Monitoring, assessment and administration of war consequences and post-war reconstruction: remote sensing and GIS economical approaches

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SUMMARY

The aftermath of war conflicts leaves a trail of destruction and displacement, demanding comprehensive strategies for fixation, monitoring, and assessment of war-related consequences. This article explores the application of remote sensing methods and Geographic Information Systems (GIS) in monitoring and assessing the impacts of war, particularly focusing on destruction, landscape transformation, and post-war reconstruction. The integration of remote sensing and GIS technologies provides valuable insights into the extent of damage, aids in demining efforts, and contributes to informed decision-making during reconstruction. This paper presents a comprehensive overview of successful GIS applications employed by various countries during wartime, highlighting their contributions to monitoring, assessment, and reconstruction efforts.

Keywords: GIS technologies, war consequences, monitoring, assessment, post-war reconstruction
Introduction

The enduring impacts of war conflicts necessitate effective approaches to understanding, monitoring, and addressing the consequences of warfare. Geographic Information Systems (GIS) have played a crucial role in enhancing situational awareness, aiding decision-making, and facilitating post-war reconstruction during times of armed conflict. GIS aids in strategic planning by analyzing terrain features, identifying advantageous positions, and assessing potential obstacles (Longley et al., 2015; Yakymchuk et al., 2022). This information guides military operations and helps formulate effective tactical maneuvers. In urban warfare scenarios, GIS provides detailed maps of complex urban environments, aiding soldiers in navigation, identifying potential ambush sites, and minimizing risks to both troops and civilians (Sarker, Ahmed, 2021). Through a series of case studies, this research demonstrates the diverse ways in which GIS technologies have been harnessed to mitigate the impacts of war and promote sustainable recovery (Shahtahmassebi, Aryal, 2021). This article highlights the significance of utilizing remote sensing and GIS techniques to comprehensively assess war-related destruction, landscape transformation, and aid post-war reconstruction efforts.

Methods and techniques

The case studies highlighted in the preceding sections showcase a range of advanced research methods that have been employed to effectively utilize Geographic Information Systems (GIS) during periods of war conflict. These methods include:

- **Remote Sensing Analysis**: Satellite and aerial imagery have been harnessed to provide real-time and retrospective insights into conflict zones, damage assessment, and changes in landscape and land cover. This analysis aids in conflict monitoring, target identification, and post-war damage assessment.

- **Spatial Data Integration**: GIS has facilitated the integration of diverse spatial data sources, including population distribution, infrastructure networks, and environmental conditions. The fusion of these data sets enables informed decision-making for effective humanitarian assistance, resource allocation, and infrastructure reconstruction.

- **Spatial Analysis and Modeling**: GIS-based spatial analysis techniques, such as terrain analysis, proximity analysis, and spatial modeling, have been utilized to inform tactical strategies, border security planning, and humanitarian interventions. These analyses provide critical insights into optimal site selection, risk assessment, and resource management.

- **Land Cover Mapping and Change Detection**: GIS has been instrumental in mapping land cover changes resulting from conflict, urban warfare, and military activities. Techniques such as supervised and unsupervised classification aid in distinguishing between various land cover classes and monitoring shifts in landscape over time.

- **Risk Assessment and Clearance Operations**: GIS-based risk assessment models have supported demining operations and post-war reconstruction. These models utilize spatial data to prioritize areas with the highest risk, optimizing the allocation of resources for safe clearance and rehabilitation.

- **Geospatial Visualization**: Interactive geospatial visualizations, including 3D modeling and virtual reality, enhance situational awareness and aid in communication between stakeholders. These visualizations facilitate better understanding of complex urban environments, assisting in urban warfare and reconstruction planning.

- **Spatial Decision Support Systems (SDSS)**: GIS-based decision support systems have been deployed to assist in strategic planning, humanitarian operations, and conflict resolution. These systems provide a user-friendly interface for analyzing spatial data and generating actionable insights.

- **Multi-Criteria Analysis**: GIS-driven multi-criteria analysis has been employed to evaluate competing factors, such as land suitability, infrastructure needs, and resource availability. This method aids in optimizing reconstruction efforts and sustainable development planning.

In conclusion, the successful application of GIS during armed conflict involves a synergy of these research methods, enabling nations to effectively navigate the challenges posed by warfare, minimize damage, and facilitate post-war recovery and reconstruction.
**Results**

GIS technologies are indispensable tools in modern warfare, offering precise, data-driven insights that improve decision-making, operational effectiveness, and the overall safety and success of military engagements. GIS provides real-time, geospatial intelligence that enhances commanders’ situational awareness, enabling them to make informed decisions based on accurate and up-to-date information about enemy positions, troop movements, and terrain conditions (Bazi, Melgani, 2011; Kuzmych et al., 2022a, 2022b). GIS enables precise targeting by integrating data on target locations, topography, and environmental factors. This results in more accurate and effective airstrikes and artillery fire while minimizing collateral damage and civilian casualties (Li, Zhou, 2021). Beyond combat, GIS assists in coordinating humanitarian assistance and disaster relief efforts. It helps map displaced populations, assess infrastructure damage, and allocate resources efficiently to provide aid to affected areas. GIS supports post-war reconstruction by mapping damaged infrastructure, assessing landmines, and identifying safe zones for rebuilding (Qiao et al., 2021; A.Yakymchuk et al., 2023). This contributes to the efficient allocation of resources and the sustainable recovery of affected regions.

The USA remains the world leader in the development of GIS (Fig. 1). However, other developed countries - Germany, Israel, China, Japan, Great Britain - have no less powerful systems. GIS aids demining efforts by identifying high-risk areas and prioritizing clearance operations, thereby minimizing casualties and facilitating the safe return of communities to conflict-affected areas. In these countries GIS assists in monitoring and securing borders by providing a comprehensive view of border regions, identifying potential infiltration routes, and enhancing surveillance capabilities. Also GIS serves as a central platform for sharing geospatial data among different military units, enhancing communication, coordination, and synchronization of operations. Through detailed analysis of potential impacts, GIS helps minimize unintended consequences, reducing collateral damage and supporting adherence to international laws of armed conflict (Geographic Information System, 2023).

**Figure 1 Geographic Information System (GIS) market revenue in the United States from 2014 to 2025, million U.S. dollars (by the data of Geographic Information System, 2023)**

GIS plays a pivotal role in disaster monitoring and response, offering a spatial framework for integrating diverse data sources. By incorporating geospatial data on affected areas, population density, and infrastructure, decision-makers can assess the scope of destruction and prioritize aid delivery during and after conflicts. It is important that establishment of a comprehensive GIS database is crucial for storing, managing, and analyzing spatial data related to war consequences. Such databases enable the tracking of damage over time, aiding in the formulation of evidence-based policies and strategies for recovery and rehabilitation. This issue is especially important now for Ukraine, which is in the stage of a hot war, when Russian missiles are destroying Ukrainian cities and killing civilians, so these technologies are of vital importance to this country.

The data of Fig. 1 shows the Geographic Information System (GIS) market revenue in the United States from 2014 to 2025 (Geographic Information System, 2023). In 2022, the GIS market in the United States generated some 1.8 billion U.S. dollars. As evidenced by the figure, GIS systems are extremely effective, despite their high economic costs, the economic effects of their use are much higher and exceed the costs several times. The statistic displays the market revenue of the global geospatial industry ecosystem from 2013 to 2020, by technology. In 2017, market revenue from the earth observation technologies amounted to 50 billion U.S. dollars worldwide (Fig. 2).
As military practice in Ukraine shows, military operations can lead to significant landscape transformations, affecting ecosystems, water bodies, and land use patterns (A. Yakymchuk et al., 2022). Remote sensing and GIS techniques facilitate the detection of changes in land cover, land use, and vegetation, offering insights into the ecological impacts of warfare. Accurate land cover mapping in conflict zones supports military operations and humanitarian efforts alike. GIS-based land cover mapping enhances situational awareness, aids in strategic planning, and assists in resource allocation during war conflicts. Post-conflict environments often face the persistent threat of landmines and unexploded ordnance. GIS-based demining strategies utilize spatial data to identify high-risk areas and prioritize clearance efforts, minimizing casualties and enabling safe rehabilitation.

The utilization of GIS technologies during armed conflicts has evolved into a valuable strategy for several nations. The authors of this paper examine case studies from different countries, showcasing innovative approaches to leveraging GIS for better understanding and management of war-related challenges. For example, the Israel Defense Forces have employed GIS to monitor conflict zones and enhance urban warfare strategies. GIS has enabled real-time tracking of military movements, target identification, and urban infrastructure assessment, aiding in minimizing civilian casualties and reducing collateral damage. Another example – the US military has utilized GIS to coordinate humanitarian assistance and disaster response efforts during conflicts. By integrating spatial data on affected areas, population movements, and critical infrastructure, GIS has facilitated timely delivery of aid to displaced populations and post-war reconstruction. Croatia has successfully employed GIS for demining and post-war reconstruction following the Balkan conflicts. GIS-based risk assessments and clearance operations have contributed to safe land rehabilitation and reconstruction, allowing displaced communities to return and rebuild their lives. In the aftermath of a prolonged conflict, Sri Lanka utilized GIS to support conflict resolution and resource management. Spatial analysis aided in identifying suitable locations for resettlement, resource allocation, and sustainable land use planning, fostering stability and development. Afghanistan has leveraged GIS to enhance border security and counterterrorism efforts. GIS-based mapping of border regions and terrain analysis has facilitated strategic planning, surveillance, and the prevention of illicit activities along national boundaries.

Conclusions

GIS technologies are indispensable tools in modern warfare, offering precise, data-driven insights that improve decision-making, operational effectiveness, and the overall safety and success of military engagements.

1. The integration of remote sensing and GIS technologies provides a robust framework for fixation, monitoring, and assessment of war consequences, as well as post-war reconstruction. These approaches contribute to informed decision-making, efficient resource allocation, and effective demining efforts, ultimately fostering sustainable recovery and rehabilitation in conflict-affected regions.

2. The case studies presented in this paper illustrate the versatile applications of GIS technologies during armed conflicts. From war conflict monitoring and urban warfare to humanitarian aid delivery, demining, and post-war reconstruction, GIS has proven to be an invaluable tool for enhancing operational efficiency, minimizing collateral damage, and promoting sustainable recovery.
3. Such systems have proven themselves well in various countries of the world - Israel, Ukraine, USA, Afghanistan, Croatia and others. By studying these international examples, it becomes evident that the strategic integration of GIS into military operations and post-conflict initiatives can significantly contribute to mitigating the adverse impacts of war and fostering a path towards lasting peace and prosperity. Remote sensing, through various satellite and aerial platforms, enables the systematic monitoring of conflict zones.

High-resolution imagery and multi-spectral data contribute to the identification and quantification of destruction caused by military operations. These methods facilitate real-time and retrospective analysis, enabling the estimation of damage to infrastructure, urban areas, and natural resources.

References


