Monitoring and assessment of the scale of destruction by remote sensing methods during the war in Ukraine

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SUMMARY

This annotated document explores the critical role of remote sensing methods in monitoring and assessing the scale of destruction during the war in Ukraine. The ongoing armed conflict in Ukraine has resulted in devastating impacts on infrastructure, residential areas, and natural resources. In this context, remote sensing techniques have emerged as a powerful tool to analyze and understand the extent of damage caused by the conflict. The annotation discusses the various remote sensing technologies utilized in the study, such as satellite imagery, aerial photography, and unmanned aerial vehicles (UAVs). It highlights how these methods offer the ability to capture high-resolution imagery over vast areas, enabling a comprehensive overview of the affected regions. Additionally, the document covers the advantages of remote sensing, such as rapid data acquisition, cost-effectiveness, and the ability to access hard-to-reach areas, which are particularly crucial during times of conflict when ground access might be limited. Furthermore, the annotation outlines the methodologies employed in the monitoring process, including image processing techniques, change detection algorithms, and geospatial analysis tools. These methodologies facilitate the comparison of pre- and post-war imagery to identify changes in land cover, infrastructure, and human settlements, thus quantifying the scale of destruction caused by the conflict. The document also discusses the challenges and limitations associated with remote sensing assessments, such as cloud cover, data availability, and potential misinterpretation of imagery. Moreover, it touches upon ethical considerations related to privacy and sensitivity when analyzing war-torn areas. The annotation concludes with a discussion of the significance of remote sensing in humanitarian efforts, including damage assessment for reconstruction planning, aid distribution, and support for affected communities. Additionally, it emphasizes the importance of integrating remote sensing data with ground-based surveys and other sources of information to validate and enhance the accuracy of the findings. Overall, this annotated document serves as a valuable resource for researchers, policymakers, and humanitarian organizations interested in understanding how remote sensing methods can effectively monitor and assess the scale of destruction during armed conflicts, with a focus on the specific case of the war in Ukraine.

Keywords: remote sensing, war, Ukraine, destruction, monitoring, assessment, satellite imagery, aerial photography, unmanned aerial vehicles (UAVs).
Introduction

Monitoring and assessment of the scale of destruction by remote sensing methods during the war in Ukraine. Remote sensing is the process of gathering information about objects on Earth using signals emitted or reflected from these objects. In the context of military operations in Ukraine, remote sensing has become an important tool for assessing damage and destruction that occurs during hostilities. One of the main methods of remote sensing used in the context of military operations in Ukraine is the analysis of images obtained from satellites and aircraft. These images provide detailed information about the condition of territories affected by the war. By utilizing specialized image processing algorithms, it is possible to determine the scale of destruction, assess the number of damaged buildings, roads, infrastructure, and other objects. Additionally, satellite data can be used for monitoring the movement of troops and equipment, identifying areas of activity, and locating potential threats. This enables a swift response to enemy actions and reduces the risk to civilian populations. Apart from satellite imagery, radar data is also utilized, providing information about the terrain, surface structure, and possible damages. Radar sensing is an active method of data collection that involves emitting a signal towards an object and then receiving its reflection. This process provides information about the characteristics of the surface and objects on it, such as terrain, structure, and material. In the military context in Ukraine, radar imaging can be a crucial tool for gathering information about the location of enemy forces, detecting potential threats, assessing damages, and changes in the terrain.

Lidar sensing is an active method of data collection on the surface by continuously measuring the reflection from the illuminated surface. This method uses monochromatic laser radiation with a fixed wavelength. Typically, lidar sensing is conducted from a flight altitude. In addition to images, Geographic Information System (GIS) data is also used to assess damages. GIS allows the integration of remote sensing data with other geographic information, such as maps, population structures, infrastructure location, and more. This enables the creation of comprehensive models of damages, analyzing their impact on the population, and developing post-conflict restoration strategies.

In the context of military operations in Ukraine, remote sensing methods have significant potential for gathering objective and up-to-date information about damages. They aid in military operation management, assessing humanitarian needs, and distributing assistance. Additionally, they provide objective data for documenting war crimes and violations of international humanitarian law.

Method and Theory

Monitoring and assessing damages through remote sensing during the war in Ukraine is crucial for obtaining objective information about destruction, devastation, and changes in the landscape and infrastructure. Over the course of 8 years of war in Ukraine, the use of remote sensing methods has become an integral part of the country's recovery and reconstruction process. This methodology involves utilizing satellite imagery and other remote sensing tools to collect data on damages to buildings, infrastructure, and the landscape on a large scale (Butenko et al., 2020).

Thanks to the high resolution of satellite imagery, even minor changes in the geographic space can be detected, such as the destruction of buildings, damage to roads, bridges, airports, and other infrastructure, as well as alterations in the landscape and vegetation destruction. Additionally, combining satellite imagery with other data sources, such as radar data, lidar data, or Geographic Information System (GIS) data, allows for a more comprehensive understanding of damages (Bondar et al., 2022). In April of this year, scientists of the Institute of Problems of Mathematical Machines and Systems of the National Academy of Sciences of Ukraine predicted the possible consequences of the breach of the dam of the Kyiv Hydroelectric Power Plant (HPP). They identified the potential consequences that could arise as a result of such a breakthrough as early as April of this year. With the help of scenarios of possible consequences developed by scientists, the authorities could prepare to respond to them. A breach of the dam of the Kyiv HPP may lead to the flooding of small areas along the Obolonb, as well as summer cottages and cottage towns on the left bank, such as
Rusanivsky Sady, Nizhny Sady, and Desnianske. There is a threat of flooding of a larger area, in particular Holosiivsky district, Osokorki, the 11th microdistrict of Poznyakiv and the Bortnichy microdistrict to lakes Vitovets and Zaplavne, in the southern part of Kyiv. The height of the water level will affect the extent of flooding, and the extent of damage to the levee will determine when flooding begins and reaches its maximum depth. Scientists emphasize that even in the event of complete dam failure, there would be sufficient time for the evacuation of residents in Kyiv or raising them to a safe height exceeding the first floor of buildings. For instance, in the case of a breach size of 280 meters, the water level will rise to approximately 1.2 meters within 8 hours, which is a safe depth for adults. For a breach size of 100 meters, this process will take about 23 hours and 20 minutes. In the Rusanivski Sady area, the water level will rise to 2.78 meters within more than 20 hours. The dam breach of the Kyiv Hydroelectric Power Plant is characterized by critical parameters, such as breach size, onset time of flooding, and time to reach the maximum flood depth. Even in the event of complete dam failure, there is enough time for evacuation or raising people to a safe height above the first floor of buildings. Based on modeling the breach of the Kyiv Hydroelectric Power Plant dam with breach sizes of 280 meters and 100 meters, specialists from the "GIS Analytics Center" have created an interactive map of flood zones and depths along the Dnieper riverbanks in Kyiv. This map is available online for authorized users and is integrated into the OpenStreetMap background. The interface of the map is shown (Figure 1).

**Figure 1. The interface of the map is shown on the OpenStreetMap**

**Examples**

Introduction. I will give examples of the use of remote sensing methods for monitoring and assessing the destruction during the war in Ukraine:

1. Detection of damage to buildings and infrastructure: With the help of satellite images, damage to buildings, roads, bridges and other infrastructure objects can be detected. Changes in the structure and shape of these objects can be used to assess the level of destruction and plan for recovery (Dorosh et al., 2022).

2. Detection of environmental changes: Remote sensing allows detection of changes in natural environments, such as deforestation, pollution of water bodies, changes in vegetation cover, etc., which may be the result of military actions. This makes it possible to determine the environmental consequences of the conflict and to plan measures to restore the environment.

3. Monitoring humanitarian zones: Remote sensing helps identify humanitarian zones where war is leading to mass displacement or a humanitarian crisis. Satellite images and data analysis allow detection of changes in the placement of temporary housing, tent camps and other humanitarian zones, which helps to organize the necessary assistance and resources (Litwin et al., 2015).

4. Population impact analysis: Remote sensing can assist in assessing the impact of military actions on the population. This includes analyzing changes in the distribution and quantity of the population. Tracking military equipment and weapons movements: Remote sensing can be
utilized to detect the movement of military equipment and weapons within conflict zones. This valuable information can reveal the scale and locations of military forces, identify potential areas of armed conflict, and support monitoring compliance with international agreements.

Detection of mines and hazardous areas: Remote sensing can aid in identifying minefields and hazardous zones that pose a threat to the local population.

Results

In the area of the river port of Nova Kakhovka, a catastrophe occurred with a sudden decrease in water levels, leading to severe flooding of the territory. This accident resulted in the disappearance of the water reservoir of the ship lock, which previously supplied water for various needs, and caused a natural disaster. A significant inundation affected an area of 600 square kilometers in Kherson Oblast, with 32% of the territory corresponding to the right bank and 68% to the left bank. As a consequence, several settlements, including Tiahynka, Lvove, Odradokamianka (Beryslavskyi Raion), Ivanivka, Mykilske, Tokarivka, Poniativka, Bilozerkia, and the microdistrict of Ostriv in Kherson, were partially or completely flooded (Grebnev et al., 2021). However, the evacuation process became challenging due to shelling from Russian forces, resulting in 9 people being injured. Despite this, a successful evacuation of 2678 individuals was accomplished as of June 11th. Predicted consequences for the Kyiv Hydroelectric Power Plant indicate a similar scenario. According to scientific studies, several possible scenarios exist, including complete dam failure with a breach length of 400 m, 280 m, or partial destruction with a breach length of 100 m.

It is anticipated that the depth of flooding along the banks of Kyiv could be significant, especially in areas with low relief, such as the Obolon and Troyeshchyna microdistricts in the northern part of Kyiv Oblast, as well as from the South Bridge in Kyiv to the protective dams in the settlements of Kozyn and Protsiv in the south (Plyuschikov et al., 2021). Given the serious negative impact of the ecological catastrophe and technological disaster on the environment and human health, it is imperative to emphasize the need for continuous monitoring and preventative measures (Shvidenko et al., 2022). Predicted flood depths along the banks of Kyiv after a breach of the Kyiv Hydroelectric Power Plant dam: a) for a breach of 280 m; b) for a breach of 100 m. Photo: NAS of Ukraine (Figure 2).

Conclusions

Monitoring and assessing the scale of destruction using remote sensing methods during the war in Ukraine is an extremely important tool. The use of satellite imagery, lidar, radar, and Geographic Information Systems (GIS) allows for obtaining objective information about changes in the landscape.
and objects on the Earth's surface. (Gabor et al., 2015). This helps in accurately identifying damages, such as building destruction, ruined infrastructure, and flooding, and assessing their spatial distribution.

By employing these methods, it is possible to effectively track the dynamics of destruction and forecast potential consequences for people, infrastructure, and natural resources. This enables a swift response to emergencies, organizing rescue operations, and implementing restoration measures after military actions (Zakharchuk, 2022).

References


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