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## ASSESSMENT OF THE ENVIRONMENTAL STATE OF UKRAINIAN SOILS: IMPACT OF RUSSIA'S WAR AGAINST UKRAINE ON THE QUALITY OF THE SOIL ENVIRONMENT AND WAYS OF ITS RESTORATION

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Ukraine is a country with extraordinary opportunities. The soil's uniqueness allows the agricultural sector to develop and make it competitive. The country has a huge potential to become a world leader in the agricultural industry and to be number one in the sales of some goods.

For several decades now, the Ukrainian agro-industrial complex has held a leading position among the world's exporters. Thus, in 2021, 40% of the country's total exports were agricultural products. Which, in turn, occupies 15% of the structure of Ukraine's GDP [1].

The soil cover of Ukraine is predominantly chernozem in nature - among the agricultural lands, the share of chernozems and similar chernozem-like soils is 71%. The share of Ukrainian chernozems among European ones is 30%, and 9% of world ones (Figure 1).

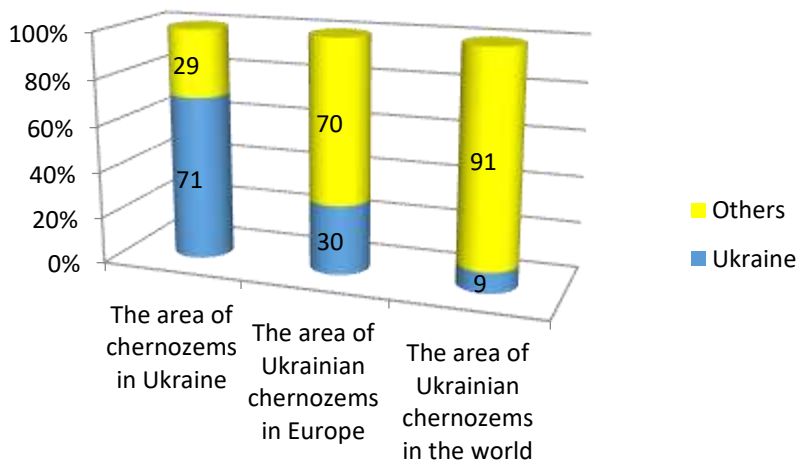


Figure 1 – Share of Ukrainian soils in different parts of the world, % (created by the author)

Since the beginning of the war, the situation has changed significantly. The war not only stopped the process of agriculture but also made it impossible for several years ahead. The consequences were that in 2022, about 8.5 thousand hectares of land were not sown and more than 12 thousand hectares came under hostilities.

As you know, before the start of the war, Ukrainian soils were not in the best condition. For more than 3 decades, independent Ukraine has been one of the main exporters of agricultural products and therefore has to satisfy a huge demand. Because of this, genetically modified products, pesticides and other chemicals began to be used [2].

The anthropogenic and man-made impact on the environment constantly increased and reached critical values, affecting soil cover degradation. As a result, problems with soil's physical and chemical properties began. Areas of land polluted by atmospheric emissions and sewage, chemicals and radionuclides are also growing.

There is a strong possibility that by 2030 the use of chemicals will increase dramatically, and it will be one of the biggest threats to the environment and human health in the coming decades [3].

But with the beginning of the war, the situation became even worse. As a result of military operations, forest areas were destroyed, and more than 200,000 hectares of territory were filled with shells, mines and ammunition fragments. The so-called ecocide began.

As of November 2022, as a result of the aggression of the Russian Federation, 291,826,950 m<sup>2</sup> of Ukrainian land was polluted, and 8,099,793,440 m<sup>2</sup> of soil was littered. The amount of damage is 488.9 billion hryvnias.

Since the start of the full-scale invasion, environmental damage from the war has amounted to 38 billion euros [4].

Ukrainian land has been turned into a terrible testing ground for various weapons, such as phosphorus bombs and rockets. The destruction of the upper fertile layer of the earth, which has been formed for centuries, occurs due to missiles, projectiles of all kinds, aerial bombs, drones, «vacuum» bombs, etc. And although over the past 100 years, the soil lost about 30% of the humus, the war accelerated this process many times. The land has lost its fertility.

As a result of the explosion of a projectile of any type, many toxic compounds fall into the soil. According to the experts of the Ecodia NGO, carbon monoxide, carbon dioxide, water vapor, nitrous oxide, nitrogen dioxide, formaldehyde, cyanic acid vapors, nitrogen, as well as a large amount of toxic organics are formed during the explosion of rockets.

According to Anastasia Sploditel, an expert in geomorphology, increased content of copper, nickel, lead, phosphorus and barium was recorded at the shelling site. Such soil results in the impossibility of growing products for a long time. An

example is the events of the First World War. After 1918, the cultivated land area in Europe decreased by 22.6%.

One of the dangerous consequences of the penetration of ammunition into the ground is the presence of heavy metals. In war zones, they can exceed background values by 30 times [5].

More than 80,000 square kilometers of the territories of Ukraine need to be cleared of mines and explosive objects. According to UN estimates, it will take approximately five to seven years to clear the territory of Ukraine using the latest satellite mine identification system. After World War II, it took Poland about 12 years to demine its territory [6].

Based on all the above-mentioned concepts, the following ways of solving the environmental crisis were developed and proposed:

- Zero soil treatment. This method eliminates the need to plow the soil or use any heavy agricultural machinery. No-tillage also improves the rate of carbon uptake by the soil. Overall, this green method of farming helps reduce the amount of greenhouse gases entering the atmosphere while simultaneously reducing costs for farmers.

- Organic agriculture. Organic farming is the process of using environmentally friendly farming methods to improve soil and human health. This method has a lower need for fertilizers and pesticides, the production of which requires a lot of fossil fuels. Instead, he uses crop rotation and compost to control pests, weeds and diseases. Using organic technologies mitigates the effects of global warming by sequestering carbon in the soil.

- Vertical agriculture. Vertical farming is the process of growing crops in vertically laid layers rather than traditional horizontal farming. It means that farmers can grow much more food on the same amount of land. Another significant advantage is that large areas of agricultural land have become unsuitable for growing crops due to armed aggression. Therefore, in this context, the application of vertical agriculture can compensate for the need for planting areas due to vertically laid layers [7].

- Hydroponics and aquaponics. These innovative farming methods involve growing plants without soil and feeding the plants with special nutrients that are added to the water.

- Crop rotation is based on the cultivation of a number of different types of crops on the same territory during successive seasons. It is one of the most effective agricultural control strategies used to prevent soil fertility loss. And since Ukrainian is exhausted by the perennial planting of sunflowers, this method will come in handy [8].

Therefore, with the beginning of the full-scale invasion of Russia into Ukraine, the losses of the agricultural sector are estimated at 40 billion dollars. The USA is suffering not only from destroyed warehouses and blocked sea routes, but

also indirect losses from soil pollution and burned forests. It should also be taken into account that the lands mined and contaminated with explosive substances, which are no longer suitable for growing crops, which make up more than 200,000 m<sup>2</sup> of land.

In connection with hostilities, the country's soils have suffered significant losses, and the only salvation for Ukraine may be the introduction of green technologies into the agricultural complex: vertical agriculture, hydroponics and aquaponics, organic farming, and crop rotation[9-28]. Implementing and applying these technologies will help restore land and make production more efficient.

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