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Short Title: Agricultural and military transformation of the chernozem and its reclamation

RESEARCH ARTICLE

Agricultural and military transformation of the chernozem and its reclamation

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Abstract

Under conditions of intensive anthropogenic impact caused by developed industry, agriculture, and military actions, the problem of chernozem degradation has become particularly relevant. Changes in the morphogenetic characteristics, chemical composition, and physico-chemical properties of the soil require a detailed analysis to develop effective reclamation strategies. The aim of this study was to assess the extent of chernozem degradation under the influence of artillery shelling and agricultural use and to evaluate the possibilities for its reclamation. The methods included field studies, soil sampling in the Bakhmut and Siversk regions, agrochemical analysis according to the methodology of Balyuk and Yatsuk, determination of physico-chemical properties, and assessment of heavy metal content using ICP-MS spectrometry. The results demonstrated significant changes in humus content, macro- and microelement composition. The crater formed by a 152-mm artillery shell explosion was characterised by a catastrophic decline in humus content (0.65% compared to 4.27% in arable land and 5.16% in virgin soil). An increase in pH to 8.44, a 8.9-fold rise in mobile sulphur concentration, and a sharp increase in heavy metal content were observed. Particularly critical was the arsenic content, exceeding the Maximum Permissible Concentration (MPC) by 5.7 times, indicating severe military-technogenic contamination. Additionally, local depletion of nitrate nitrogen, potassium, and magnesium in the explosion zone was recorded, significantly reducing the soil's fertility potential. The conclusions confirm that military actions cause severe disruptions in agroecosystems. Effective land reclamation should involve a phased restoration of soil structure through green manuring, organic fertilisation, and the implementation of adaptive land-use systems.

Keywords: Soil degradation, Heavy metals, Explosive impact, Fertility restoration, Environmental safety

Introduction

Farmers for forty centuries, and agricultural science for three or more, have known that humus is fundamental to soil fertility (King., 1911; Wallerius and Gyllenburg., 1761; Thaer., 1809-12; Liebig., 1859). Nowhere more so than on the steppes, where the black earth boasts a humus horizon up to a metre thick with a natural humus content of up to 12 per cent. But more than a century under the plough has burned off two thirds of that humus (Lal., 2004) and now, not for the first time, the steppes are a battlefield and the soil is a casualty (Dmytruk et al., 2023).

Here we examine the extent of these human impacts on the black earth: its morphology, ecology, chemical and physical properties, and composition in particular, its pollution with heavy metals that impair the growth and development of crops and public health. And we propose a plan to reclaim the land.

Material and Method

The object of the study is the medium-humus, thick chernozem of the Bakhmut and Siver communities of the, studied according to the methodology of Balyuk & Yatsuk (Baliuk and Yatsuk., 2018). Elemental analysis of soil samples under No. 0702-24-S was carried out at VSP Institute of Plant Health LLC at UKRAVIT Science Park.

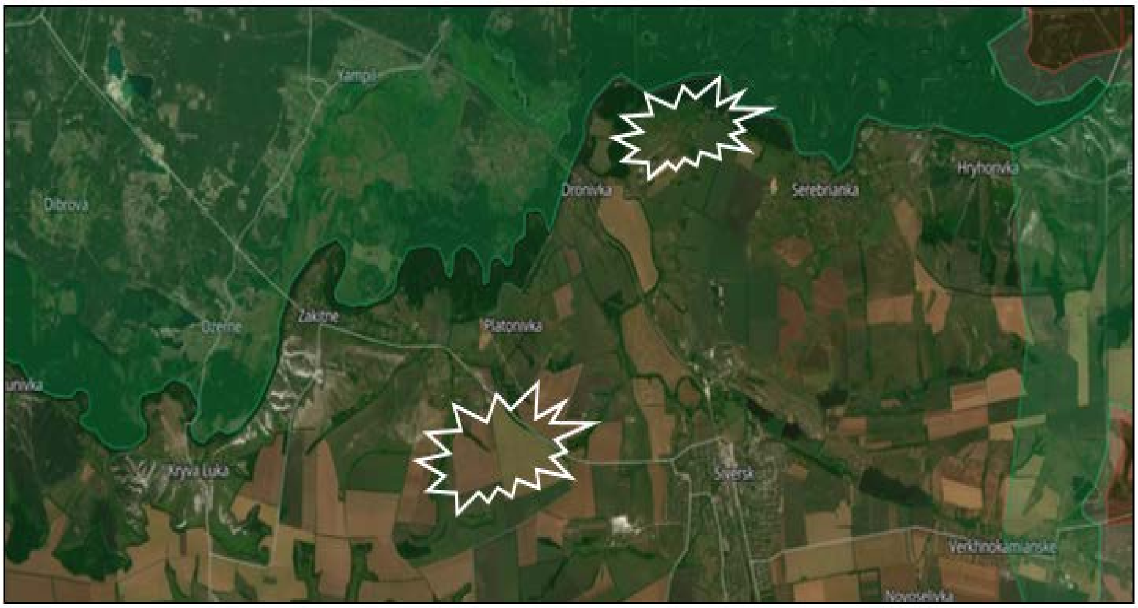

Figure 1. Locations.

Our purpose is to study changes in the properties of ordinary black earth and the content of heavy metals in the 0-40cm layer as affected by:

- explosion of a 152mm artillery shell, in 2024
- arable farming, results of agrochemical analysis for 2020
- control profile under fallow 2020.

Results and discussion

Table 1. Physico-chemical characteristics, 0-40cm layer.

Units of measurement		Variants		
		I	II	III
Humus content, %		0.65 ± 0.05	4.27 ± 0.41	5.16 ± 0.17
	easily hydrolysed	14.02 ± 3.05	Not determined	114.83 ± 5.58
Content of nitrogenous compounds, mg/kg	nitrate	2.51 ± 0.75	8.46 ± 0.88	4.25 ± 2.23
	ammonium	1.14 ± 0.33	Not determined	Not determined
Mobile phosphorus, mg/kg		9.27 ± 2.11	14.46 ± 8.91	8.71 ± 3.37
Exchangeable potassium, mg/kg		121.06 ± 19.02	241.67 ± 24.17	165.14 ± 13.08
Soil reaction (pH - H_20)		8.44 ± 0.12	7.16 ± 0.38	6.77 ± 0.16
Cation exchange capacity, mmol/100 g		29.53 ± 2.27	37.43 ± 1.46	32.17 ± 1.06
Mobile sulphur, mgS/kg		81.91 ± 13.54	9.23 ± 5.84	7.38 ± 0.82

	B	0.88 ± 0.29	1.83 ± 0.86	0.27 ± 0.11
	Fe	3.81 ± 1.05	84.31 ± 21.58	Not determined
Microelements, mg/kg	Mn	8.82 ± 2.03	57.33 ± 13.86	34.26 ± 5.71
	Cu	0.13 ± 0.06	1.67 ± 0.44	1.17 ± 0.18
	Zn	0.44 ± 0.16	1.28 ± 0.35	0.56 ± 0.14

Humus and macro-elements

Unsurprisingly, the most important indicator of soil fertility – humus – differed significantly in the shell crater compared with the entire soil profiles: 0.65% compared with 4.27% in the arable topsoil and 5.16% under fallow; compared with the control, the humus content was less by 17% under arable but less by 87% in the crater (Fig. 2, 3) – blown up along with every living thing.

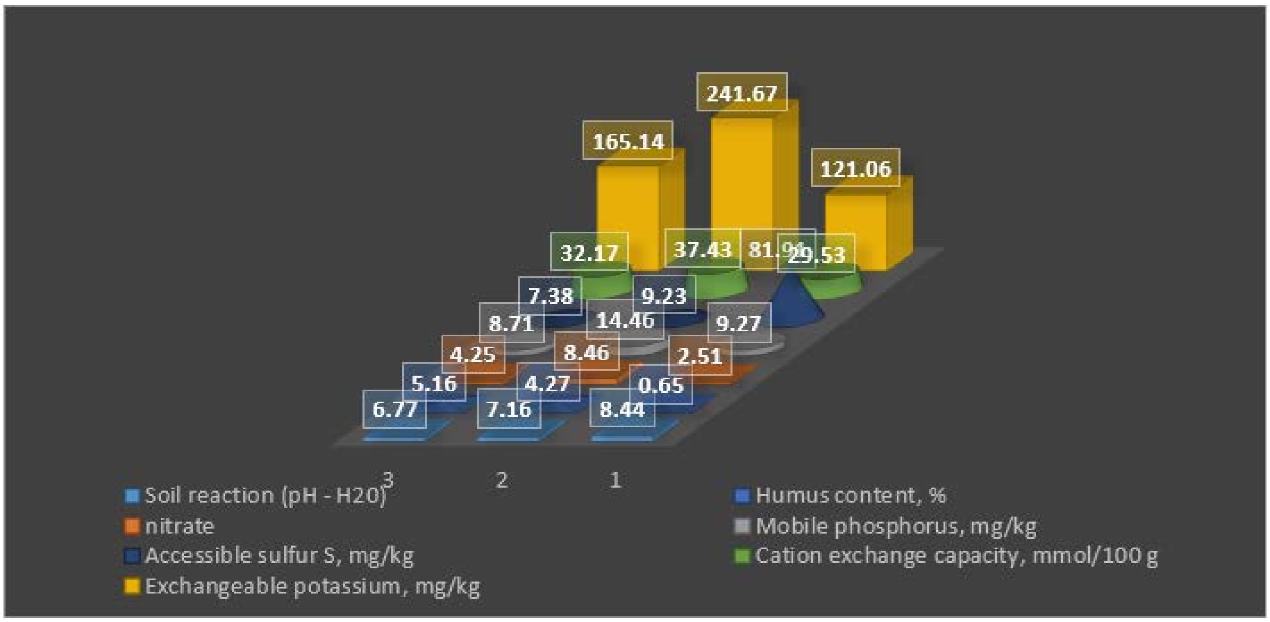

Figure 2. **Characterization of macro-elements.**

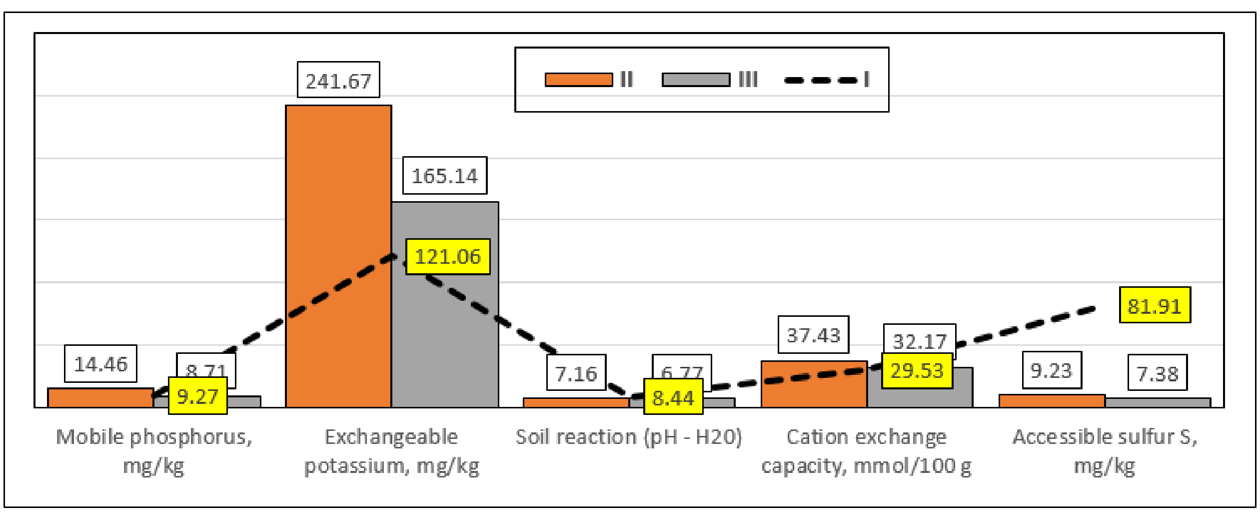

Figure 4. **Comparative edaphic case study locations.**

Accordingly, there was a parallel decrease in the content of nitrogenous compounds; nitrates in variant I amounted to 2.51mg/kg and, in variants II and III, 8.46 and 4.25mg/kg, respectively. Mobile phosphorus was at similar levels in all three: 8.71-14.46mg/kg. Exchangeable potassium much lower in I: 121mg/kg as against 242 mg/kg and 165 mg/kg in variants II and III. ph water increased from 6.77 to 8.44 as a result of the explosion and the content of mobile sulphur was 9.2 mg/kg and 7.4 mg/kg in variant II and in the control, respectively, but 81.9mg/kg in the crater an increase of an order of magnitude.

Heavy metals

Continually increasing levels of toxic heavy metals and arsenic in soils, in arable soils in particular, has been a characteristic of the Anthropocene. Tab. 2 and Fig.4 present the data for our small sample.

Table 2. **Content of heavy metals in soil samples (0-40cm layer) MPC, maximum permissible concentration.**

Indicator, units of measurement		Variant I	II	III
Cadmium, mg/kg	gross content	0.55 ± 0.19	0.36 ± 0.13	0.31 ± 0.11
	MPC	3		
Arsenic, mg/kg	gross content	11.41 ± 2.53	0.58 ± 0.07	0.26 ± 0.03
	MPC	2		
Nickel, mg/kg	gross content	38.13 ± 7.02	11.92 ± 0.15	10.14 ± 0.17
	MPC	50		
Mercury, mg/kg	gross content	0.17 ± 0.07	0.03 ± 0.002	0.02 ± 0.001
	MPC	2.1		
Lead, mg/kg	gross content	19.01 ± 3.91	1.42 ± 0.82	0.93 ± 0.11
	MPC	32		
Chromium, mg/kg	gross content	48.7 ± 8.71	18.11 ± 1.06	17.07 ± 1.08
	MPC	100		

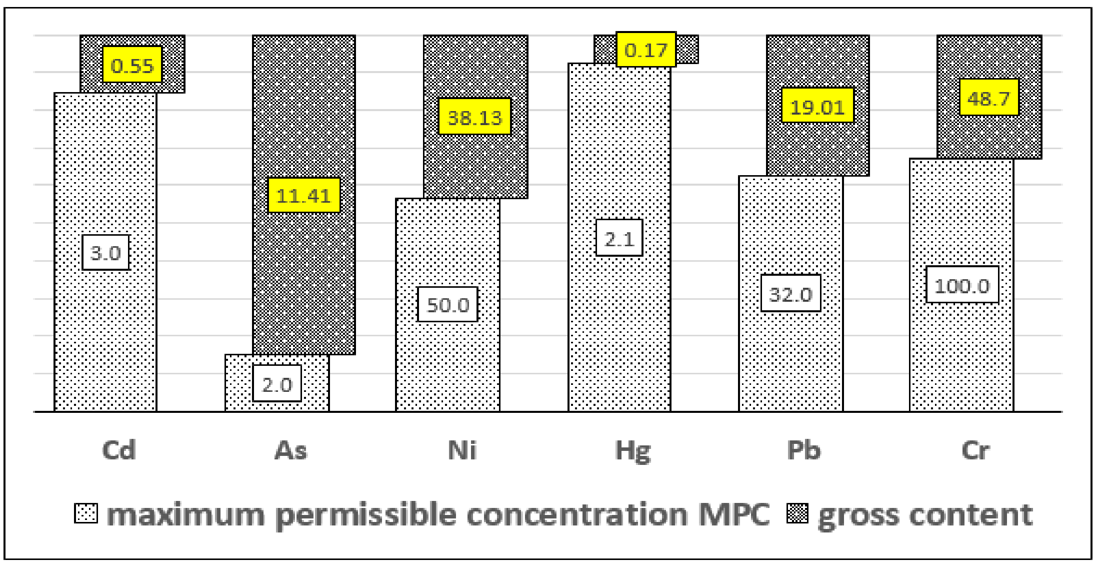

Figure 4. **Correlation between gross content and MPC heavy metals in variant I.**

They indicate exceedance of the maximum permissible concentration (MPC) of arsenic; its concentration coefficient was 5.7, and a high levels of nickel, lead and chromium resulting from a single 152mm artillery shell giving concentration coefficients of: As (5.7) > Ni (0.8)) > Pb (0.6) > Cr (0.5) > Cd (0.2) > Hg (0.1).

These data strongly suggest that the exceedance of the MPC for arsenic in the studied soils was caused by the detonation of the shell. Significantly, Biyashev et al. (Biyashev et al., 2024), drawing on substantial sampling across the combat zone, report concentrations of iron, zinc, cadmium, lead and copper exceeding MPC by 1.5 to 3-fold; and concentrations of barium, nickel, arsenic and phosphorus exceeding MPC by about 4-fold as a result of detonation of munitions and inherited pollution by heavy industry. This pollution affects not only technogenic but, also, biogenic territories. Heavy metals accumulate soils and vegetation and enter the metabolic cycles of living organisms, forming toxic, carcinogenic, organometallic compounds.

What to do about it?

Unfortunately, to survive the Russian assault, we have to resist with artillery of our own. Then, facing a cratered and polluted landscape, we need to level it and restore the soils.

The black earth was created by grassland and earthworms. Therefore, we propose a national program of land reclamation, as demonstrated by Professors Uzbek and Kharytonov (Uzbek et al., 1975; Kharytonov et al., 2018; Mytsyk, et al., 2024; Shevchenko et al., 2024) simply by growing crops [Mytsyk, et al., 2024] but accelerated by a national program of filling the craters with sewage sludge – that will replace the humus, feed the worms, solve several problems at once – and we shall have the last laugh.

Conclusions

Quinoa is a promising crop based on organic crop production technologies, which in turn involves the active use of biological mechanisms to increase its productivity. The most relevant areas of biologisation are the use of symbiotic relationships to increase the level of adaptability, quantity and quality of the crop. Despite its long history, modern quinoa crop has virtually no technologies using biological products. The possibilities of practical use of the identified symbiotic relationships of quinoa with many species of bacteria and fungi remain poorly understood. Future research should focus on the genetic basis and mechanisms involved in the study of the relationship between quinoa resistance to abiotic stress and plant chemical composition. This additional information will allow breeders to develop new varieties that are widely adapted to different environmental conditions and, in turn, will contribute to the global spread of quinoa.

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