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Understanding the impact of the war on people-nature relationships in Ukraine

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ABSTRACT

This study investigates the impact of the Russian invasion of Ukraine on the relationship between people and nature in three settlements in the Kyiv Region that were occupied by Russian forces and later liberated by the Ukrainian Army. Using semi-structured interviews with local inhabitants, we documented the ecosystem services that people relied on before the war and the changes that occurred after deoccupation. The findings reveal a significant reduction in access to essential ecosystem services, exacerbated by new disservices such as flooding and environmental contamination. The study underscores the vital role of cultural ecosystem services, with many respondents expressing deep emotional and spiritual connections to their natural environment. Despite these challenges, private gardens and urban greenspaces have emerged as crucial elements for post-war recovery, fostering reconnection and psychological healing. Post-war restoration strategies should prioritize not only the rehabilitation of ecosystem services but also the restoration of cultural and spiritual ties between people and nature. A forward-looking, community-inclusive approach to ecological restoration will be critical for Ukraine's recovery, supporting both environmental sustainability and human resilience.

1. Introduction

Since the 1990s, Eastern European countries outside the European Union have experienced armed conflicts, including recent examples in Armenia and Georgia. The most significant of these is the large-scale Russian invasion of Ukraine on February 24, 2022, which has heightened instability across the region (Pereira et al., 2022; Sousa et al., 2022). Armed conflicts cause serious environmental damage emphasized by previous and recent studies such as the degradation of air, water, and soil quality caused by widespread pollution, deforestation, biodiversity loss, and the depletion of inland and coastal fisheries (Aung, 2021; Broomandi et al., 2020; Khordagui and Al-Ajmi, 1993; Leal Filho et al., 2024; Pereira et al., 2022; Protopsaltis, 2012; Rawtani et al., 2022; Solokha et al., 2023; Vyshnevskyi et al., 2023). Armed conflicts also pose a severe threat to human health and lives. Beyond the direct impact on combatants, civilians face injuries, fatalities, restricted access to essential resources, and widespread human rights violations (Meddings, 2001; Murthy and Lakshminarayana, 2006; Priebe et al., 2010). In some instances, warfare results in temporary or prolonged occupations, during which occupying forces often restrict local populations' access to

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natural resources, accompanied by repression and resource shortages (Weir, 2023). War's impact on agriculture is also particularly alarming, and in this regard the Russian invasion of Ukraine poses a serious threat to both Ukraine's and the global food supply, given Ukraine's crucial role in exporting key agricultural commodities (Chepeliev et al., 2023; El Bilali and Ben Hassen, 2024). Scholars warn that Russia's war in Ukraine may severely jeopardize efforts by European and global nations to achieve the United Nations' Sustainable Development Goals (SDGs) by 2030 (Pereira et al., 2022; Tollefson, 2022).

This study aims to examine the evolving relationship between people and nature in war-affected areas of Ukraine, with a focus on ecosystem services – the direct and indirect benefits humans derive from nature (MEA, 2005; Dzyba & Saveliev, 2023; Francis & Krishnamurthy, 2014; Munang et al., 2013; Reyers et al., 2015; Schillinger et al., 2020) – and how these services are perceived by local residents. War-induced environmental degradation inevitably undermines ecosystem services, placing a significant burden on communities that rely on them for sustenance and well-being (Homer-Dixon, 1991; Meaza et al., 2024). Yet, during the crisis, ecosystem services become even more vital for communities, as nature can buffer communities against severe stressors, such as war, particularly when individuals perceive their natural surroundings as being in good conditions (Gunko et al, 2022a). Even after hostilities cease, environmental degradation can persist, continuing to impact ecosystem services negatively, and even driving migration as rural populations, feeling neglected by authorities, seek refuge elsewhere.

This study also reveals the connections between nature, the local environment and well-being. Research shows that people's relationships with their local environment significantly influence communities' well-being (Russell et al., 2013). These perceptions provide valuable insights for researchers and policymakers, particularly in regions where direct access is restricted (Gunko et al., 2022b). The deep interconnection between human well-being and ecosystem services highlights the critical importance of preserving ecosystem integrity. Scholars conceptualize human well-being as a multidimensional construct, encompassing critical aspects of life across disciplines such as philosophy and social sciences (Clark, 2014). According to the Millennium Ecosystem Assessment (MEA, 2005) and subsequent research (e.g., Loveridge et al., 2020; King et al., 2014), human well-being comprises five key dimensions: good social relations, freedom of choice and action, security, health, and basic materials for a good life. Ecosystem services play a vital role in fulfilling these dimensions (Daily, 1997, Salzman et al., 2001). For example, provisioning services, such as food, fresh water, and clean air, directly meet basic needs and promote health (Tzoulas et al., 2007). Regulating services, including climate regulation, flood control, and disease prevention, enhance security by mitigating vulnerabilities to environmental and health risks (King et al., 2014). Supporting services, such as biodiversity conservation, soil formation, and nutrient cycling ensure ecosystem stability and indirectly sustain all other services (Costanza et al., 2007). Cultural services, meanwhile, enrich emotional health, cultural identity, and spiritual fulfillment, particularly in post-disaster and post-conflict contexts, where these benefits can aid psychological recovery (Chan et al., 2012).

The ongoing war in Ukraine has compounded multiple challenges, particularly in formerly occupied areas where scorched-earth tactics, landmines, and unexploded ordnance have devastated ecosystems and endangered lives (Hryhorczuk et al., 2024; Kondratenko, 2023). These hazards restrict access to nature and exacerbate long-term issues such as water shortages and sanitation challenges (Shumilova et al., 2023). For many Ukrainians, the degradation of local ecosystems poses significant threats to their well-being, as they rely on these services for survival and recovery (Gunawan et al., 2023; Irland et al., 2023; Petryna, 2023). Recognizing the vital role of ecosystem services in supporting human well-being underscores the urgency of integrating them into post-conflict recovery strategies. Such strategies must address interconnected challenges, including environmental degradation, migration, and the restoration of social cohesion, to ensure long-term resilience and sustainability. During wartime, scholars often face limited access to affected areas, underscoring the critical role of local residents as experts on their environment (Weir et al., 2019). Despite this, studies examining the impact of armed conflicts on people-nature relationships, especially immediately after de-occupation, remain scarce. Addressing this gap is crucial for designing post-conflict recovery strategies that incorporate the perspectives and needs of local communities, who bear the brunt of war's consequences.

Drawing on 69 interviews with residents from three settlements in the Kyiv Region – previously occupied by Russian forces and later liberated by the Ukrainian Army – the study addresses two key research questions: (1) What ecosystem services did residents rely on to sustain their well-being before the war? (2) How has the war-induced disruption of local ecosystems affected the perceived availability of these services? By incorporating the perspectives of residents from war-affected communities, this study seeks to inform future strategies for post-war recovery.

2. Methods

2.1. Study area

We used the following criteria to select the study area: (i) The natural environment should be diverse, encompassing various ecosystem classes such as forests, arable land, grasslands, and aquatic ecosystems, to explore the importance of different ecosystems in providing demanded services. (ii) The area should include settlements that were occupied by Russian forces and later liberated by the Ukrainian Army. (iii) The settlements should vary in size and be surrounded by diverse ecosystems at varying proximities to inhabitants. (iv) The area should offer relatively safe conditions for conducting fieldwork, far from areas of active fighting.

The chosen study area is located in a northwestern suburb of Kyiv, in the Kyiv administrative region, encompassing three settlements—Borodianka, Demydiv, and Moshchun—along with their environs within approximately a 10-km radius. The study area is bordered by the Kyiv Reservoir in the east and the dense urban fabric of Kyiv in the southeast. The Belarus and Russian borders are located approximately 80 km to the north and north-east, respectively (Fig. 1).

The study area is part of Ukraine's mixed forest zone and belongs to the geographical region of Ukrainian Polissia. The area is primarily a fluvioglacial wavy plain dissected by boggy river valleys, with elevation varying from 100 to 200 m. The climate is temperate and moderately continental, with four distinct seasons. Average monthly air temperature ranges from −6 °C in January to +19 °C in July, and annual precipitation is around 650 mm. The soil is predominantly low-productive sandy sod-podzolic (Gleyic Arenosol), developed under a natural mixed forest dominated by Scots pine and pedunculate oak (Brun et al., 2022). Over the centuries, the natural ecosystems were replaced by agricultural fields and settlements. Valleys have been drained and occupied by grassland and water reservoirs, while forests have predominantly been managed as pine monocultures, sometimes on former arable land.

The Russian army invaded the region on February 24th, 2022, and committed mass killings of civilians and significant destruction of infrastructure. There was also widespread contamination of ground water and soils due to unexploded and exploded ordnance. The Ukrainian Army liberated this region in April 2022.

Borodianka is a town with a population of 12,838 as of January 1, 2022 (Fig. 1). The town is surrounded primarily by agricultural land and small forest areas. The main sectors of economic activity include the production and processing of agricultural products, forestry, trade, transport, the service sector, and industry (such as wood processing and aluminum production). At the beginning of the full-scale Russian invasion, Russian planes fired missiles at residential buildings in Borodianka from low altitudes. As a result, the central street of the town was reduced

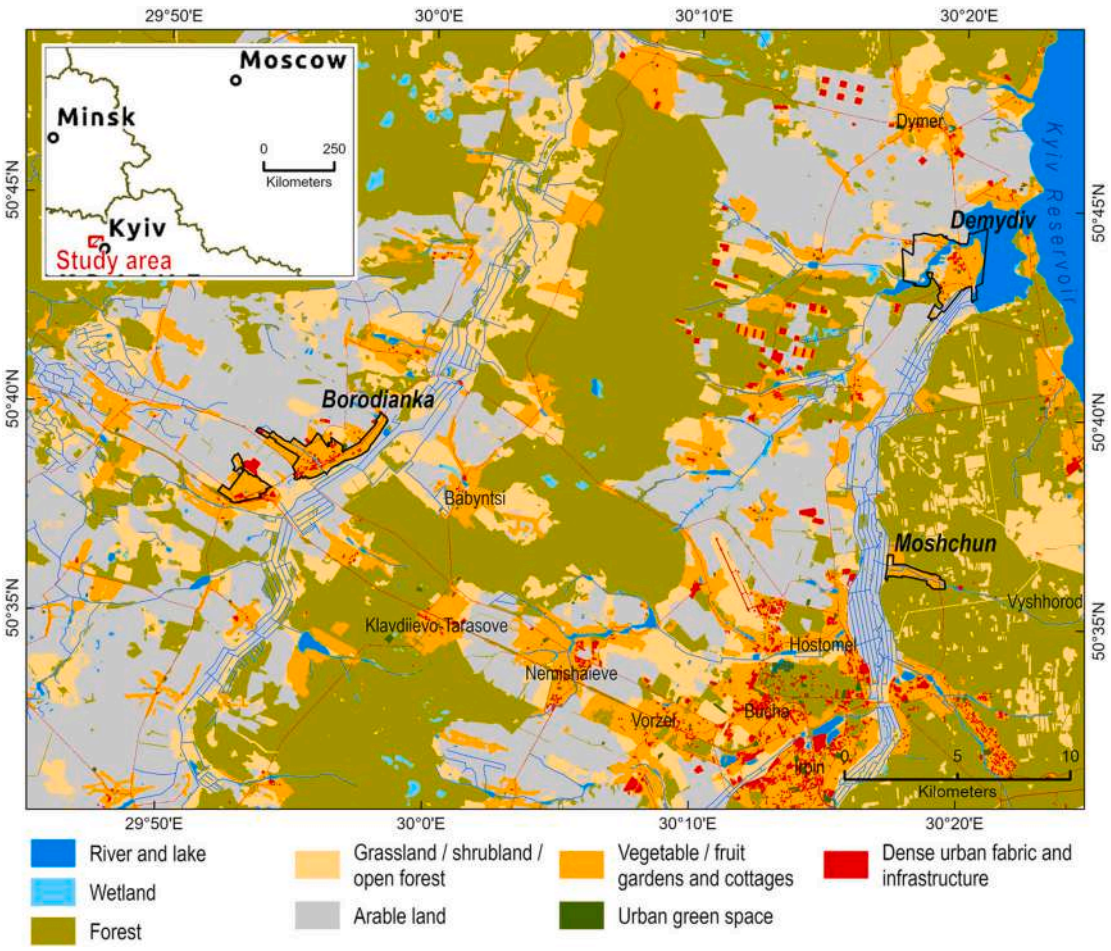

Fig. 1. Location of the study area (in the upper left corner) and land cover classes in and around the studied settlements – Borodianka, Demydiv and Moshchun – that are designated by a black outline. (The data source for land cover classes is presented in Section 2.2).

to ruins, with destroyed high-rise buildings, damaged road surfaces, fallen trees, and burnt cars. During the hostilities, 1,534 out of 9,969 buildings were damaged, and 144 buildings were completely destroyed. The total estimated amount of damage is assessed at USD 148.4 million (KSE, 2022a).

Demydiv is a village with a population of 3,702 people, founded in 1026, making it one of the oldest villages in Ukraine (Fig. 1). Demydiv is surrounded by agricultural land in the Irpin River valley and adjacent to a block of forest to the west. The local population is primarily employed in small-scale agricultural production (vegetables, grain crops, animal husbandry) and community livelihood sectors such as trade, transport, education, and services. Similar to other settlements in this part of the Kyiv region, a significant portion of the population works in neighboring Vyshgorod and Kyiv. On February 26, 2022, near the village of Kozarovychi, Ukrainian troops destroyed the Kozarovytska dam that separated the Irpin River from the Kyiv Reservoir. This action forced water from the Kyiv Reservoir into the Irpin River, creating a natural barrier that effectively restricted Russian forces from accessing Moshchun, which they saw as the gateway to Kyiv (Ukrainer, 2024). The flooding impacted the floodplain and neighboring estates along the Irpin River, covering over two thousand hectares. The river overflowed its natural channel by 1.5–2 m, complicating river crossings. Within a month and a half, water from the reservoir had flooded the Irpin floodplain more than 20 km upstream. The floodplains turned into a shallow swamp covering 2842 ha (UNCG, 2022). The flooding adversely affected the village of Demydiv, where 120 houses were damaged by water.

Moshchun is a village that was home to about two thousand people. Although officially 850 people were registered living in Moshchun, many people had Kyiv registration. Surrounded by forests, its western part extends to the floodplain of the Irpin River (Fig. 1). The western section is relatively new, developed as a holiday retreat primarily for people from Kyiv. The inhabitants are mainly engaged in agriculture, forestry, and the service sector. A significant tourist and recreation complex is located on the outskirts of the village. Many residents also had jobs in Kyiv. The Battle of Moshchun was one of the fiercest battles during the defense of Kyiv, lasting from February 27 to March 21, 2022, during the initial phase of the Russian invasion of Ukraine (Ukranews, 2022). Due to the active hostilities, the village was almost completely destroyed and is currently one of the most devastated settlements in the Kyiv region. A total of 1597 shell craters have been identified in Moshchun. During the heavy fighting, about 2000 out of 2800 buildings in Moshchun were destroyed (KSE, 2022b). This includes 921 private houses and an equal number of farm buildings and structures, the owners of which were both local residents and citizens of other cities, primarily Kyiv. Additionally, 20 industrial buildings, 18 greenhouses, three shops, two hotels, a school, a church, a cultural center, and a post office were destroyed or damaged. The damage to the infrastructure of Moshchun amounts to almost 1.1 billion hryvnias or $37.3 million (KSE, 2022b).

2.2. Land cover classes

To delineate the land cover classes, which are used to geographically interpret ecosystem services (Burkhard et al. 2012, Open Street Map (OSM / https://www.openstreetmap.org) land cover geodata were used as a primary source. Where there were gaps in the OSM data, data from

ESRI land cover geodataset of 2023 was used (https://livingatlas.arcgis.com/landcoverexplorer). The datasets were merged, reprojected on a 10*10 m UTM grid, and reclassified into eight categories: 1) river and lake, 2) wetland, 3) forest, 4) grassland /shrubland /open forest, 5) arable land, 6) vegetable /fruit gardens and cottages, 7) urban greenspace, and 8) dense urban fabric and infrastructure. The resulting geodataset was used for the subsequent collection of field data and spatial analysis. However, the densely built-up area of Kyiv and the vast body of the Kyiv Reservoir were excluded from the analysis,

2.3. Data collection and analysis

We applied semi-structured interviews to gather data in the three selected settlements – Borodianka, Demydiv, and Moshchun. Our interview manual included questions designed to explore the perceived benefits crucial to residents' well-being attributed to various ecosystems surrounding their settlements. These ecosystems included forests, lakes/rivers, arable land, pastures, fruit and vegetable gardens, and urban greenspaces. We sought to understand residents' use of ecosystem services prior to the war and the reasons for their importance for human well-being (see Appendix 1). For the period following occupation, we investigated how the use of each ecosystem class changed as a result of the war and occupation and its impact on people's relationships with the natural environment.

Data collection was done between November and December 2023 in Borodianka, Demydiv, and Moshchun – regions heavily impacted by the war. Conducting a statistically representative study in this context posed significant challenges due to: (i) the urgency to capture people's perceptions within a limited timeframe, which constrained participant recruitment, and (ii) prioritizing the safety and well-being of respondents over achieving statistical representativeness. To address these constraints, we employed a purposive sampling strategy (Creswell, 2013; Patton, 2002) to document diverse and in-depth perspectives critical for understanding the complex socio-ecological dynamics in war-affected regions. To reflect the social diversity of the studied settlements, we deliberately selected respondents representing a broad range of demographic groups, including variations in age, gender, and household characteristics, such as size and levels of destruction experienced during the war. Furthermore, the study encompassed three distinct settlements within the affected region to capture geographic and conflict-related variations in perceptions of ecosystem service loss. Collaboration with key informants, such as local community leaders and NGOs, ensured the inclusion of voices from marginalized and underrepresented groups.

Interviews were conducted in various locations, including streets, respondents' homes, and their gardens, depending on their preference and convenience. Prior to each interview, respondents were provided with a concise description of the project to familiarize them with its objectives and ensure they understood the purpose of the study. They were also given the opportunity to ask questions about the project to ensure transparency and informed participation. Respondents were assured of their right to decline answering any question or to discontinue participation at any point, even after giving initial oral consent. It was emphasized that consent could be withdrawn at any stage of the research process by contacting the designated researcher. To uphold privacy and confidentiality, respondents' names were not collected, and all gathered data underwent pseudonymization before being processed and securely stored. Each interview was assigned a unique reference number to facilitate organization and ensure anonymity. This approach upheld the principles of voluntary participation and data protection throughout the research process.

In total, 69 interviews were conducted (n = 21 in Borodianka, n = 27 in Demydiv, and n = 21 in Moshchun). The interviews were conducted in Ukrainian and recorded, with durations ranging from 30 to 130 min. With a refusal rate of approximately 10 %, the majority of individuals approached demonstrated a willingness to participate in the study. Many respondents exhibited openness, sharing their personal stories and experiences.

All collected data were fully transcribed and analyzed using qualitative content analysis (Bryman, 2008). The qualitative data related to the perceived benefits attributed to different land cover classes were categorized into different types of ecosystem services. We applied the Ecosystem Service Coding Protocol (CP) proposed by Wilkinson et al. (2013), which ensured coding consistency of ecosystem services across all analyzed interviews. For example, the respondent statement *'I love the forest; it provides us with clear and fresh air. Forests are like our lungs, ensuring our health'* was coded as regulating ecosystem services. While the statement *'Before the war, when it was blueberry and mushroom season, I went with my granddaughter. She is good at picking mushrooms and berries. We picked and ate berries right there in the forest'* as provisioning ecosystem services. The CP included four categories of ecosystem services: supporting, provisioning, regulating, and cultural services (MA, 2005).

3. Results

3.1. Land cover classes

The largest portion of the study area, totaling 1,597 square kilometers, belongs to forest land cover class (45.0 %) (Fig. 1). These are predominantly managed pine forests. Arable land occupies 26.2 % and is mainly represented by large rectangular fields (1–4 km^2) on drained, less-productive soil, separated by ditches and windbreaks, sometimes dissected by shallow gullies. Grassland, shrubland, and open forest are the third most prevalent land cover class (13.7 %), encompassing pastures in drained valley bottoms and succession vegetation on abandoned fields and forest clear-cut patches.

Vegetable and fruit gardens with cottage-type buildings comprise 10.9 % of the area and are associated with rural settlements. Rivers and artificial lakes occupy another 1.2 % of the study area. The large water surface near Demydiv is mainly the result of artificial flooding caused, as mentioned above, by military activities during the Russian invasion. Wetlands account for 0.9 % and include partially drained patches in valley bottoms as well as mesotrophic and oligotrophic swamps and bogs on interfluves.

Urban greenspace occupyes a modest 0.2 % of the study area, with small parks and playgrounds available only in larger settlements. These settlements also have patches of dense urban fabric (housing, commercial, industrial zones), which, together with transport infrastructure (roads, railways, airfields, parking lots), occupy another 1.9 %.

3.2. Perceived ecosystem services attributed to forests prior to the war and after de-occupation

All respondents shared tragic stories about life during the russian occupation, and the lives of many of the respondents underwent dramatic changes due to the war. Many lost family members and friends, their homes, and endured extreme physical and emotional traumas. Their relationship with their natural environment has also been drastically altered and has not been restored even two years after the de-occupation.

Prior to the war. Forests were particularly important for providing numerous provisioning and cultural services across the three settlements (Fig. 2a). Regarding provisioning services, most respondents reported consuming forest berries and mushrooms, with some also collecting medicinal plants. Respondents commented that they picked mushrooms and berries for their own consumption. However, in Borodianka and Moshchun, some respondents mentioned that their neighbors sold berries and mushrooms in local markets to gain additional financial support to sustain their livelihoods.

Many of these provisioning services had cultural components, as people associated these practices with traditions inherited from their

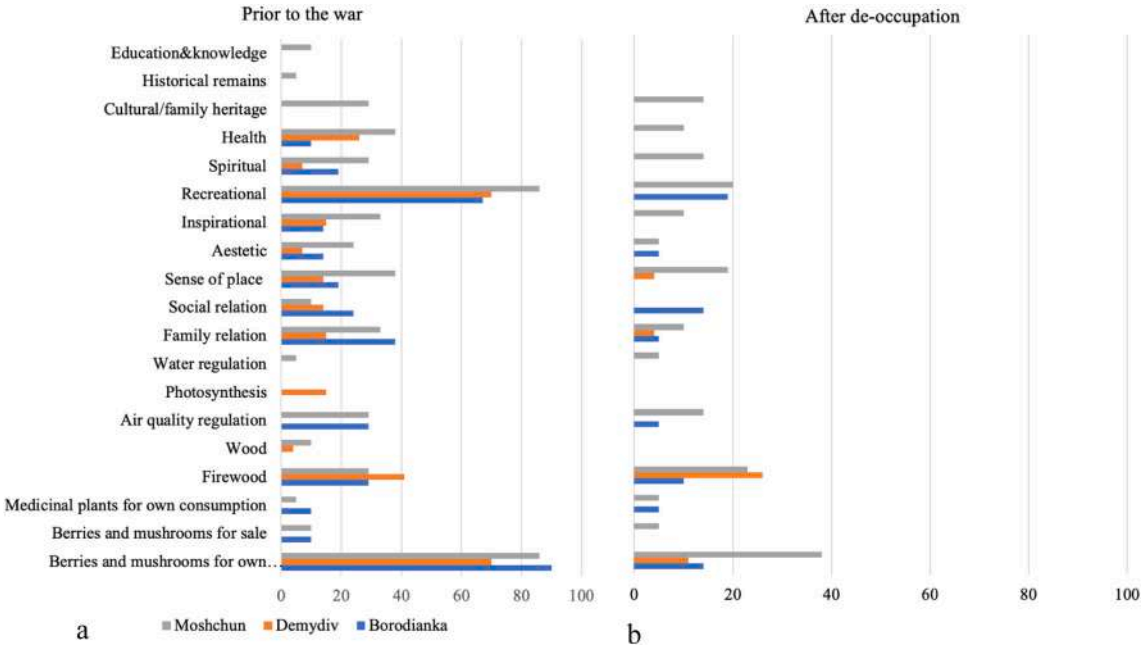

Fig. 2. Ecosystem services attributed by respondents (in % from the total number of respondents in each settlement) to forests in Moshchun, Demydiv and Borodianka prior to the war (a) and after de-occupation in 2022 (b). *Note: The percentages represent responses within a non-representative, purposively selected sample. The figure is intended to illustrate qualitative trends and differences in ecosystem service perceptions across settlements and time periods rather than provide statistically generalizable findings.*

grandparents, recreational activities, or facilitating family bonding. One respondent (B05) shared, '*My grandmother was a great collector of mushrooms and berries. We never bought tea from the store; instead, we always used dried blackberry or wild strawberry leaves for tea. My grandmother lived to 96, and she continued going to the forests until the end, teaching me to love forests*.' Another respondent (M04) similarly explained that picking berries and mushrooms was important as a time that she spent with her family, including grandkids. *'Before the war, when it was blueberry and mushroom season, I went with my granddaughter. She is good at picking mushrooms and berries. We picked and ate berries right there in the forest. I also loved going to the forest with the whole family.'* Another respondent (B14) discussed picking berries and mushrooms as a recreational activity, saying, *'Particularly for me and my family, it was recreation to use the forest; it was an environment where I felt inspired and we simply enjoyed the fresh air, picking berries or mushrooms'*. In addition, some respondents also noted that they used firewood that originated from the nearby forests, but they did not directly associate it with their own use of forests, as the firewood was supplied by forest enterprises.

Regarding other cultural services, respondents also attributed improved health, spiritual value, sense of place, and facilitation of social connections to forests. Despite numerous complaints that forests had been overharvested by the forest companies or despoiled by trash, respondents often described the forests as *'my home'*, *'my place'*, or *'my place of inner power'*. As articulated by one respondent (B05), *'I have always found peace in the forest since childhood. That's why the forest in my life is like an oasis. And even when things are difficult for me, I close my eyes and envision a place where I feel safe, where I feel good. I always imagined a forest.'* Many respondents described using forests throughout all seasons to relish moments of solitude in nature. As respondent (B33) articulated, *'My husband and I liked to visit forests in winter. The forests look different – it was beautiful with sounds, snow around. It gave us inner power'*. Another respondent (M33) told, '*After winter, we go to the forest to see the first flowers. We'd take food with us and organize a quick table. We sit and admire. The forest helps us with its energy, enriches us. I have my own oaks, I talked to them: 'How are you? Give me strength.' The forest is a giant, our everything'*. Regarding health benefits from forests, respondents primarily associated them with the opportunity to breathe fresh air and restore their mental health by walking in nature.

A few respondents in the studied settlements also attributed regulating services to forests, including water regulation, photosynthesis, and air quality regulation, acknowledging that these services were important for their well-being. For example, some respondents commented that they visited forests to enjoy the fresh air they provided. One respondent (B05) explained, *'I love the forest; it provides us with clear and fresh air. Forests are like our lungs, ensuring our health.'* Another respondent (M31), while complaining about the intensive forest harvesting before the war, explained, *'Forests should be preserved because they are our lungs. If we cut everything down now, we would have polluted air, strong winds, and floods after heavy rains. We would constantly have problems with this, but the forest helps with water regulation – it's all part of nature's balance.*'

After de-occupation. One of the most disruptive changes was the alteration of people's interactions with their forests. A high proportion of respondents in all three studied settlements reported losing several provisioning and multiple cultural services (Fig. 2b). Among the provisioning services, the loss of berries, mushrooms for personal consumption and sale, as well as wood, occurred because the forests were either destroyed during battles or extensively blanketed with mines or unexploded ordnance (Fig. 3). For these reasons, local authorities have restricted access to forests after the liberation of these areas. Most respondents expressed fear of entering the forests due to the presence of mines and cited incidents where people encountered mines or other explosives. One respondent (B33) recounted, *'Some villagers go to the forest; they have their own paths. They joke, 'Oh, we are going demining.' These are bad jokes to me. I don't think a mushroom is worth my life. I know the danger; I saw the deaths, I saw everything. We have not yet recovered from this disaster to take risks by going to the forest, which has many mines.'* At the same time, some respondents admitted that they were ready to take risks because they could not live without the forests. A respondent in Moshchun (M33) explained, '*Nothing has changed, we are not afraid. Just like it was before the war; whatever is meant to happen will happen, we still go to the forest.'*

To offset the loss of forest provisioning services such as berries, mushrooms, and medicinal plants, respondents described various

Fig. 3. Remnants of unexploded ordnance in a forested landscape, illustrating the long-term environmental impact of armed conflict. The left image shows a projectile embedded in the forest floor, while the right image captures a munition fragment lodged in a tree. Such remnants pose significant risks to ecological recovery, human safety, and the restoration of ecosystem services in post-conflict landscapes (photos – Marine Elbakidze).

strategies. They mentioned using berries from their own gardens, purchasing mushrooms from nearby markets, or requesting friends from villages distant from the active war zone to bring berries or mushrooms. One respondent (B33) shared, *'Today, my friend came from the Chernihiv region with Polish mushrooms* [*Imleria badia – added by authors*], *still with moss on them. The scent of the mushrooms and moss brought so much joy and nostalgia. We were all in a great mood. Later, another friend from the army visited us, and we decided to give all these mushrooms to him.'*

Regarding cultural services, respondents described the emotional burden of losing their connection with the forests. Respondent (B45) elaborated, *'We do not go to the forests at all after the de-occupation because it is prohibited due to the presence of many mines and grenades. Recently, we passed by the forests we used to frequent, stopped by the road, stepped out to touch the trees, breath in the fresh air, look at the sky, and listen to the sounds of the forest.*' Many respondents, particularly in Moshchun, who inherited their strong connection to the forests from their grandparents, felt particularly affected by the disruption caused by the war. Respondent (M04) shared, '*We loved our forest very much since childhood. Both my grandmother and grandfather taught us to live in harmony with the forest. My grandmother knew a lot about herbs; she used to dry and use them for treatment. She knew it well, and I used to go with her. Now we terribly miss this, it is hard without the forest. This year, I even made a special trip to the Carpathians (600 km away from the village) just to visit the forest.'* For those who were not afraid to enter the forests and had a dog, recreational use of forests was mainly limited to walking their dogs.

Despite the loss of physical contact with the forests, many respondents still evaluated the importance of forests for their well-being as high. This was primarily attributed to their emotional attachment to the

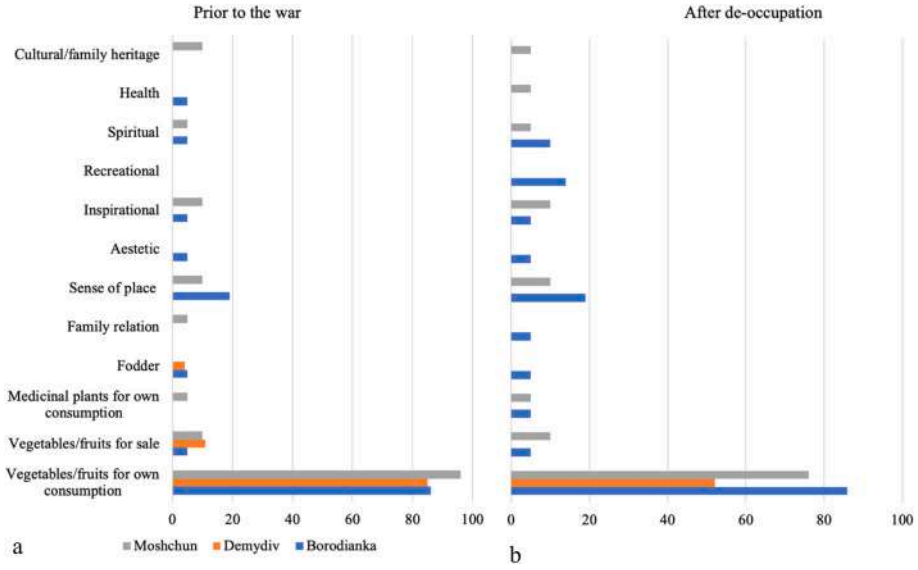

Fig. 4. Ecosystem services attributed by respondents (in % from the total number of respondents in each settlement) to vegetables/fruit gardens in Moshchun, Demydiv and Borodianka prior to the war (a) and after de-occupation in 2022 (b). *Note: The percentages represent responses within a non-representative, purposively selected sample. The figure is intended to illustrate qualitative trends and differences in ecosystem service perceptions across settlements and time periods rather than provide statistically generalizable findings.*

forests, which they greatly enjoyed before the war.

3.3. Perceived ecosystem services attributed to fruit and vegetable gardens prior to the war and after de-occupation

Prior to the war. Regarding their own fruit and vegetable gardens, respondents attributed provisioning services across three settlements and cultural services in two studied settlements (Fig. 4a). Concerning provisioning services, the vast majority of respondents in all three settlements acknowledged that they grew and consumed vegetables, fruits, and berries from their gardens. A garden was considered an important part of people's lives. Respondent (B33) explained, *'Prior to the war, our garden was always important to us because we got all we needed from our garden. We had potatoes, carrots, cucumbers, beetroot, cabbage, and tomatoes, which we canned and used for salads.'* Most respondents used the products from their gardens for consumption in their own family or larger kinship and friend networks; at the same time, some respondents also sold them to sustain their livelihoods. A few respondents also grew some plants for fodder. As respondent (M35) elaborated, *'We enjoyed going to our garden. People went beyond the village to Irpin, where we have a river, for nettles and all. But we sowed our own so that we had clover, alfalfa, and fed the poultry and ducks.'*

Regarding cultural ecosystem services, only respondents in Borodianka and Moshchun explained that gardening and gardens provided a sense of place, were important for their health, and had spiritual significance. For example, one respondent (B32) explained, *'The food products that I grow and later consume, it is one thing, but I get more—energy from the earth, strength, joy from gardening. And it is not about owning the land; it's something bigger, as it's the air, the sun. Especially in the morning—the birds are singing, the air is clean, the sun has risen, the smell of the earth, plants, life.'* A respondent in Moshchun (M35) told us, *'We had our vegetable gardens in several places in our village. My mother and I went to our gardens every day, and it was joyful for us. My father often joked about it by saying, forgive me for the rough language, 'The cow with the heifer have already tramped.'* In Borodianka, some respondents also acknowledged that fruit and vegetable gardens played a crucial role in family bonding. They explained that each family member, including children, had their own responsibilities in gardening or household chores while others tended to the garden. Respondent (B33) elaborated, *'Our personal garden brought immense joy to our family. Each of us had specific tasks, from planting and preparing the soil to clearing and harvesting. Often, after returning home tired and dirty from working in the garden, we would simply wash up, sit down to dinner as a family, and engage in lively conversation. Family unity was a significant resource for us.'*

After de-occupation. Fruit and vegetable gardens suffered losses in ecosystem services in Demydiv and Moshchun (Figs. 4b and 5); while an increased number of respondents attributed provisioning and cultural ecosystem services in Borodianka. In all three studied settlements, the main restorative efforts organized by the people were directed towards rebuilding their homes wherever possible and restoring their gardens.

Regarding provisioning services, gardens continued to provide vegetables, fruits, and berries in all three studied villages. However, the number of respondents who relied on these ecosystem services decreased in Demydiv and Moshchun, while remaining the same in Borodianka. This decline was due to the destruction of gardens by bombs and fires during combat activities in Moshchun, and by flooding that affected private houses and gardens in Demydiv. Respondent (M06) explained, *'Phosphorus bombs landed in our garden. There are two spots where nothing grows at all. We have tried everything, adding all kinds of fertilizers, but it does not work.'* Another respondent (M21) added, *'Currently, I cannot use the garden because my house is completely destroyed and the garden is filled with debris like bricks and glass from the destruction. However, I have the opportunity to set up a greenhouse. Once it is provided to me, I will set it up and start my farming activities again.'* In Demydiv, many respondents explained that their gardens were partially or completely destroyed by flooding caused by the river dam's destruction. Either the soil was too wet or remained covered with water. As respondent (D15) elaborated, *'People in the village live off their gardens. Salaries and pensions are one thing, but we primarily live off our gardens; everything we have is our own. But now, people have nothing. No gardens. We were lucky that the water receded. Our neighbors' gardens are still flooded. The moisture and water caused everything to grow over immediately. It is overgrown with grass, and it's impossible to manage.'*

In all three settlements, respondents highlighted the significance of gardens and the produce they cultivate there to survive during the Russian occupation. Respondent (D15) said, *'The garden saved us from starvation. During the russian occupation, it was good to have potatoes, carrots, and other vegetables stored in the cellar. We could cook borscht or something else, even on a campfire if there was no gas. There was no gas, no electricity, and no water'.*

In relation to cultural ecosystem services, respondents emphasized that gardens and gardening had become even more crucial since the war,

Fig. 5. War-induced destruction in rural settlements, highlighting the socio-ecological consequences of armed conflict in Moshchun. The image to the left depicts extensive landscape degradation, with debris and remnants of damaged structures scattered across a private fruit and vegetable garden. The image to the right captures the remains of a burned-down house, illustrating the impact of warfare on both the built environment and surrounding ecosystems. Such devastation poses significant challenges to post-war recovery, land restoration, and community resilience (photos – Marine Elbakidze).

as they helped to re-establish a sense of place, foster family bonding, and overcome psychological traumas caused by the war's disruptions. As respondent (B33) articulated, '*Our own garden holds greater significance now than ever before. Gardening serves as a form of rehabilitation for us, both physically and mentally. I even prefer to work in the garden without gloves, feeling the soil with my hands. It brings me happiness to have a garden. Our kitchen window overlooks our garden, and my husband and I often sit at the table, watching it as we talk, feeling content. Working together in the garden is also immensely important for us.'* Some respondents considered gardening a recreational activity that helped them relax and restore their mental and physical health. As respondent (B42) noted, '*When I go out to my garden, I feel alive because I know that something will grow. I relax there.'*

3.4. Perceived ecosystem services attributed to lake and rivers prior to the war and after de-occupation

Prior to the war. Lake and rivers provided essential services that enhanced people's well-being prior to the war (Fig. 6a). These cultural services were recognized in all three settlements. Lakes and rivers were pivotal for various recreational activities, social interactions, and family bonding. Respondents used these water bodies to spend time with their families and friends and to celebrate religious events when the entire village gathered together. As respondent (D37) elaborated, *'Before the war, our river was clean, and the area along the river was well-maintained. Whenever I had free time, I would go to the river with my friends and family. We didn't fish; we just spent time together.'* Another respondent (B15) shared, *'The river was important for my kids and me as we enjoyed swimming and playing in the water, while my husband liked to fish.'* They mentioned that these ecosystems were used in different seasons; for example, in winter, people organized an ice-skating rink for kids and adults.

Lakes and rivers in and around studied settlements also provided a sense of place, inspiration, aesthetic enjoyment, and served as cultural/family heritage and spiritual places (Fig. 6). Respondents reminisced about using rivers and lakes during their childhood. Respondent (D15) shared, '*I grew up on the river. The river was everything for us, kids. As they say in folklore, you sit in that water until a willow grows on you*'. Respondents also mentioned that rivers and lakes were important as cultural heritage. *'Every river and lake is our cultural and natural heritage. If they are not there, it [our heritage] will be somehow poorer*', explained respondent (M05).

Regarding provisioning services, many respondents attributed fish and fresh water to lakes and rivers in all three settlements. Fish were used for their own consumption, and often fishing was considered a recreational activity. Regarding fresh water, respondents explained that water from rivers was important for watering their fruit and vegetable gardens. Some respondents also acknowledged the importance of lakes and rivers as a habitat for species (supporting services) such as fish and birds. For example, respondent (B41) shared the significance of a lake in their village by saying, *'We have a lake here. The lake was very, very important for our village. In summer, children used to swim there, people sunbathed, relaxed, and fished. Our lake was specially stocked with fish. People caught grass and silver carp there. It was a great place to relax. There were also ducks, and swans. It was very good for the soul.'*

After de-occupation. The war also impacted people's relationships with lakes and rivers (Fig. 6b). The most devastating change occurred in Demydiv, where the water dam on the Irpyn River was destroyed by the Ukrainian Army to prevent the Russian occupation forces from advancing on Kyiv, Ukraine's capital. The river water flooded a vast area, including people's houses, fruit and vegetable gardens, grasslands, and arable land. This drastic change in the natural environment has profoundly impacted people's relationships with their surroundings in Demydiv, resulting in new ecosystem services and disservices.

Despite the continued use of lakes and rivers by many respondents in all three studied settlements, the variety and abundance of ecosystem services associated with these water bodies had declined. Most respondents lost multiple cultural ecosystem services, such as opportunities for recreation, a sense of place, and places for social and family interactions. Additionally, the proportion of respondents who relied on these ecosystems for fish and fresh water has decreased as well. At the same time, the proportion of respondents who acknowledged the importance of lakes and rivers for species and as habitats had increased in Demydiv.

In relation to cultural ecosystem services, lakes and rivers were no longer frequented for recreational purposes as extensively as prior to the war, and they ceased to be regarded as hubs for social interactions and family bonding. Respondents observed a deterioration in water quality in some lakes due to the presence of grenades and mines, leading to a reluctance to visit these areas due to extended mental trauma. As respondent (B34) explained, *'During the initial year after de-occupation, I couldn't bring myself to visit the lake where I encountered the Russians. It held too many painful memories. However, with time, I managed to overcome these associations and replace them with positive emotions.'* Some respondents admitted that they still used rivers and lakes in and around their settlements for recreation, but only in places they considered safe and free from explosives. When it came to other cultural ecosystem services with a strong emotional component, such as inspirational, spiritual, and aesthetic values, only a few respondents associated these with lakes and rivers. Their answers were brief, describing them as 'my lake', 'beautiful,' and 'gives energy.'

In relation to provisioning services, respondents noted that while they still engaged in fishing, it lacked the joy and frequency it once had. As expressed by respondent (B15), '*We only went fishing twice this summer. It used to be a source of fun and joy to visit the lake. Now, amid the ongoing conflict, it doesn't feel the same.*' In Demydiv, where the water covered a vast area after the dam was destroyed, fishing became more accessible. Many respondents commented that they did not have enough time to go fishing, citing various reasons: some had volunteered to assist people in the Army, while others needed to work more to financially support their families after losing loved ones, such as spouses, mothers, or fathers. Another reason to stop fishing was the decline in water quality due to contamination from explosive residues from mines and ordnance, which also affected the taste of the fish. As respondent (D17) explained, *'We went fishing with the children. First, there was an unpleasant smell from the water itself, and second, the fish had a bad odor. We simply released the fish. The children caught it, but we let it go because it didn't look appetizing, and we didn't want to eat it'*. Despite the overall decrease in the proportion of respondents who fished, some explained that they started fishing because, due to the flooding of the Irpyn river mentioned above, some in Demydiv could now '*fish from their house thresholds*' (D01).

Regarding supporting services, an increasing proportion of respondents in Demydiv acknowledged the importance of lakes and rivers for species and habitats. Respondents admitted that removing the river dam caused many troubles for families in the village, but they also enjoyed seeing the influx of birds. Respondent (D03) noted, '*Swans, ducks, and various birds have arrived. It's beautiful.'* Another respondent (D01) elaborated, '*To be honest, I wouldn't mind having this 'sea.' It is nice here when I go out with my fishing rod from the garden, sit down, and see so much wildlife—ducks, swans, herons. If they release the water so that people don't have water in their houses and gardens, I would be happy if the water stayed here. There will be some wildlife, fish.'*

3.5. Perceived ecosystem services attributed urban greenspace prior to the war and after de-occupation

Prior to the war. Regarding urban greenspace, respondents in Demydiv and Borodianka attributed only cultural services, viewing these areas as places that provided opportunities for recreation, family bonding, and social interaction (Fig. 7a). Respondents in Moshchun explained that there was no greenspace in their village as the forest was just 'behind their doors'. Many respondents complained that there were not enough green areas in their settlements where people could meet and rest.

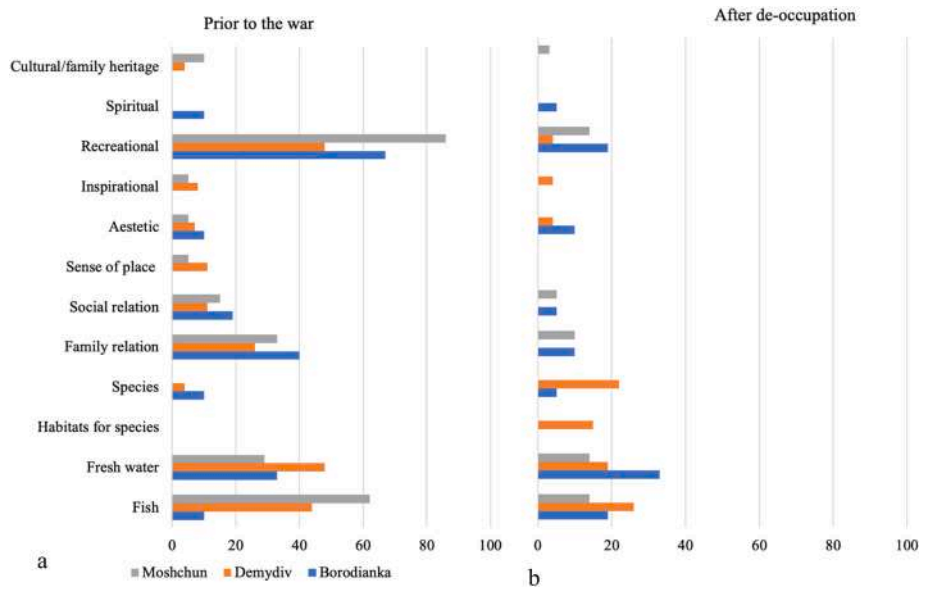

Fig. 6. Ecosystem services attributed by respondents (in % from the total number of respondents in each settlement) to lakes and rivers in Moshchun, Demydiv and Borodianka prior to the war (a) and after de-occupation (b) in 2022. *Note: The percentages represent responses within a non-representative, purposively selected sample. The figure is intended to illustrate qualitative trends and differences in ecosystem service perceptions across settlements and time periods rather than provide statistically generalizable findings.*

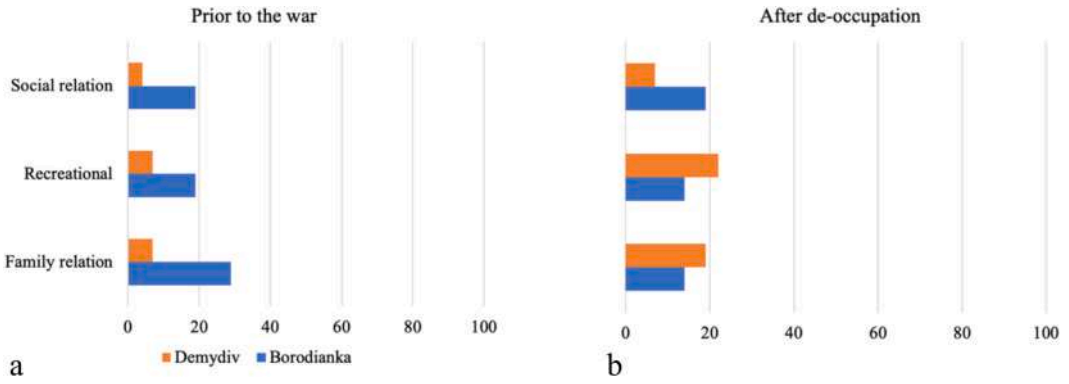

Fig. 7. Ecosystem services attributed by respondents (in % from the total number of respondents) to urban greenspace in Moshchun, Demydiv and Borodianka prior to the war (a) and after de-occupation (b) in 2022. *Note: The percentages represent responses within a non-representative, purposively selected sample. The figure is intended to illustrate qualitative trends and differences in ecosystem service perceptions across settlements and time periods rather than provide statistically generalizable findings.*

In relation to arable land and grassland, respondents commented that they no longer used it. The grassland was mainly abandoned, while the arable land was rented out to farmers who lived in the region.

After de-occupation. In relation to urban greenspaces (Fig. 7b), those few land covers in this category that existed continued to provide opportunities for recreation, social interaction, and family bonding for most respondents. However, a few respondents noted that their use of urban greenspaces declined after the de-occupation. This decline in use was attributed to various reasons: some individuals were relocated to new areas after their houses were destroyed by bombs, urban greenspaces lost their attractiveness due to their proximity to destroyed houses, or people simply lacked the free time needed to visit these areas due to the numerous challenges they faced in sustaining their livelihoods.

At the same time, despite being dissatisfied with the quality of urban greenspaces, many respondents commented that these areas were important for people, especially for youth and women with children. These spaces were often the only places in the town where people could rest and socialize while feeling relatively safe.

3.6. Ecosystem disservices

Regarding ecosystem disservices, respondents raised concerns about forest management, particularly the extensive logging carried out by state forest enterprises prior to the war. They also expressed dissatisfaction with the garbage left near and in rivers and lakes. However, they did not suggest that these perceived threats to the local environment impacted the ecosystem services they associated with forests or water bodies. Therefore, we cannot attribute these complaints to perceived ecosystem disservices. After de-occupation, many ecosystem disservices emerged as a result of the war's impact on the natural environment. In Demydiv, they emerged as a result of the increased water level and the enlarged water body following the dam destruction. Among the disservices, respondents pointed out (i) an increased number of mosquitoes, (ii) poor quality of drinking water, and (iii) poor quality of fish. For example, respondent (D13) explained, *'In the summer, we have a lot of mosquitoes. There was a period when you would go outside in the morning, and your house would be completely covered with some kind of midges, so much that you couldn't see. In the evening or morning, you couldn't go out into the yard because they were everywhere. Yes, the environment has*

changed'. Regarding poor quality of drinking water, respondent (D42) explained, *'In short, the quality of drinking water is a catastrophe. We don't have drinking water in the wells anymore because the groundwater has risen so much that the wells are flooded, as are the cellars. Even my well, for example, at home is 13 m deep, but it's not suitable for drinking: everything is off the charts. The sanitary station and volunteer organizations did free water analyses, and everything is exceeded by 100 times'*.

4. Discussion

4.1. Effect of the war on perceived ecosystem services loss and human well-being

This study enhances our understanding of how armed conflict disrupts the relationship between people and nature, impacting various dimensions of human well-being – an area that remains underexplored. The concept of ecological embeddedness in human well-being is an emerging field of research (King et al., 2014). Scholars emphasize that the linkages between ecosystem services and well-being are context-specific, place-based, and time-dependent (Wu, 2013; Petrosillo et al., 2013). Our findings demonstrate that the loss of ecosystem services in war-affected areas created multiple pathways of disruption, each highlighting how ecosystem service loss influences distinct dimensions of well-being.

First and foremost, the war severely disrupted the cultural ecosystem services that respondents associated with different land covers. We argue that the loss of these services had a profound impact on their mental and physical health, as well as on their social relationships – two dimensions of human well-being. Prior to the war, natural spaces such as forests, gardens, and water bodies provided emotional solace, recreational opportunities, and spaces for family and social bonding. Many respondents highlighted their deep cultural connection to the local environment, including spiritual ties to nature, often referring to it as their 'home'. This is a clear reference to the role of local nature as a significant element of place identity, which aligns with previous findings (Lewicka, 2011), but also sheds light on nature's importance in a stressful situation. However, after de-occupation, fear of landmines and contamination restricted access to these spaces. The war disrupted family and community practices that depended on the natural environment, eroding traditions and communal activities – such as celebrating cultural events – that had previously reinforced social bonds and collective identities. The destruction of forests, gardens, and water bodies caused profound cultural dislocation and grief. Respondents shared the emotional toll of losing nature that was central to their lives and heritage. Additionally, the erosion of intergenerational knowledge of nature-based practices further weakened community ties. While some respondents adapted by gardening in smaller spaces or seeking alternative sources of cultural fulfillment, the cultural void left by the war-related damage to nature remains deeply significant. These findings highlight the importance of non-material values associated with nature for human well-being (Daniel et al., 2012; Schaich et al., 2010; Bieling, 2014; Plieninger et al., 2013). Nature has long been shown to possess buffering qualities during times of stress (Gunko et al., 2022b), and our findings align with broader research emphasizing the positive impact of natural environments on mental and physical well-being (Gunko et al., 2022c; Russell et al., 2013). The therapeutic potential of these cultural ties to nature holds profound implications for individual and community well-being, particularly in the reintegration of civilian populations and ex-soldiers post-conflict (Loucks et al., 2009).

Secondly, the war severely disrupted access to essential ecosystem services that provided basic materials for a good life. Forests offered resources like berries, mushrooms, and firewood, gardens supplied staple crops, and water bodies supported fishing and irrigation. However, military destruction, contamination by unexploded ordnance, and flooding severely undermined these services. As mentioned above, flooding in Demydiv rendered gardens unusable, while phosphorus bomb contamination in Moshchun made the soil infertile. Limited access to forests due to landmines further exacerbated resource scarcity. Our study also reveals that, before the war, activities such as gathering non-wood forest products, fishing, and gardening were deeply embedded in local culture. Thus, we argue that the loss of provisioning services was not only a loss of material resources but also of cultural ecosystem services, with profound implications for health and social relations.

Therefore, our study demonstrates that the perceived loss of ecosystem services due to the war directly impacted three of the five key dimensions of human well-being mentioned above: basic materials for a good life, health, and social relations. Additionally, we argue that security – the fourth dimension – was also significantly affected through various pathways stemming from the disruption of ecosystem services. Physical security was compromised by the presence of landmines, unexploded ordnance, and other hazards in previously accessible natural spaces. Fear of injury or death prevented people from using forests, rivers, and gardens – spaces that had once provided sustenance, recreation, and cultural identity. This restricted access created a pervasive sense of danger. Furthermore, the disruption of cultural ecosystem services contributed to psychological insecurity. Respondents described how fear of contamination and the destruction of landscapes deepened feelings of instability and loss. The inability to access spaces once associated with solace and spiritual connection undermined their sense of safety and well-being. Finally, the erosion of social cohesion – exacerbated by the loss of shared traditions and communal activities – also undermined social security. People experienced greater isolation, which reduced the collective resilience necessary to navigate the challenges of recovery. Therefore, our findings suggest that the war-induced loss of ecosystem services not only disrupted material, social, and emotional well-being but also had profound implications for security. Addressing these intertwined dimensions in post-conflict recovery is crucial for fostering a comprehensive sense of safety and stability in affected communities.

Our study also reveals that the majority of respondents did not explicitly associate their well-being with supporting ecosystem services. This finding aligns with broader research indicating that people often have a more immediate and tangible connection with provisioning, regulating, and cultural services, as these directly affect their daily lives (MEA, 2005; Díaz et al., 2018). Supporting services, despite being fundamental to ecosystem functionality, tend to be overlooked in public perception because their benefits are indirect and less visible in short-term well-being assessments (Costanza et al., 2007; Reyers et al., 2013; Bennett et al., 2015). This gap in perception may have significant implications for policy efforts, as it suggests that conservation and ecosystem management strategies should include more educational and participatory approaches to highlight the importance of supporting services in maintaining long-term well-being (Chan et al., 2012; Kadykalo & Findlay, 2016).

4.2. Gardening and interaction with nature for healing and recovery during the war

Our study reinforces emerging evidence on the critical role of nature and gardening in both community and individual recovery, not only after but also during armed conflicts (Krasny and Tidball, 2012; Krasny et al., 2015). The findings demonstrate that private fruit and vegetable gardens became vital spaces for both cultural and provisioning services after de-occupation, even amid the ongoing war. Despite widespread destruction, respondents' deep attachment to the land motivated them to restore their gardens, which not only reestablished a sense of normalcy but also provided a therapeutic outlet to cope with trauma. Gardening offered both a purpose and a means of enhancing mental well-being. Similarly, urban green spaces, though limited before the war, gained new significance after de-occupation. They became essential refuges, particularly for youth and women with children, serving as substitutes for lost recreational opportunities in forests and lakes. These

spaces facilitated social interactions and emotional recovery, mirroring patterns observed in other post-conflict contexts (Tidball and Krasny, 2013) and underscoring the crucial role of green spaces in fostering resilience and well-being.

Building on the frameworks of Stedman and Ingalls (2014) and Tidball and Krasny (2010), we argue that post-de-occupation gardening as a form of greening practice and increased importance of urban green spaces in the studied settlements are deeply embedded in the intersection of biophilia – the innate human affinity for nature—and topophilia – the emotional attachment to place. Biophilia reflects an inherent human tendency to seek environments that provide safety and sustenance, both of which are fundamental to well-being (Stedman and Ingalls, 2014). This was evident in our findings, as respondents frequently described their local forests as a 'home' where they felt safe. Topophilia, introduced by Tuan (1974), reflects the deep emotional bonds individuals, social groups, and communities form with specific places or socio-physical landscapes, shaped by personal, cultural, and historical ties. These attachments play a critical role in enhancing mental and social health (Stedman and Ingalls, 2014). Previous research highlights how greening actions in post-conflict or post-disaster contexts not only restore the natural environment, but also promote social well-being, providing opportunities for biophilic expressions (Tidball and Krasny, 2014). Similarly, topophilia suggests that greening practices both emerge from and further strengthen place attachment.

We emphasize the need for further research to deepen our understanding of why individuals form strong attachments to specific places and how these attachments drive engagement in environmental stewardship and restoration efforts – not only in post-conflict periods but also during active armed conflict. Unpacking this relationship is essential for enhancing greening practices both during and after war, where fostering human well-being and strengthening community cohesion are critical. By investigating the emotional and cultural drivers behind community-led environmental initiatives, we can gain valuable insights into how these practices promote long-term engagement in nature restoration. Given our findings, we urge policymakers to recognize and integrate the therapeutic benefits of nature into future restoration strategies for Ukraine.

4.3. *Post-war restoration of nature for human well-being: where to start?*

There are number of implications for restoration of damaged environments that follow from our results. Though the word "restoration" is used frequently when discussing how to alleviate environmental damage, we need to unpack this term to ensure we understand what is actually meant. First, ecological restoration has been criticized, among other things, for an overemphasis on specific past ecosystems as a guide for restoration, for ignoring or downplaying important social aspects of restoration projects, and more broadly because restoration to a "pristine" pre-disturbed condition is actually quite difficult in a world undergoing drastic environmental change (Hobbs et al., 2011). In response, there have been calls for ecological restoration to be "future oriented"; to openly recognize the "value-laden" nature of the endeavor; and to redefine the goal of restoration as "rehabilitation", i.e. putting ecosystems on a sustainable trajectory, instead of restoring to a historical state (Choi, 2007; Hobbs et al. 2011; Martin 2017).

Second, the literature on ecological restoration has traditionally looked at restoring abiotic or biotic systems, or more recently, ecosystem processes or functions. However, it has been noted that recovery in damaged ecosystems does not always entail improvements in ecosystem services provided by these ecosystems (e.g. Shimamoto et al. 2018). Given this, some scholars argue that restoration should more explicitly target improvement in ecosystem services (Carlucci et al., 2020; Kollmann et al., 2016). Alexander et al write (2016, p. 34) in this regard: "in practice, the key challenge is to identify the type of intervention needed to reinstate particular ecological processes and functions and thereby generate the ecosystem services required or desired in a given context.".

Finally, the related concept of regenerative landscape design (Smithwick et al 2023) provides additional helpful clarifications about the restoration task facing Ukraine. Regenerative landscape design (RLD) is defined as a "process for finding pattern-based solutions, emphasizing cooperative, iterative, and facilitated engagement for the co-production of locally relevant knowledge for desirable landscape stewardship." (ibid, 5). Several aspects of RLD are important for our case here. First the word "process" indicates that the restoration challenge is not delimited to a set of one-off interventions, but is rather a longer-term challenge. Second, "pattern-based solutions" refers to the need to ensure that restoration measures address the long-term and systematic causes of ecosystem disruption. We have primarily discussed war damage in this paper, but our respondents mentioned ecosystem disruptions occurring from e.g. unsustainable logging before the war (see Section 3.6), and these would have to be addressed as well to ensure proper restoration. Third, we have already mentioned above the importance of involving local communities, but this definition emphasizes sustained and "iterative" engagement to build up and continually update the knowledge base needed to push disturbed ecosystems towards a more sustainable trajectory. Sustained engagement, plus iterative learning is needed as the specific challenges involved with restoring these ecosystems are likely to evolve over the long-term. Finally, the landscape scale is important. In this paper we have spoken of land covers, however our area of interest can be delimited as a landscape, and this delimitation helps to focus attention on the ecosystem services to be prioritized. RLD should not be seen as a separate endeavor from restoration, but rather a complementary concept that emphasizes and develops aspects that are relevant and discussed in the broader literature on ecological restoration.[1]

Keeping the above in mind, we see restoration of environments in Ukraine as a forward looking and long-term process that prioritizes improvement or recovery in ecosystem services (as discussed above) and that is in line not only with the "common values and beliefs" (Martin, 2017) of affected people, but actively involves local communities in a such a way that there is iterative social learning as the restoration progresses. Importantly, emphasis should be placed on "restoring" cultural values and emotional attachments connected to specific land covers, though this aspect – as noted above – requires more research. Currently, the dominating slogan when discussing reconstruction in Ukraine is "build back better." On the one hand this slogan expresses an important objective – not just to rebuild, but to improve. On the other hand, the slogan of build back better is as yet a diffuse concept without proper definition and there is a risk that different groups define it differently. We argue in this regard that the principles of ecological restoration and RLD that we have put forward here could serve as appropriate animating and unifying principles for "build back better", at least as far as rectifying damage to landscapes and environments caused by the war.

These clarifications on restoration help illuminate the task ahead, but at the practical level questions remain on what to prioritize. The principles outlined above and the findings of this study underscore the critical need for comprehensive and community-inclusive approaches to ecosystem restoration and management in post-war areas. Restoration efforts should prioritize not only the physical rehabilitation of ecosystems but also the restoration of the cultural and spiritual connections that communities have with these natural environments crucial for their well-being. Here, we would argue that centering people-nature relations in general, and our empirical results in particular, can suggest some answers. Our respondents tended to stress cultural ecosystem services and the overall positive impact of close contact with nature on well-being. As noted above the trauma of war and occupation may have

[1] See for example Méndez-Toribio et al (2021) who in an overview of restoration projects in Mexico stress the importance of "collaborative monitoring" involving local communities, leading to "social learning and adaptive management" over the long-term.

accentuated these aspects in the minds of respondents. In any case, given the importance that respondents attached to these aspects, we argue that these aspects should aid in prioritizing restoration activities, and have in mind two specific priorities.

The first priority is to restore the most valuable ecosystems and ensure access to them, as they are crucial for the well-being of local communities. Our study shows that, following de-occupation, fruit and vegetable gardens have become essential for (re)establishing a sense of connection and belonging, as well as for overcoming psychological trauma. Another priority is the demining of forests. Currently, forests in our study areas are inaccessible due to the presence of mines and unexploded ordnance. Given the importance that current residents (after liberation) place on forests and gardens, we speculate that restoring land for gardens and gardening and ensuring safe access to forests could even encourage people to return to these areas. Additionally, urban greenspace should be expanded and improved to provide the community with safe and accessible recreational areas. These spaces can serve as critical areas for social interaction and community rebuilding in the aftermath of war.

The second priority would more explicitly embody the restoration principles outlined above to not prioritize fidelity to past landscapes, but rather work to set damaged environments on a new, but sustainable trajectory, in a way that balances the local community's needs and preferences with respect to ecosystem services and disservices. Above, we reported on the difficulties faced by the inhabitants of Demydiv, who have experienced significant flooding due to the dismantling of the dam on the Irpin River. While it is imperative that the authorities now address the resulting flooding, we noted several positive comments about the new wetlands that have developed from the released water. Residents appreciated the wildlife that has appeared in these new wetlands and the opportunities for fishing, including in areas close to their homes. In other words, even amid the various ecosystem disservices (such as flooding, mosquitoes, and bad quality water affecting the quality of fish) caused or facilitated by the dismantling of the dam, respondents also highlighted some ecosystem services arising from the new wetlands that benefit recreation and well-being. A forward-looking restoration solution would seek to rectify as many disservices as possible while preserving some of the new ecosystem services that have appeared. This would involve preventing the flooding of houses, and restoring now flooded land for gardens, while preserving at least some of the newly created wetlands. Such restoration priorities could be seen as a practical exemplification of "building back better".

5. Conclusions

This study highlights the profound impact of war on the relationship between people and nature, emphasizing the significant loss of ecosystem services and the cultural connections that once sustained local communities. The findings reveal that forests, water bodies, and gardens played crucial roles in providing both material and non-material benefits before the war; moreover, their destruction and restricted access due to landmines, flooding, and contamination have severely disrupted human well-being. Cultural ecosystem services, in particular, were central to respondents' lives, with nature serving as a space for recreation, social bonding, and emotional healing. The disruption of these services has led to a psychological and social void, exacerbating the trauma experienced by war-affected populations. However, the study also underscores the resilience of communities, as many individuals actively sought ways to restore lost connections with nature, whether through rebuilding gardens, adapting to new landscapes, or finding alternative means to sustain traditions. These insights reaffirm the necessity of integrating ecological restoration with social recovery efforts in post-war regions to ensure that environmental rehabilitation aligns with community needs and cultural values.

Moving forward, post-war restoration strategies in Ukraine must prioritize both ecological and social dimensions to support long-term recovery. A future-oriented approach to restoration – one that acknowledges the dynamic relationship between people and nature – should focus on rehabilitating ecosystem services that directly contribute to well-being while also fostering cultural and emotional reconnections with landscapes. Demining forests, restoring gardens, improving urban greenspaces, and preserving newly formed wetland habitats are critical steps in this process. Additionally, policies should actively engage local communities in decision-making to ensure that restoration efforts reflect their lived experiences and priorities. The study's findings emphasize that rebuilding natural environments is not just about ecological repair but also about restoring a sense of place, security, and resilience for war-affected populations. By centering people-nature relationships in recovery efforts, Ukraine can create a more sustainable and inclusive path toward healing and post-war regeneration.

CRediT authorship contribution statement

Marine Elbakidze: Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Brian Kuns:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Ruslan Gunko:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Ivan Kruhlov:** Writing – original draft, Software, Formal analysis. **Olena Maslyukivska:** Writing – original draft. **Victor Karamushka:** Writing – original draft. **Olha Adamenko:** Formal analysis, Data curation. **Oleksandra Holub:** Data curation. **Liudmyla Kleba:** Data curation. **Yuliia Melnyk:** Data curation. **Yana Mylysiuk:** Data curation. **Olha Pidust:** Data curation. **Ivanka Slobodian:** Data curation. **Yevheniia Tkachenko:** Data curation. **Taras Yamelynets:** Data curation, Conceptualization.

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Appendix 1. The interview manual

I. **Use of nature prior to the war**
Which types of natural environments were most valuable in ensuring your well-being, your family, and your community before the war?
- Forest
- River, lake

- Community lands (pastures, arable land)
- Private garden
- Urban green spaces
- Protected areas

Forest:

What was most valuable to you, your family, and your community?
How did you use the forest?
What forest products did you use? How much (berries, mushrooms, firewood, etc.) did you collect? For personal use or for sale?
How often did you visit the forest for recreation?
How would you assess the condition of the forest before the war?

River, Lake:

What was most valuable to you, your family, and your community?
How did you use the river/lake?
What resources did you collect? How much? For personal use or for sale?
How often did you visit the waterbody for recreation?
How would you assess the condition of the river/lake before the war?

Community-owned pastures and arable land:

What was most valuable to you, your family, and your community?
How did you use these lands?
Did you receive income from agricultural lands now flooded or otherwise affected? What type of income (salary, rent, etc.)? How much?
How would you assess the condition of the land before the war?

Protected areas (PA):

What was most valuable to you, your family, and your community?
How did you use PA?
How often did you visit protected areas for recreation?
How would you assess the condition of the PNA before the war?

Private personal garden:

What was most valuable to you and your family?
How often did you work in your garden?
How did you use your garden/orchard?
How much income did you generate from selling homegrown produce?
What products did you harvest? How much? For personal use or for sale?

Urban green spaces:

What was most valuable to you, your family, and your community?
How did you use urban green spaces?
How often did you visit green areas for recreation?
Were you satisfied with the condition of green spaces before the war? Rate from 1 (very poor) to 5 (very good). Please explain your rating.

II. **Use of nature after de-occupation**

Forest:

What is most valuable to you, your family, and your community now?
How do you use the forest now?
Has the presence of mines and unexploded ordnance affected access to the forest?
What forest products do you use now? How much do you collect? For personal use or for sale?
How would you assess the condition of the forest now?
Have these changes affected your well-being? Your family? Your community?
How often have you visited the forest since the full-scale invasion on 24/02/2022?
How often have you collected berries, mushrooms, or other resources since 24/02/2022?
Have you started visiting forests further away? How far? Where? How often?

Waterbodies:

Why is the river/lake still important to you? How do you use it now?
Have you changed how you use the river/lake? If so, how and why?
Has the presence of mines and unexploded ordnance affected access?
Have you noticed changes in the condition of the waterbody? What changes? Why?
What impact do these changes have on your well-being?
How often have you visited the waterbody since 24/02/2022?
How often have you fished or collected resources from the water since 24/02/2022?
Have you started visiting other waterbodies further away? Where? How often?

Community-owned agricultural lands:

Show on the map the land you use now.
Why are they important to you now? How do you use them now?
Has the presence of mines and unexploded ordnance affected access?
Have you noticed changes in the condition of the land? If so, what changes?
What impact do these changes have on your well-being?
Has the war affected your agricultural income? How? Rate your income loss or increase

Protected areas (PA):

Has the use of PAs changed? If so, how exactly and why?
Have you noticed any changes in the condition of the PAs?
Have the presence of mines or remnants of shells affected access to the PAs?
What are the consequences of these changes for your well-being, your family, and your community?
Has the frequency of your visits to protected areas near your settlement changed since the full-scale invasion on 24/02/2022? If so, by how much?
Have you started traveling to other recreational areas since the full-scale invasion on 24/02/2022? Where and how often?

Private personal garden:

Has the way you use your garden changed? If so, how exactly and why?
Has the condition of your garden (or orchard) changed? If so, how exactly and why?
How often do you currently work in your garden?
What are the consequences of these changes for your well-being and your family?
Have military actions affected your income from agricultural activities? If so, how exactly? Please estimate the extent of income loss or, on the contrary, any benefits gained. For example, has there been more or less space for grazing livestock?

Urban green spaces:

How do you currently urban green spaces?
Has the condition of green areas changed? If so, how? Why?
What are the consequences of these changes for your wellbeing and your family?
Have you started visiting green areas farther from your settlement? How often? Where exactly?

Data availability

The data that has been used is confidential.

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