MILITARY SOIL DEGRADATION OF AGRICULTURAL LAND IN UKRAINE

The publication contains some results of the research obtained during the implementation of the project “Assessment of the impact of armed aggression on the state of black soils and the development of measures for the accelerated restoration of soil fertility in the context of ensuring food security” No. 2022.01/0031 of the competition “Science for the recovery of Ukraine in the war and post-war periods” under the grant support of the National Research Foundation of Ukraine.
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A map of the black soils distribution in Ukraine and the zone of military operations.
Example of satellite images from Sentinel 2 (EO Browser)
Many fields in the war zones on Eastern Ukraine look like Izyum district, Kharkiv region (Photo of Maxar Technologies, June 2022)
The area near Bakhmut with a difference of 6 months

August 1, 2022
January 7, 2022
Soil compaction from the passage of military equipment

Trenches in the Zaporizhzhia region
# Types of soil degradation

**The new type of degradation - military**

<table>
<thead>
<tr>
<th>Types of degradation</th>
<th>Describe of degradation</th>
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<tbody>
<tr>
<td>Mechanical</td>
<td>Activation of erosion processes, landslides</td>
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<td></td>
<td>Mechanical disturbances of the morphological structure of the soil profile</td>
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<td>Mixing of genetic horizons</td>
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<td>Formation of funnels, ditches, pits</td>
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<td>Physical</td>
<td>Deterioration of physical properties of soils</td>
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<td>Persistent changes in particle size distribution</td>
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<td>Persistent changes in aggregate composition (destructuring)</td>
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<td></td>
<td>Compaction</td>
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<tr>
<td>Chemical</td>
<td>Deterioration of humus state of soils</td>
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<td>Trophic depletion of the soil</td>
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<td>Salinization</td>
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<td>Pollution</td>
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<tr>
<td>Physico-chemical</td>
<td>Acidification, alkalization</td>
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<tr>
<td>Biological</td>
<td>Reduction (narrowing) of biodiversity</td>
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<td></td>
<td>Reduction of soil biological activity</td>
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<td></td>
<td>Deterioration of the sanitary state</td>
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<td>Soil toxicity</td>
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</tbody>
</table>
Examples of the impact of heavy equipment (its debris) due to explosions and burning on the soil cover

Examples of intensive soil compaction due to the movement of heavy military equipment (mechanical soil degradation)

Examples of physical, chemical and physico-chemical soil degradation as a result of hostilities

Examples of biological soil degradation (territory burning)
The influence of military actions on the soil cover of Ukraine (as of March 2023)
Soils in the war zone, occupied and liberated territories, %

Area of military actions impact by main soil types
Soil resources of the Kharkiv region under the influence of military operations
Main soil types (subtypes) with biggest area

**Chernozem typical medium-humus**
45.2%
(of the total soil cover war zone area)

**Chernozem podzolized**
15.6%

**Chernozem ordinary medium-humus deep**
12.3%

**Chernozem ordinary medium-humus**
12.0%
The impact of military actions on the soil cover of the Kharkiv district of the Kharkiv oblast (as of September 2022)
The different kinds of military action’s impact on the soil cover of the Chkalovska hromada of the Kharkiv oblast (after the end of active fightings on September 2022)
Craters from explosions and traces of heavy military machines

Agricultural fire

Forest strips condition after hostilities

Shell explosion against the background of damaged soil
Flooded area after Kakhovka dam destruction

Damaged soils as a result of flooding
## Methodology of the Ukrainian Researchers Society

### Step 1: Geospatial analysis
- Deciphering satellite images for the assessment of war-induced soil cover disturbances
- Identification of cultivated land as of autumn 2021 based on remote sensing data
- Identification of cultivated and uncultivated agricultural land as of May-June 2023
- Vectorization of the soil cover map and identification of exclusively valuable soils
- Modeling the potential of soils to retain pollutants
- Assessment of soil erosion risk and risk of pollutant migration with surface runoff
- Identification of localities with potential geomorphological hazards

### Step 2: Field studies
- Ecological and soil studies including description of the morphological features of the bomburbation
- Field instrumental measurements: pH, mV, soil density, colour (Munsell scale)
- Sampling for geochemical and soil studies
- Field geomorphological observations: morphological and morphometric

### Step 3: Data synthesis and processing
- Geochemical analysis: heavy metals, inorganic pollutants content etc.
- Laboratory soil survey: grain-size analysis, organic matter content etc.
- Synthesis and processing remote sensing, field and laboratory data

### Step 4: Economic assessment and recommendations
- Economic assessment of soil loss due to military operations
- Economic assessment of direct and potential crop losses due to military operations
- Developing recommendations for the use and reclamation of damaged agricultural land
Remote sensing data analysis (Kyinska territorial hromada of Chernihiv region)

Steps of the assessment of the soil cover damages due to military operations

Analysis of remote sensing data enabled to:
- Identify craters with a diameter >0.5 m;
- Identify bombturbation and potentially contamination zones;
- Identify with potential soil compaction due to military vehicles tracks;
- Distinguish degree of potential agricultural land contamination.

Additionally the following maps were created:
- The soil map;
- The map of potential geomorphological hazards.

2912 craters were identified.

Study area location

For more info:

The map of identified craters
Analysis of the Kyinska territorial hromada

44.3 ha of bombturbated soil

907.6 ha of potentially compacted soil

386.9 ha of potentially contaminated soil

The bombturbation and the contamination zones*

The potentially compacted soil

The degree of potential agricultural land contamination

*The bombturbation zone is an area around the crater that was directly affected by the blast of an explosive munition, namely redeposition, displacement, compaction and deformation.

The contamination zone is a larger area around the crater that is mostly physically undisturbed, however, contaminated by explosive compounds, shells, and bomb fragments.
The amount of damage and losses caused to lands and soils of Ukraine as of February 24, 2023

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Damage and losses</th>
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<tbody>
<tr>
<td></td>
<td>billion UAH</td>
<td>billion USD</td>
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<td><strong>Losses of the land fund:</strong></td>
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<tr>
<td>Land reclamation costs (according to the estimates of the NSC ISSAR)</td>
<td>171.0</td>
<td>4.672</td>
</tr>
<tr>
<td>Damages caused to the owners (land users) (according to the estimates of KSE)</td>
<td>88.2</td>
<td>2.409</td>
</tr>
<tr>
<td>Costs for the restoration of reclamation areas (according to the estimates of the working group “New Agrarian Policy” of the Plan for the Restoration of Ukraine)</td>
<td>148.0</td>
<td>4.000</td>
</tr>
<tr>
<td><strong>Damage caused to land resources and soils:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Damage caused to soils and land plots as a result of soil pollution and contamination of land plots (according to the calculations of the Operational Headquarters at the State Environmental Inspectorate of Ukraine)</td>
<td>855.0</td>
<td>23.361</td>
</tr>
<tr>
<td><strong>In total</strong></td>
<td>1262.2</td>
<td>34.442</td>
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The amount of damage and losses caused to lands and soils of Kharkiv district, Kharkiv region

Cartogram of the impact of the war on the soil cover of Kharkiv district, Kharkiv region, according to the data of the NSC ISSAR (Baliuk et al., 2022)
Current projects on the survey and restoration of the war-affected Ukrainian soils

1. GLOBAL LEVEL

FAO and World Food Program (WFP) Project on demining and rehabilitation of war-affected agricultural land for small farmers

Project has already started on the territory of the Kharkiv region, (June 2023).

2. EUROPEAN LEVEL

Currently absent

3. NATIONAL LEVEL

Project of the National Research Fund of Ukraine: WAR AND CHORNOZEMS started in August 2023.

Project Goal: Assessment of the impact of armed aggression on the state of black soils and the development of measures for the accelerated restoration of soil fertility for food security ensuring.
Some perspective European soil survey and restoration projects for war-affected Ukrainian soils

- Creation in Ukraine of several Living Labs for support of soil health rehabilitation technology implementation for war-damage land plots
- European support of Ukrainian infrastructure development to accelerate and improve the quality of field survey and analytical work with war-affected contaminated/degraded soils
- International support of the reparations system for the compensation of damage and losses caused to the Ukrainian land and soil resources as a result of the armed aggression of the Russian federation
- Support of creation in Ukraine of an effective system of modern monitoring of the soil cover
- Implementation of pilot projects for practical rehabilitation of war-damaged soil cover in different region
- Preparing and implementation of the “Marshall Plan” for the large scale post-war restoration of Ukrainian soil
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