Monitoring the impact of military actions on the environment using GIS and remote Earth sensing methods

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SUMMARY

Thanks to the methods of remote sensing of the Earth and geoinformation technologies, the possibilities of monitoring the impact of military actions on the environment were investigated.

This topic is currently the most relevant because it allows for the shortest possible time to assess and predict various emergency situations that may be caused by military actions, namely: fires, water pollution, air pollution, and others.

These data and the methodology itself can further help in monitoring this situation, as well as in the implementation of appropriate measures to prevent the deterioration of the ecological environment.
Introduction
Ensuring environmental safety is a strategic national priority of our country. The state of the environment today is one of the key indicators of the sustainable development of society at both the global and regional levels. Internal threats to environmental security are: high level of pollution of all components of the biosphere; resource intensity of industries; outdated, environmentally inefficient technologies, etc. Therefore, maintaining an optimal (favorable) state of the natural environment aimed at achieving this state is an extremely urgent problem (Semeniaka et al., 2022).

According to Protocol I to the Geneva Conventions of August 12, 1949, relating to the Protection of Victims of International Armed Conflicts, adopted in 1977, belligerent states are required to protect the natural environment from "extensive, lasting and serious damage" and prohibit methods or means of warfare "intended or likely to lead to" the infliction of such harm.

Method and Theory
From the first days of the Russian military invasion of Ukraine on February 24, 2022, they began the targeted destruction of our country's critical infrastructure, both with the use of high-precision missiles and rocket artillery. The purpose of such actions was to weaken the supply of Ukrainian cities with fuel and resources for recovery and to inflict maximum economic damage. However, some cases indicate that the purpose of individual shelling was directly to worsen the ecological situation in populated areas.

During the hostilities, surface water quality control posts and atmospheric air quality control posts stopped working, the work of the State Environmental Inspections was paralyzed, and the radiation background was not controlled.

The shelling of industrial facilities and infrastructure led to fires, which caused additional air, soil and water pollution. Where fire extinguishing measures were carried out, pollution was additionally aggravated by the remains of firefighting foam, which also negatively affects the health of the population (Environmental consequences ..., 2022).

The problem of environmental security in the war zone has reached an unprecedented scale. The main danger is related to the possibility of environmental pollution due to accidents, and serious work disruptions at industrial and other enterprises.

Remains of military equipment, buildings, structures and infrastructure elements were added to the traditional household waste, the disposal of which requires additional capacities and is impossible without prior demining of the territory and cleaning it of ammunition.

As a result of military maneuvers or military exercises, the construction of fortifications, explosions and the burning of ammunition, the surface layer of the soil is disturbed. The use of lands damaged as a result of hostilities will be complicated by the need for their reclamation, demining of territories, and disposal of ammunition (War and the environment..., 2022).

Nature reserves are one of the sources of improving Ukraine's ecological situation. These areas play an important role in protecting biodiversity and preserving the climate. However, according to the Ministry of Environmental Protection and Natural Resources, as of March 1, 2022, the aggressor was conducting combat operations on the territory of 900 objects of the nature reserve fund with an area of 12,406.6 sq. km, which was about a third of the area of the nature reserve fund of Ukraine (Fig. 1).

About 200 territories of the Emerald Network with an area of 2.9 million hectares are under threat of destruction. The habitats of some rare and endemic species and habitats found themselves in the zone of active hostilities, which threatened their existence. As an example, we can cite virgin unplowed steppes, chalk slopes in Donetsk region, seaside settlements in the southern regions, swamps in the north, etc.

Russian armed aggression led to serious environmental consequences - the destruction of intact natural landscapes, pollution of groundwater, surface water bodies, atmospheric air pollution, disabling of large tracts of arable land, destruction and damage of nature reserve objects, forest fires and destruction of biological resources are huge and in time, the rehabilitation of these environmental objects will last a rather significant period (Lisova, 2015).
In addition to forests, in the north of the country, where active hostilities took place and continue to take place, swamp ecosystems and peatlands were seriously affected. A significant part of the peatlands of Ukraine is drained, and therefore they have become a potential source for the occurrence of peat fires. Such fires are difficult to put out even in normal peacetime, and during the period of active hostilities in the territory of the northern regions, it becomes an extremely difficult task.

Risks associated with damage to communications, enterprises and other objects that pose an increased environmental hazard are of particular importance, because in the absence of control and opportunities to eliminate their negative consequences, the scale of negative impact potentially increases every day.

Fires are one of the significant modifying factors that have a negative impact on the natural environment and people, destroy objects of the technosphere and plant ecosystems, reduce the ecological safety of territories and the quality of the environment.

During the burning of peatlands, oxide and carbon dioxide, fine dust with a particle diameter of 2.5 microns (typical for burning), volatile organic compounds, which include acrolein, formaldehyde, etc., are released into the air (Lisova, 2015).

Russian troops are also attacking port infrastructure along the coasts of the Black and Azov seas, ships at anchor. And this additionally leads to water pollution and the spread of dangerous and poisonous substances in the sea. Petroleum products have a negative effect on marine biocenoses, forming films on the surface of the water, which disrupts the exchange of energy, heat, moisture and gases between the sea and the atmosphere. In addition, they directly affect physico-chemical and hydrological conditions, cause the death of fish, seabirds and microorganisms. All oil components are toxic to marine organisms. Oil has another side property. Its hydrocarbons are able to dissolve a number of other pollutants, such as pesticides, heavy metals, which, together with oil, concentrate in the near-surface layer and further pollute and poison it.

Soil contamination with fuel and lubricants and other petroleum products occurs as a result of the movement and damage of ground military equipment. In soils impregnated with fuel and lubricants, water permeability decreases, oxygen is displaced, and biochemical and microbiological processes are
disrupted. As a result, the water and air regimes and the circulation of nutrients deteriorate, the root nutrition of plants is disturbed, their growth and development are inhibited, which causes death. As an example, in fig. 2 presents the calculated NDTI turbidity index in the Mariupol region, which characterizes the decrease in water transparency due to the presence of inorganic and organic impurities, suspensions, as well as the development of plankton in the water body (Semeniaka et al., 2021).

Algorithm for estimating water turbidity index. Today in Ukraine, 14 Ramsar sites with an area of 397.7 thousand hectares are used by the Russian invaders during hostilities against the Ukrainian people. This applies to the coasts of the Azov and Black seas, as well as the territories in the lower reaches of the Danube and Dniipro rivers. The NDTI index is calculated according to formula (1):

\[ \text{NDTI} = \frac{\text{RED}[3]-\text{GREEN}[2]}{\text{RED}[3]+\text{GREEN}[2]} \]  

where RED[3] is the reflection coefficient in the near-red range of the electromagnetic spectrum; \( \text{GREEN}[2] \) – reflection coefficient in the green range of the electromagnetic spectrum (Vegetation indices ..., n. d.).

This index is a global indicator, it is very sensitive to changes in moisture reserves in plants. It is also useful for predicting drought. As evidenced by the received space photographs (one from 2022 (during military operations), and the other from 2021), the amount of organic and inorganic impurities in the water has increased, the water has become cloudy, which may cause serious problems in the future, close to the drying up of the reservoir (War and the environment..., 2022).

\[ \text{NDMI} = \frac{\text{NIR}[4]-\text{SWIR1}[5]}{\text{NIR}[4]+\text{SWIR1}[5]} \]  

where NIR[4] is the reflectance coefficient in the near-infrared range of the electromagnetic spectrum; \( \text{SWIR1}[5] \) is the reflection coefficient in the short-wave infrared range of the electromagnetic spectrum (Vegetation indices ..., n. d.).

As a result of the invasion, the natural environment of Ukraine will suffer significant damage. The conducted analysis indicates the possibility of a drought in the zone of active hostilities, an increase in fire danger and, as a result, additional pollution of the environment.

**Figure 2 Calculated index NDTI on the butt of the place Mariupol**

In fig. 3 presents the calculated NDMI index - a standardized index of moisture differences, which is very sensitive to the level of moisture in the vegetation.

Used to track droughts, can also be used to detect fuel and lubricant levels in fire-prone areas (like NDWI, it is more sensitive to moisture). Uses the NIR and SWIR channels to create a coefficient designed to dim lighting and atmospheric effects. It is calculated according to formula (2):

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Conclusions
At this point in time, there is the destruction of ecosystems, soil pollution, a decrease in biodiversity, and significant forest fires. There is also a risk that Ukraine will not fulfill the already set climate goals, because the war is a contribution to climate change, and the recovery of the country will inevitably be accompanied by significant emissions of greenhouse gases.

As significant chemical contamination of soils and water resources is expected, it is important to ensure an effective environmental monitoring system that would allow recording the real extent of environmental damage and allow the most effective measures to be taken to avoid further deterioration and to restore ecosystems to a safe state - and for humans and wildlife. DZZ technologies can significantly help in this.

It is also important that the recovery plan of Ukraine includes measures for the restoration and preservation of ecosystems, and that the plans for the reconstruction of settlements include nature-oriented solutions and measures for adaptation to climate change.

References


Figure 3  Calculated index NDMI on the butt of the place Mariupol