian occupation until the city was liberated on 02 October during the Second Battle of Lyman. During the Russian occupation, 2 mass graves were used to bury approximately 200 people, the majority of them civilians.[137] One site consisted of clustered single burials of civilians in trenches, the other a mixed mass grave of civilians and Ukrainian defenders. The mass grave appears to be on the outskirts of the city in a clearing bordered by woods, while the clustered single burials are an extension of an existing cemetery in a forested area.

Luhansk Oblast

Rubizhne Cemetery mass grave, Rubizhne

The Battle of Rubizhne began on 15 March and ended on 12 May with Russian forces claiming the city. The city remains under Russian control as of the time of writing. A Telegram post from user @den_kazanskyi is some of the only evidence of a mass grave in Rubizhne Cemetery.[138] According to the post, the mass grave consists of trenches extending off an existing cemetery on the outskirts of the city. The area appears to be partially forested, and the bodies appear to be buried in body bags.

[137] "Ukraine Completes Exhumation of Soldiers at Lyman Mass Grave," Reuters (Thomson Reuters, October 14, 2022), https://www.reuters.com/world/ukraine-completes-exhumation-soldiers-lyman-mass-grave-2022-10-14/.

[138] Казанський, Денис (@den_kazanskyi), "В захваченном и разрушенном армией РФ городе Рубежное очень много погибших гражданских, поэтому их хоронят просто в братских могилах.", Telegram post, April 30, 2022. https://t.me/kazansky2017/2602.

Kharkiv Oblast

Izium Cemetery mass grave, Izium

Russian attacks on the city began on 28 February with the Battle of Izium beginning on 03 March for control of the strategically significant transport hub. Control of the city transferred hands frequently during heavy fighting in mid-March as Russian forces slowly advanced from the north. On 01 April Izium fell under Russian control until it was liberated on 10 September. On 15 September a mass grave containing at least 447 bodies was discovered in the woods outside Izium,[139] with two more mass graves announced in late September with bodies in the hundreds. The gravesites are in heavily forested areas with at least one grave extending off a preexisting cemetery. It appears that at least some of the bodies were buried without any type of wrapping or containment.

[139] Iryna Balachuk, "Exhumation Was Completed in Izyum - 447 Bodies Were Raised, among Them Many Women and Children," Pravda (Pravda, September 23, 2022), https://www.pravda.com.ua/news/2022/09/23/7368817/.

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