РОССИЙСКАЯ АКАДЕМИЯ НАУК
ФГБНУ «ВСЕРОССИЙСКИЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ АГРОХИМИИ ИМЕНИ Д.Н. ПРЯНИШНИКОВА»

Главные редакторы: Виктор Г. Сычёв и Лотар Мюллер

НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

Том I Ландшафты в XXI веке: анализ состояния, основные процессы и концепции исследований

В содружестве с Академией почвенного плодородия Митчерлиха (МИТАК), Паулиненауэ, Германия

Москва 2018

RUSSIAN ACADEMY OF SCIENCES
FSBSI «ALL-RUSSIAN RESEARCH INSTITUTE OF AGROCHEMISTRY
NAMED AFTER D.N. PRYANISHNIKOV»

Main editors: Viktor G. Sychev and Lothar Mueller

NOVEL METHODS AND RESULTS OF LANDSCAPE RESEARCH IN EUROPE, CENTRAL ASIA AND SIBERIA

Monograph in 5 Volumes

Vol. I Landscapes in the 21th Century: Status Analyses, Basic Processes and Research Concepts

With friendly support of the Mitscherlich Academy for Soil Fertility (MITAK), Paulinenaue, Germany

Moscow 2018

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Chapter I/10: SOILS AS WITNESSES OF WARS: AN OVERWIEV AND FURTHER RESEARCH NEEDS

Глава I/10: Почвы как свидетели войны: обзор и дальнейшие исследования

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DOI 10.25680/9680.2018.48.98.010
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ABSTRACT. Wars and the military use of landscapes have influenced and changed the soils at all times to varying extents. World War I (WWI) at the latest indicates the beginning of the age of „technical warfare". Technical warfare has led and leads to severe impacts on the landscape and therefore on the soils. For a long time the legacies of these military and warfare activities were primarily a realm of archaeologists and historians. But activities use like digging field fortifications, the impact of explosives or chemical and radio-nuclear contamination lead to non-reversible changes of soils. Such war-influenced soils can therefore be classified as archive soils, which can be used to illustrate the catastrophic impact of mankind to human civilisations and to soils. From the authors´ point of view there is a strong need for more research into these often „forgotten" influence factor on soils, which affected landscapes especially in Europe and Asia at a scale of tens to hundreds, in some places of up to many thousand square kilometers.

Резюме. После войн, а также после изпользования местности в военных целях, почвы различаются по степени деструкции и изменения почвенных горизонтов. Начиная с Первой мировой войны, хронологически возрастающие «Технические войны» оказали сильное воздействие на ландшафт и, следовательно, на почву. Долгое время наследие всех военных действий было, прежде всего, сферой исследований археологов и историков. Но такие виды деятельности, как строительство полевых укреплений, воздействие взрывчатых веществ или химическое и радиоактивное загрязнение, приводят к необратимым изменениям почв. Поэтому такие почвы, подверженные влиянию войны, могут быть классифицированы как архивные почвы, и которые могут быть использованы для иллюстрации катастрофического воздействия человечества и цивилизации на почвы. С точки зрения авторов, существует настоятельная потребность в более широком изучении этого часто забываемого фактора воздействия на почву, который затрагивает ландшафты, особенно в Европе и Азии, в масштабах от десятков до сотен, в некоторых местах до многих тысяч квадратных километров.

KEYWORDS: Anthrosol, archive soil, bombturbation, impact on soils, soil destruction, soil regeneration, soil awareness, war influenced soils
Ключевые слова: Антропозоль, архивная почва, бомботурбатия почв, воздействие на почву, разрушение почвы, почвообразование, почвенная осведомленность, влияние войны на почвы

INTRODUCTION

Soils are significant parts of landscapes, which can influence battles and warfares in a crucial way [1]. But struggles and wars in history also influenced and changed the soils themselves on the battlefields as well as in the hinterland. Especially with beginning of the age of "technical warfares", which at the latest began with WWI, large-scale and long-term transformations of natural soil-landscapes occured [2]. These soils are not only a "matrix" in which archaeologists find war related artifacts, but soils are also an independent geoscientific and pedological archive with a very long memory. The investigation and understanding of the effects of war and also military use to soils can lead to an increased awareness of the drastic impact of these (from a pedological point of view) very short events on soils, which usually have developed over centuries or thousands of years. Furthermore investigating such war influenced soils allows an evaluation of the temporal dimensions of regeneration and new soil-formation processes in post-war times. Fossilized horizons buried beneath ejected soil-material function as a precise time-marker and allow the differentiation of soil properties between pre- and post-war developed soils [3]. Against this background the following article

i) will give an overview of the manifold impacts of warfare and military use including their long-term effects on soils and landscapes with the focus on the Eurasian continent,

ii) will show research needs especially concerning the "ground-truth" pedological description and analysis of war-influenced soils and

iii) wants to raise awareness of war influenced soils, which quite frequently are the last remaining visible witnesses of war-history.

IMPACTS AND INDUCED EFFECTS ON SOILS CAUSED BY WARFARE AND MILITARY USE

Overviews on the impacts of warfare and military use on nature and environment in general are given by Machlis & Hanson, 2008 [4] and Lawrence et al., 2015 [5]. Certini et al. 2013 [6], also Steinweg & Kerth, 2013 [2] placed the focus on the soil-environment and Zalasiewicz & Zalasiewicz, 2015 [7] pointed out the additional geological dimension of modern wars on the geosphere. In the following subchapters the most important impacts and direct effects of warfare and military use on soils are described and illustrated by examples. It should be noted, that every type of impact usually has various effects on soil, the allocation here has been made by the most significant one.

Change of land-use. At any times wars and conflicts, including military training and armament, resulted in a change of land use. Land consumption up to complete sealing of soils was caused by the construction of military infrastructure (e. g. air strips, protected boarder strips, shooting-ranges), facilities (e. g. barracks, camps, bunkers) or the expansion of arms industry.

In both World wars there were also efforts for an intensified agricultural self-sufficiency of the population in many involved countries. This led to a significant increase of gardening land (Hortisols), in Berlin between 1914 and 1924 the area of garden plots has quadruplet [8]. Also barren land was converted to agriculture, accompanied for example by the drainage of peatland (= degradation of soil) or deep ploughing to enhance the soil fertility. The excessive use of raw material for the strengthened armaments production in some regions led to an exuberant logging of timber or to intensified mining activities with the effect of decreased vegetation covering, so that soil erosion processes were intensified.

But military use and the outcomes of wars can also induce extensification of land use. In some regions of Central-Europe up to 70% of the population perished due to the effects of the Thirty Years´ War (1618-1681), resulting in deserted landscapes. Military training areas, border strips and mine fields are often "no go-areas", so that the absence of agriculture, intensive forestry and other human activities enables undisturbed pedogenesis and renaturation processes, often attended by increased biodiversity [9].

Change and mixing of the naturally developed soil-horizons. Already the roman army has constructed on site field fortifications like entrenchments, walls, ditches, just by digging, relocating and accumulating the in situ soil material. With the beginning of the modern era and the accompanying fundamental changes in battlefield weaponry and tactics these earthworks were getting more enlarged and complex [10]. But the wars in the 20th century manifolded the spatial dimensions of soil disturbance caused by the building of field fortifications. The trench-system of the 750 km long western front in WWI reached a length of around 40.000 km, the German armend forces moved 46 Mio m^3 of soil material [11] – 18-fold more than the volume of the Cheops-Pyramide. Brenot et al., 2017 [12] investigated a WWI battlefield in the Argonne (France) with the result of a displaced sediment volume between 1.000 and 2.000 m^3/ha. More examples for the dimension of these impact type to soils are shown in Table 1.

A second significant physical influence factor on soils is the impact of explosives (bombs and shells). Hupy & Schaetzl (2007) [13] introduced the term "bombturbation", describing the mixing and relocation of soil material to a depth of some meters depth. The morphological changes are accompanied by the destruction of the natural horizontal soil structures down to the C-horizons. Due to WWI an estimated amount of 1,45 Billion of artillery shells and grenades were fired [14], concentrated mainly on an area of some ten thousand square kilometers. To the east of Ypern (West Flanders) the impact crater density can exceed 700 per square kilometer [15], the same magnitude of crater densities described by Kiernan, 2015 [16] in some of his study sites in Laos – here remains from the Indochina war. At the beginning of the "Battle of the Reichswald" (Germany) in February 1945 the attack started with an opening fire of 500.000 artillery shells [17] which destroyed the soils on an estimated area of 5 km^2 within a few hours.

After the war many of the hollow moulds (trenches, craters etc.) were leveled by human activities, which again resulted in mixing processes of soil material. Müggenburg et al., 2014 [18] showed wide spread turbated soils in the region of Hürtgenwald -an area with one of the fiercest battles in WWII within Germany in 1944/45- to a depth of eight decimeters. Furthermore, sectors with soil mixing processes were caused by prisoner of war camps, where soldiers dug burrows to protect themselves against the weather conditions. Also, soldier´s graves and war cemeteries, which can have significant extension in some historical war-landscapes led to wightspread soil turbation.

Fig. 1: Regosol developed at the edge of a bomb crater over 75 years on a layer of a thickness of about 25 cm ejected soil material overlying the buried original top soil (Podzol - Duisburg/Germany).

Chemical alteration, contamination and input of artefacts. Wars and the military use of landscapes caused the input of manifold chemicals and substances into the subsurface. The soils of historical battlefields are a "storehouse" for military artefacts, but also can have different chemical properties due to the increased input of phosphate [10]. In the wars of the 20th century more or less local scale contaminations were caused by the destruction of infrastructure like industrial sites, fuel depots and

arsenals during the war. Additionally the elimination of war remnants in the post war period can lead to the input of harmful substances into the soil [19].
Furthermore, wide spread increased contents of chemical substances in the soils are described for some regions: Souvent & Pirc, 2001[20] found significant enhanced contents of heavy metals like lead, copper and mercury, derived from corroded metal-residues of explosive remnants in the area of the WWI Isonzo-(Soca-)front (Slovenia), which was hard-fought between 1915 and 1918. More examples for wide spread contaminations are listed in table 1. Beside the chemical pollution with a large number of potential substances also radioactive substances were used in form of depleted uranium shells like in the former Yugoslavia or in Iraq [21] – detailed investigations to the extent and long-term environmental consequences are missing to date.
The artefacts from war and military use found in soils include a wide range of objects and materials and range from cannon balls over equipment parts of the soldiers up to the remnants of construction materials for the defensive positions (timber, concrete, barbed wire) to metal from bombs and shells. The first "harvests" of the farmers in Flanders after WWI consisted of brass relicts from the shells; until today every year up to 200 tons of these relicts are "harvested". Shelling and bombing of cities resulted in huge amounts of rubble and debris, which was disposed often at the periphery of the cities. The "Teufelsberg" in Berlin for example, which contains about 25 million m^3 of debris, covers an area of nearly 5 ha. The typical soil type which has developed on the carbonate-containing rubble is a Regosol – with including increased pollutant contents of e.g. lead and PAH originating from the technogenic substrates, which are the parent material of these young soils.
Other types of impacts. Compaction of vulnerable soils can occur due to military vehicle driving, in particular due to tanks with a weight up to 70 metric tons. Strategically planned or collateral caused fires destroyed the vegetation cover as did defoliation actions. This leads to extensive nutrient-leaching and erosion processes, as do deliberately caused floodings e.g. the destruction of dams and dikes. If seawater infiltrates in terrestrial soil-landscapes chemical and redox-system changes start and can alter soil-properties for long times.

Table 1: Wide-spread and long-term soil-alteration in different war areas of the 20th century.

Name / Site and Time	Type of impact considered here	Area of long-term altered soils (km^2)*	Basic Source
Siege of Leningrad, 1941-44	Soil relocation and mixing due to the construction of trenches + anti-tank ditches; often refilled and levelled after war	34	[22]
Voronezh Front, Battle for Kursk, 1943		38	[23]
Westwall, Rhineland, western Germany, 1944/45		95	[24]
West Flanders, 1914-18	Increased copper background concentrations from shells	640	[25]
Kuwait, 1990/91	Contamination with spilled oil	953	[21]
Vietnam, 1955-75	Sprayed herbicides (especially Agent Orange)	26.313	[26]

* partly own calculations on the basis of modern regulations for constructing field fortifications

CONCLUSIONS

1. The presented main types of impacts on soils due to warfare and military use of landscapes had led to wide spread changes of natural soils in many regions of Eurasia.
2. One can conclude that wars left behind a specific soil signature which will exist for centuries or even thousands of years. Typical resulting soil types are Regosols, Anthrosols and Technosols including buried (fossilized) soils with a whole range of unique characteristics and time stamps.
3. Future archaeologists can use the buried „Techno-fossiles" to reconstruct e. g. weapon-technology and strategies of warfare.
4. In contrast to the significance of these impacts, the present research into this war- and military influenced soils is still in an initial stage.

5. Development and establishment of a system of soil description and exploration for typical characteristics of war influenced soils on the national, but also the international level (WRB) is needed.

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