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Original article

The scars of war: A programme for the identification of the environmental effects of Word War II bombings for the purposes of spatial management in the Koźle Basin, Poland

Jan M. Waga, Maria Fajer*, Bartłomiej Szypuła

Institute of Earth Sciences, Faculty of Natural Sciences, University of Silesia in Katowice, 60 Będzińska Str., 41-200 Sosnowiec, Poland
*E–mail address (*corresponding author): maria.fajer@us.edu.pl*
ORCID iD: Jan M. Waga: https://orcid.org/0000-0002-6216-7530; Maria Fajer: https://orcid.org/0000-0002-7179-3998; Bartłomiej Szypuła: https://orcid.org/0000-0002-1466-0128

ABSTRACT

Poland's Koźle Basin contains numerous craters created from the explosions of World War II aerial bombs as well as craters left by unexploded ordnance. The state of the local environment has been severely affected. This situation presents an obstacle to spatial management of the land to this day. This research programme studied the distribution of postmilitary anthropogenic geohazards in the area. It was intended to help to indicate the appropriate courses of action, including in the field of spatial planning, in the areas affected by former bombing. Desk studies focused on photo-interpretive analysis of archival aerial photographs and took advantage of the potential of high-resolution shaded relief rasters created from digital terrain models derived from LiDAR scanning. Field studies used classic geomorphological methods. Studies conducted so far in the bombed areas indicate the necessity of carrying out systematic, anticipatory, accurate surveys of the land and soil surface with the use of geophysical methods. Currently, the traces identified in the field suggest that the amount of unexploded ordnance remaining in the ground is very large.

KEY WORDS: postmilitary anthropogenic geohazards, bomb craters, unexploded bombs, spatial management, LiDAR

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1. Introduction

Reports regarding the neutralisation of post-war explosive devices, including aerial bombs (e.g., HIGGINBOTHAM, 2016; WW2-ERA BOMB..., 2019; GONZALEZ, 2019; MADEJ, 2020), as well as fatalities from unexploded ordnance detonations (ROUTINE DISPOSAL..., 2010; WW2 BOMB BLAST..., 2014) repeatedly find their way into the press all over the world. There have long been efforts to disseminate knowledge about the principles of the operation of aerial bombs and munitions by publishing textbooks (e.g., TARNOWSKI, 1938; COOPER, 1996; HANDBOOK..., 2002; MILITARY MUNITIONS..., 2006) and post-conference materials (e.g. BYRNES, 2009). A number of research articles have been devoted to this issue (e.g. BAUM, 1999; SPYRA & KATZSCH, 2007; FOLEY, 2008; O'NEILL & FERNÁNDEZ, 2008; MAHLING ET AL., 2013; SHEPHERD, 2016; BRENNER ET AL., 2018; BARONE, 2019). The problem of unexploded ordnance (UXO) and unexploded bombs (UXBs) is therefore being taken seriously, although for various reasons, in some parts of the world, the rate of progress in identifying and neutralising them is unsatisfactory.

The problem of air warfare remnants belonging to the group of anthropogenic geohazards from World War II, is not widely known in Poland. It is related to the strategic bombing by the Western Allies of chemical plants, military equipment production plants, and transportation hubs and routes. After the war, this topic was not widely discussed. The remnants of bombardments are not reported in the provisions of land use plans. Today in Poland, the most numerous data concerns the Baltic Sea – port entrances and shipping lanes (Chmieliński, 2017; Madej, 2020).

In an era of widespread access to online databases, this issue is emerging out of the shadows, yet it is treated as an unwelcome truth by numerous groups. Because of the danger involved, however, it cannot be silently passed over. Today, there are opportunities for earlier identification and neutralisation of UXBs. Failure to do so will result in much higher costs for subsequent actions such as: evacuation of persons, securing assets, disrupting production, shutting down infrastructure lines, or repairing damage from ordnance explosions.

In Poland, procedures for handling unexploded ordnance (UXOs) are clearly defined (Rozporządzenie Rady Ministrów..., 2003; Rozporządzenie Ministra Infrastruktury..., 2003; Ustawa..., 2007). At the same time, one can see clear moderation towards taking pre-emptive search actions and these are kept to a minimum. This results in many so-called accidental findings of UXOs, which must then, by law, be handled by the relevant authorities. In the studied Koźle Basin, due to the "saturation" of the area with undetonated, large-size aerial bombs, there are unequivocal reasons to undertake a coordinated, systematic, full-surface reconnaissance survey. Such activities have been carried out in an exemplary manner in Germany for many years (Baufachliche Richtlinien..., 2018; 3.Kampfmittel-fachtagung..., 2019).

The aim of this artcile was to present the first thematic module of a programme undertaken by the authors to identify the environmental effects of World War II aerial bombardment. It includes the study of the morphology and morphometry of bomb craters, analysis of geotechnical changes in soils and the identification of UXB occurrence sites. The perspective of the study of the nature, water and soil environment, and socio-historical and urban studies in militarily transformed areas are also presented.

1.1. Historical sketch of the bombings

During World War II, the Germans were producing liquid fuels from coal due to insufficient oil stores. Three coal hydrogenation plants were constructed in Koźle Basin, then in Germany. In the Koźle Basin, as in Brandenburg and Saxony, there are similar geology (glacial and fluvioglacial sediments) therefore similar solutions to construction were used there.

Germany-controlled oil refineries and synthetic fuel factories became the targets of massive strategic bombings by the Western Allies (Craven & Cate, 1983; Mahoney, 2013). On the present territory of Poland, there are 5 industrial centres that were subject to such bombings in 1944 (Fig. 1). The largest synthetic fuel production area in the Third Reich was located in the Koźle Basin (Ehlers, 2009; Haduch, 2019). It consisted of three chemical plants: in Odertal (Zdzieszowice), Blechhammer (Blachownia Śląska) and Heydebreck (Kędzierzyn) (Fig. 2). The planned production (730,000 t of fuel per year) was not achieved due to technical difficulties and bombing by the 15th U.S. Air Force (Konieczny, 1998; Haduch, 2019). This area is one of the most geo-mechanically deformed by bomb explosions in Europe.

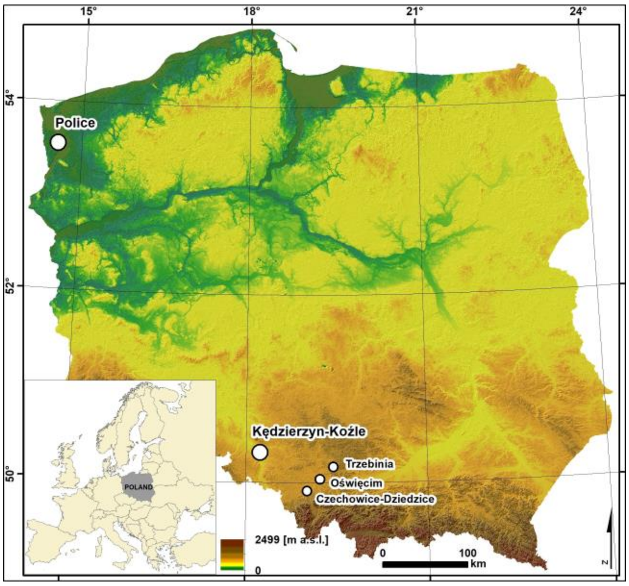

Fig. 1. Location of synthetic fuel plants and oil refineries bombed by the Western Allies during World War II (figure prepared by the authors)

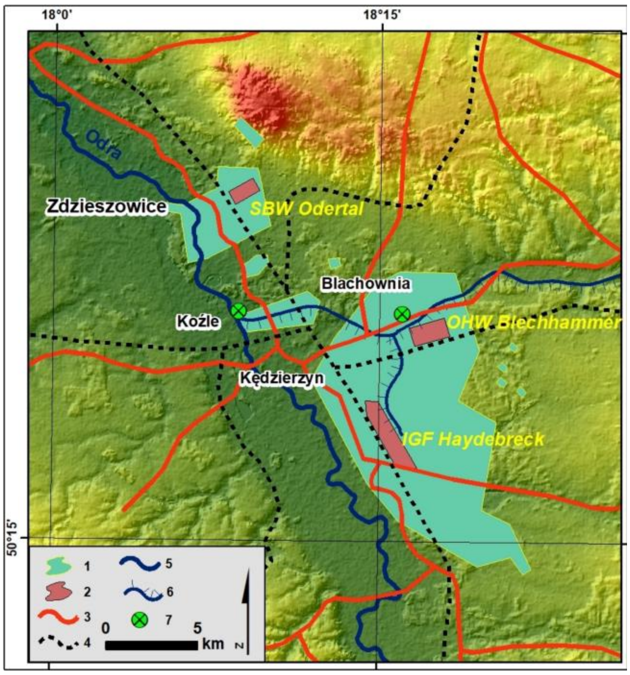

Fig. 2. Location of the study area. 1 – surface bombing areas, 2 – former synthetic fuel plants, 3 – roads, 4 – railroads, 5 – rivers, 6 – canals, 7 – ports (source: Waga et al., 2022b, modified)

Surface bombing of the Koźle Basin was carried out by B17 and B24 bombers between 7.07.1944 and 26.12.1944, dropping almost 40 thousand bombs on an area of approx. 150 km² (KONIECZNY, 1998; WAGA & FAJER, 2021). These were mainly 500 lb and 250 lb demolition bombs as well as general-purpose bombs.

1.2. The socio-economic aspect of the presence of bombed areas

Despite unfavourable conditions, which are the legacy of World War II, one should be aware of the development needs of the Kędzierzyn-Koźle agglomeration – one of the most important economic areas in the Opole region (cf. STRATEGIA ROZWOJU..., 2001; LOKALNA STRATEGIA..., 2016; PORT AZOTY..., 2019; KUBICA ET AL., 2020). This refers to the rational use of land affected by military activities in the past. This also holds true for many cities in other European countries affected by the war (e.g. SHEPHERD, 2016; BARONE, 2019; DOLEJŠ ET AL., 2020).

The problem of war remnants should be treated as a development barrier that must be overcome in a well-considered and systematic way, under conditions of full recognition of geoenvironmental changes, with particular knowledge of the hazards related to UXBs. As shown by German experience (KATZSCH, 2009), the actions taken must involve a survey of the entire bombed area, carried out to considerable depths. The results of the study should inform decisions about spatial development in the area. Due to the high costs involved, such activities can be carried out in stages.

1.3. Characteristics of the problem of bombing remnants

The World War II military actions that disrupted the Koźle Basin geosystem continue to be a source of what is referred to as anthropogenic geohazards. Through technical activities (such as mining and the detonation of buried explosives, among others), humans trigger geodynamic and geochemical processes, often of large size and intensity.

After the end of World War II the insufficient level of the identification of bombing remnants in Poland was determined by the technological barrier in the available means of research and the lack of financial resources and equipment required to extract the UXBs. Some areas were left "to their own devices."

In the Koźle Basin by 1944, after the first air raids of the 15th USAAF, the German administration noted the cases of unexploded ordnance and appointed special military units to neutralise them (KONIECZNY, 1998). Actions to remove unexploded ordnance involved areas with the highest economic and military importance at the time. The large UXOs removal campaigns conducted in the second half of the 1940s and into the 1950s did not include unexploded airborne ordnance buried at greater depths and outside the areas then occupied by the residential, industrial, and transportation infrastructure. The craters in the fields and grasslands were simply backfilled. Unfortunately, the easiest thing to do was to backfill the smaller craters left by UXBs.

Today, bomb craters and craters left by unexploded ordnance have a significant impact on the economy and land use – especially on zoning decisions, the determination of conditions for building structures, the planning of the course and parameters of infrastructure lines, and the management of agriculture and forestry. These impediments are related to the adverse changes of:
(a) – land surface morphology and soil properties caused by explosions and the subsequent achievement of environmental stability,
(b) – presence of undetonated bombs in the ground,
(c) – physical and chemical properties of soils and water bodies in the area with multiple bomb craters.

The problem of the presence of UXBs is the most complicated and dangerous because of the difficulty in determining their location and the potential effects of an explosion.

Changes in the morphology of the area are caused by the formation of numerous, sometimes overlapping depressions, which are flooded by water in the case of areas with lower altitudes (WAGA ET AL., 2021b, 2022a). Adverse changes in ground conditions include an increase in the variability of the area's complex natural geological setting (most of the land there is built up by Quaternary river sediments, including highly waterlogged quicksands). Perforation of the land surface, local compaction, or loosening of sediment cohesiveness by explosions occurring at different depths (HUPY & SCHAETZL, 2006; HUPY & KOEHLER, 2012; ROGER, 2015; MANLEY, 2019) results in complications in structural design and construction, increased construction costs (JEŻ, 2001, 2008), and limits to performance parameters. In the Koźle Basin, especially in areas with shallow groundwater levels, highly intense geodynamic processes were observed in the bomb detonation zones (WAGA & FAJER, 2021).

Many of the technologies for stabilising soil for civil structures involve deep penetration of the soil. This brings up a particularly dangerous aspect of the presence of UXBs and the possibility of encountering an unexploded ordnance during piling, for example. Attempts to distribute ground pressure through the use of slabs are in turn fraught with the danger of accumulating and adversely directing the energy of a possible explosion. Detonation can be triggered by works generating pressure, vibration, shock, as well as sand or gravel mining.

Identification and neutralisation of UXBs, due to the size of the ordnance and most often the considerable depth of their deposition, is particularly difficult. According to post-war estimates conducted in Western European countries, between 10 and 15% of the aerial bombs used were not detonated as intended (Baldoli et al., 2011; Shepherd, 2016; Barone, 2019; Kruse et al., 2019; Dolejš et al., 2020). At least the same average rates are also to be expected in the vicinity of Kędzierzyn-Koźle.

In agriculture and forestry, in addition to relief, soil loading by military-derived substances and substances from damaged industrial installations are significant, resulting in reduced crop yields (Hupy & Schaetzl, 2006, 2008; Bridges et al., 2008; Manley et al., 2019) and the potential for food and feed contamination. These are typically RDX and TNT derivatives, and mainly – carbon-based industrial products.

2. Methods

The authors suggest starting an appropriate programme for the identification of the environmental effects of bombings.

2.1. Research and thematic modules

The research on the remnants of bombing in the Koźle Basin has been divided into three thematic modules, with the following corresponding objectives:

Thematic module I
(1) Determination of the extent, abundance, distribution, morphology, and morphometrics of post-bomb fall and explosion formations.
(2) Determination of the extent of occurrence and nature of geotechnical changes in bombarded soils.
(3) Identification of unexploded ordnance locations and hazard zones from the effects of their potential explosions.

Thematic module II
(4) Determination of changes in soil conditions in the areas with bomb craters, including post-military and industrial substance loads.
(5) Hydrological studies of the craters and their surroundings along with water chemical parameters.
(6) Determination of the biological potential of craters and their local vicinity (biological resources of water bodies in craters, floristic resources in heavily bombarded areas, habitat condition in the crater zone, among others, for potential reintroduction and introduction of species).

Thematic module III
(7) Studies of the historic and urban fabric affected by the bombing.
(8) Verification of existing land use plans in the context of the survey and proposing new functional zones taking into account the staged process of detailed removal, securing and neutralisation of unexploded ordnance.

Activities under thematic module I are currently being implemented, and preliminary results are being presented. Module I addressed the delineation of areas with craters, areas with the geotechnical properties of soils deteriorated by detonations, and the identification of zones and locations of the occurrence of UXBs.

The first step involves a thorough study of crater locations based on archival pre-bombing reconnaissance aerial photos, post-bombing photos taken for the purposes of air raid effectiveness analysis, and post-war photos, as well as contemporary orthophotomaps and DTM-based images. In the second step, the data resources are supplemented with field observations, information from land users, and data from institutions. In the third step, field surveys of selected proving grounds are carried out using methods applied in physiography and geotechnics with appropriate safety measures. The fourth step – a review of UXBs – involves the determination of the number, morphometry and distribution of craters that may indicate the presence of unexploded ordnance (cf. Waga et al., 2022b). These activities are conducted separately for unreclaimed areas and reclaimed areas, according to the scheme presented in Table 1. In the first case, the activities started with the analysis of airborne laser scanning data, further data are treated as auxiliary. Reclaimed areas will be surveyed at a later date.

2.2. Research methodology of module I

There are two directions adopted in the studies on UXB locations and risk zone identification conducted globally:
(1) – based on the analysis of remote sensing and cartographic sources, the theoretical risk level of the possibility of the presence of unexploded ordnance is determined using statistical methods. The greater density of detonated bomb craters involves a higher risk due to the higher potential occurrence of unexploded ordnance.

(2) – active searching for undetonated bombs in bombing zones. First, analyses of aerial photographs from different periods, shaded relief models generated from digital terrain models (DTM), and images obtained using other scanning methods are performed, including advanced automatic and semi-automatic detection of UXOs (MERLER ET AL., 2005; MAHLING, 2013; MAHLING ET AL., 2013; BYHOLM, 2017; BRENNER ET AL., 2018; KRUSE ET AL., 2019). Various algorithms are used to find small craters occurring in the vicinity of large post-explosion craters (BAUFACHLICHE RICHTLINIEN..., 2018). Then, a non-invasive ground survey using geophysical equipment is conducted (O'NEILL & FERNÁNDEZ, 2008; TANG ET AL., 2017; NOTE ET AL., 2019). Electromagnetic technologies, thanks to the range of radiation used, enable distinguishing objects made of metal from, for example, erratic boulders.

Table 1. Algorithm for UXB studies in reclaimed (A-G) and unreclaimed (B-G) areas (source: Waga et al., 2022b, modified)

A	- The analysis of existing materials: -- thematic maps, plans and sketches (e.g. geological and hydrogeological), -- aerial photos from the period before, during and after the bombing, -- archival materials (descriptions, reports, comparisons, press articles, accounts of witnesses and service representatives, e.g. foresters'), -- multimedia recordings, including both video and audio, -- examination of exhibits - Detailed analysis of use of the area and land cover during the bombing
B	- Making shaded relief rasters for different parameters - Remote sensing analysis of shaded relief rasters -- general 1 x 1 m (0.5 x 0.5 m), -- detailed 0.1 x 0.1 m (0.05 x 0.05 m) - Identifying structures belonging to different categories - Identifying potential structures with UXBs - The analysis of the relationship of UXB craters and similar forms with other structures - Preparing materials for field work -- cartographic -- text (instructions)
C	- Examination of geoenvironmental conditions in the field - Verification of forms in the field - research -- location -- surroundings -- morphology and morphometry
D	- Research to find traces of explosions on walls and at the bottom of craters -- geophysical -- geochemical
E	- Mapping and describing the conditions in which craters occur for the purposes of deep geophysical scanning - Field-work planning -- areas of study -- selection of the profiles lines
F	- Conducting deep geophysical scanning down to different depths -- conductometric -- georadar
G	- Drawing up final results, preparing graphic and text materials - Preparing instructions for spatial development

The resulting data are overlaid on the land use plan drawing. For particularly sensitive spots and conflict zones, decisions can already be made during this phase regarding the ad hoc treatment of bombing remnants, including the extraction of unexploded ordnance and the current land use. This opens the possibility of making more complex final decisions. Both approaches also use data from archives.

The authors chose the second course of action. In the first phase, archival materials were analysed, including aerial photographs from the period of the air campaign. The next step was checking high-resolution elevation data in * .las format. This format is a file format designed for the interchange and archiving of LiDAR point cloud data. It is an open, binary format specified by the American Society for Photogrammetry and Remote Sensing (ASPRS, 2008). The *.las file contains a number of fields for each point that can be useful for analysis and display (i.e. x, y coordinates in a given specific coordinate system, z as the elevation, surface classification). For the study area, these data files had a resolution of a minimum 12 points/m^2, with a mean vertical accuracy of < 0.1 m.

In many exposed places, the actual point cloud density was much higher than 12 points/m^2 (even several dozen points). Based on this, we decided to generate a digital terrain model (DEM) with very high resolution (0.1 m x 0.1 m), enabling precise analysis of such small (few to ten meters in diameter) forms of bomb craters. On the base DEM we derived rasters of the shaded relief with standard illumination settings (azimuth 315°, altitude 45°).

The resources prepared in this manner enabled a study of the distribution and morphology of craters throughout the study area and detailed analyses conducted on four proving grounds with a total area of approx. 130 ha, located on wastelands or land used extensively as forests. The method selected by the authors yielded best results in areas where no advanced reclamation work had been previously carried out. In these areas, clearly visible forms were preserved, including UXB markers (Fig. 3). The application of this method will greatly facilitate the planning of further studies, including geophysical surveys (WAGA ET AL., 2021a).

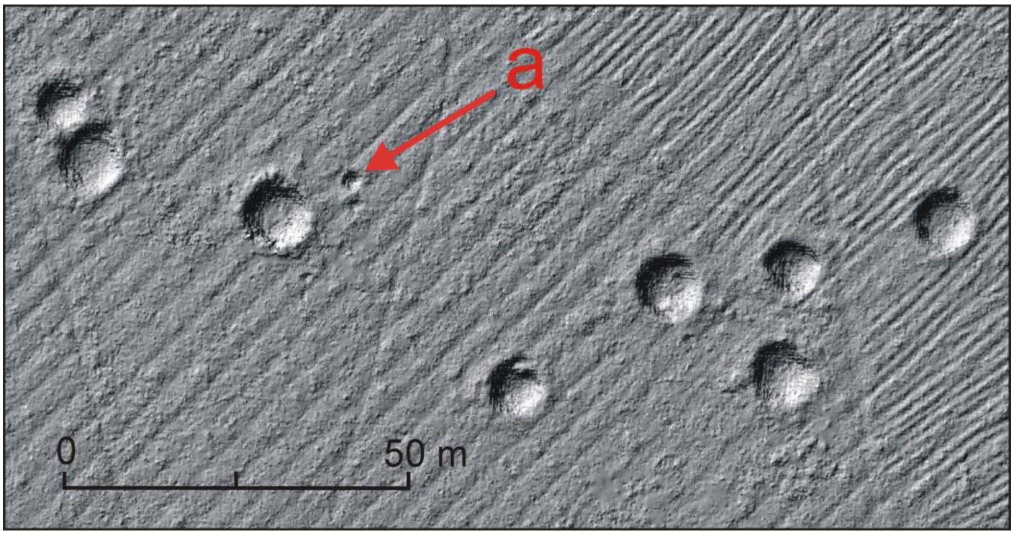

Fig. 3. Crater caused by UXB (a) between craters from bomb explosions (figure prepared by the authors)

The studies also comprised the necessary analysis of contents of thematic maps at the scale of 1:50000: geological, sozological (i.e. environmental map), hydrographic and soil maps as well as information from the Geological Database of the Polish Geological Institute. Mission data and publications of the Air Force Historical Research Agency https://www.afhra.af.mil, National Archives https://www.archives.gov, National Collection of Aerial Photography in Edinburgh, https://www.historicenvironment.scot/archives-and-research/archives-and-collections/national-collection-of-aerial-photography/ and The Fifteenth Air Force https://15thaf.org as well as memoirs and other materials collected by the BLECHHAMMER – 1944 Association provided important sources of information.

After the identification of the distribution of craters based on remote sensing analyses, field observations were undertaken. Zones of major disturbance of original soil properties due to explosions were mapped in order to conduct geotechnical investigations.

It is particularly important and difficult to study the locations of UXBs due to their often significant depth of deposition. In Brandenburg and Saxony, with geoenvironmental conditions similar to those of the Kędzierzyn area, UXBs were deposited at depths of 1–7.25 m (KATZSCH 2009). According to the author of the study, the complex process of analysis of the remote sensing materials, together with surface and ground surveys resulted in finding 32-70% of all UXBs, relative to all objects found in various parts of Germany.

3. Results and discussion

Nearly 6,000 craters left by aerial bomb explosions were recognized in the Koźle Basin on the digital terrain model with a resolution of 1 m x 1 m. These included large explosion craters 8–14 m in diameter and up to 3.0 m in depth, smaller ones 5–9 m in diameter and up to 1.5 m in depth, and small hollows indicating the presence of undetonated bombs. In dry areas, these craters have a diameter up to 3 m and a depth up to 1 m, and in marshy areas, they have a diameter up to 4 m and are slightly shallower (WAGA ET AL., 2022a, b). Numerous comparable examples related to combat actions were presented by PASSMORE & CAPPS-TUNWELL (2020).

These craters are often found in higher concentrations in forests and marshes, and sometimes on now abandoned but formerly used plots of land. Some of the arable fields and meadows have become wasteland or afforested.

Many more craters have been backfilled. One of the most densely bombarded areas has survived almost intact in the vicinity of the Zakłady Azotowe Kędzierzyn S.A. chemical plant in Kędzierzyn-Koźle (Fig. 4 & 5A). The hit rate of large bombs there reached 77 craters per hectare and is one of the highest in Europe (vide PASSMORE ET AL., 2020). In the area, numerous bombs fell within the outlines of older craters. In flooded forms, an attempt was made to recreate the complex sequences of explosions (WAGA ET AL., 2021b, 2022a). Being very difficult to use, this area could become an object of research and a wartime historical monument.

More than 800 aerial bomb explosion craters left by 250 and 500 lb bombs have already been accurately identified at selected proving grounds (Fig. 5). Well over one hundred smaller hollows suggesting the presence of undetonated bombs were also located. The authors' research has shown that in one formerly heavily waterlogged area, out of eight 500 lb bombs dropped from one of the USAAF machines, only 1 exploded.

As the fifth step, ground surveys and geophysical searches for the UXBs will be conducted, following an appropriate safety regime, in selected test zones located within areas with various geoenvironmental conditions.

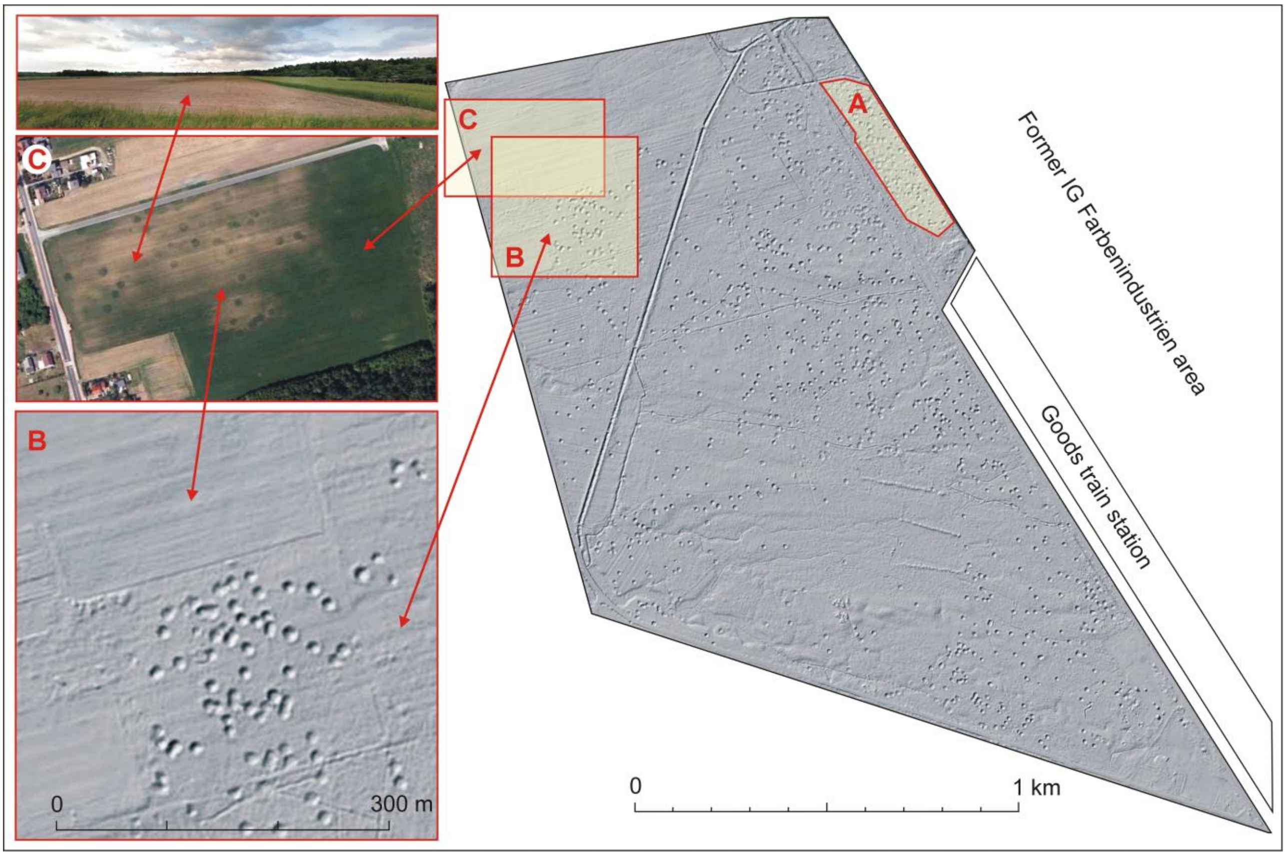

Fig. 4. Contemporary shaded terrain models and orthophotomap of one of the bombed areas in Kędzierzyn-Koźle (prepared by J.M. Waga, maps available from polska.e-mapa.net). A – area with the highest density of craters up to 77 per ha, B – concentration of craters, C – outlines of backfilled craters highlighted by varying vegetation

This will form the basis for preparing the next stages of the programme, which will consist of performing detailed field surveys for areas of interest, according to a key agreed upon with local authorities, land managers, and spatial planning offices. A review of the methods and obtained results will be conducted at each stage of the programme.

From the commencement of the works, particular emphasis was placed on the greatest threat related to bombing remnants – UXBs. Throughout the Koźle Basin, unexploded ordnance should be precisely located, a detailed identification and hazard assessment should be conducted, buffer zones should be delineated, and the land use should be adjusted to the diagnosed situation. In the event that the works of an explosive ordnance disposal team is required, extreme caution will need to be exercised, due in part to the potential presence of multiple other UXOs in the vicinity. They are at risk of detonation by the occurrence of impulse pressure during the explosion of the first ordnance (LIU ET AL., 2019). The study area is largely swampy and is composed of waterlogged clastic (quicksand) formations. Such environmental conditions greatly hinder the efforts to neutralise unexploded ordnance, primarily due to the fact that they require prior drainage of groundwater from an environment constituting an abundant aquifer. Teams working at similar sites in Germany have very extensive experience in the identification and neutralisation of unexploded bombs, as well as in cooperation with local authorities and the public (see: poster informing the public about the works carried out to identify and neutralise UXB, titled „BOMBEN IN ORANIENBURG 1945-2016“, source: https://www.oranienburg-erleben.de/oranienburg/das-ist-oranienburg/800-jahr-feier-2016/ open-air-ausstellung and ELKE ERTLE, 2013; HIGGINBOTHAM, 2016; 3.KAMPFMITTELFACHTAGUNG..., 2019; KAMPFMITTELBESEITIGUNG). Therefore, their expertise and advanced technologies should be applied.

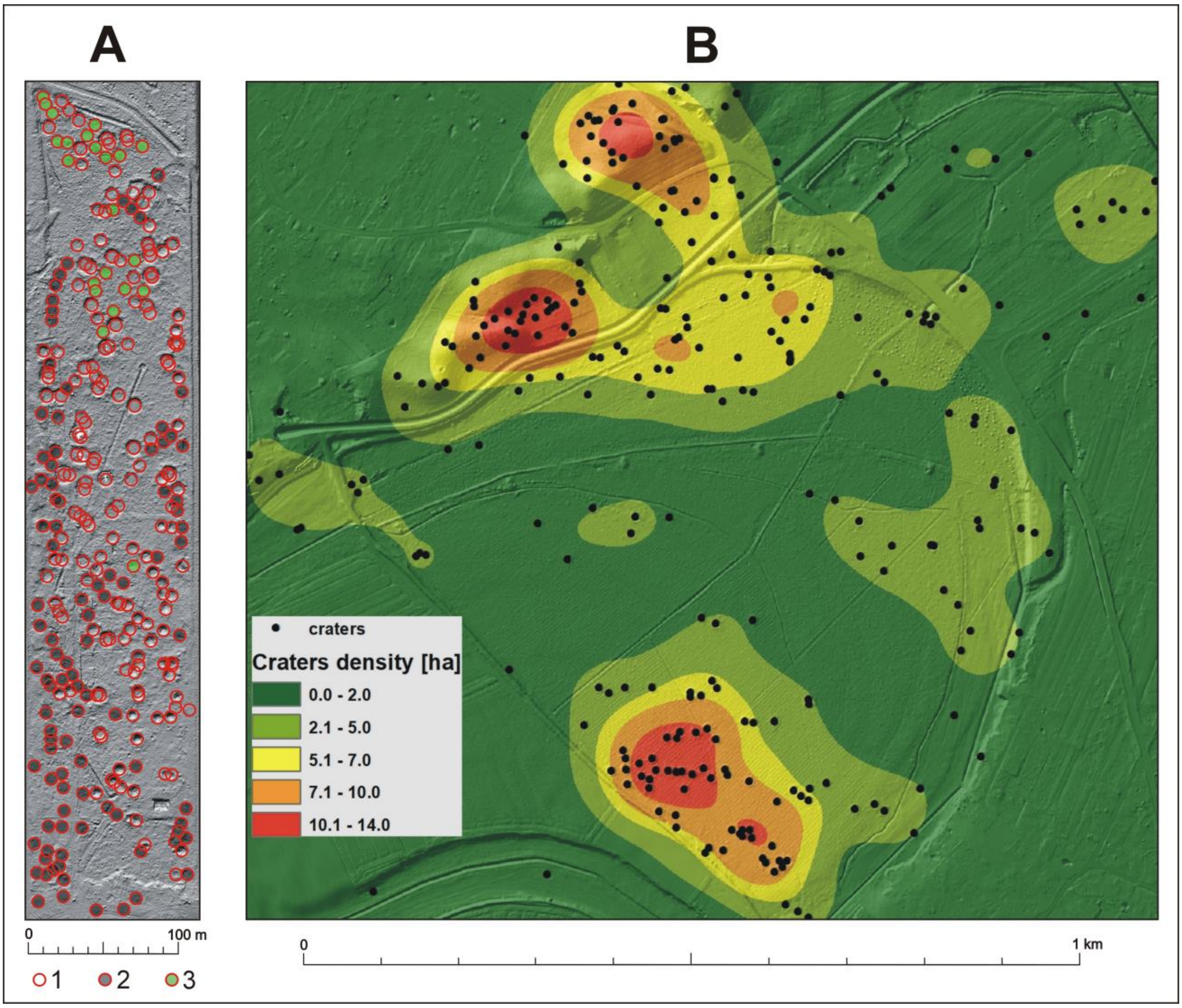

Fig. 5. Two proving grounds near Kędzierzyn-Koźle (figure by the authors)
A. Location and preservation status of craters. Craters: 1 – well preserved, 2 – backfilled, 3 – strongly altered by natural geomorphological processes. B. Crater density

Projects of a similar nature to the one presented in this article are being carried out in other countries in Europe, USA, Vietnam, Laos, Cambodia, Iraq, Kuwait, Afghanistan, Nigeria (e.g. NOYES, 1996; MCGRATH, 2000; HARPVIKEN, 2002; MILITARY MUNITIONS..., 2006; SPYRA & KATZSCH, 2007; LAO NATIONAL...; ENVIRONMENTAL REMEDIATION..., 2015; MARTIN ET AL., 2019; HIDDEN SCARS...) and take into account the neutralisation of UXOs and are funded from various sources. Some are even implemented by non-governmental organisations.

3.1. Difficulties

In Poland, active UXB field surveys are often hindered by the owners, managers, and current users of the land. Underlying this behaviour is primarily the fear of being ordered to cover the costs of neutralising any found UXBs, or at the very least, suspending or limiting business operations. Pre-emptive explosive ordnance surveys are performed to the minimum possible extent required for the investment project. This presents a situation in which not only the mentioned entities, but also representatives of the owner of the deeper ground layers, i.e. the State Treasury, are not interested in a comprehensive solution to this problem due to the high cost of neutralisation measures. It is clear that such a problem will not be addressed by landowners, land users, or local governments. Furthermore, the layers under the surface of the land are already the property of the State Treasury – with all the consequences of this state of affairs. Therefore, the solution of the problem must be carried out with the participation of state institutions and funds from the national budget, assuming that they will be gradually obtained from other sources as well.

Similar difficulties in searching for and efficiently neutralising UXBs also exist in other countries. It is clear, however, that failure to act appropriately can lead to tragic consequences during inappropriate operations in areas with the occurrence of UXBs.

4. Conclusions

The contemporary development needs of the Kędzierzyn-Koźle agglomeration and the neighbouring municipalities require further study of the areas subjected to airborne military activity during World War II. Current geoinformation and geophysical technologies, and especially access to high-resolution spatial data (ALS, orthophotomap) provide new opportunities. Their use in contemporary spatial planning and architectural design should become the prevailing standard. In addition to spatial and technical needs, safety, historical, natural, and educational considerations should be taken into account for the development of new civil structures. Therefore, in the course of this process, as a temporary or target solution, it is necessary to take into account the inclusion of areas transformed as a result of military activities in land use plans as zones left to nature – urban green areas, nature conservation sites or wartime historical monuments and scientific research zones. This practice has already been applied in the municipality of Bierawa. A preservation programme can be introduced together with a broader landscape preservation project that serves important functions in historical education and remembrance of victims of war. Examples of such solutions can be found in France, Belgium, and the Netherlands. The remaining area can be gradually studied and adapted for socio-economic needs in a considered and thorough manner.

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