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After-The-War Recovery of the Environment of Ukraine: the Vision and Provision

The war in Ukraine has caused significant losses and damage to the environment; the cost of its post-war restoration is already estimated by experts at more than USD 1 trillion. The paper presents key approaches to restoring Ukraine's environment in the post-war time. Necessary measures to recover forests, rivers, lands, and biodiversity are presented. Special attention is paid to the necessity of adaptation of environmental legislation to European standards, environmental modernization, and the implementation of innovations, the ways to improve the national system of administration financing the environmental policy in Ukraine as well as the importance to significantly restructure and improve the national system of environmental management.

Keywords: *natural resource, environment, ecosystem, natural reserve, protected area*

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Introduction

Ecocide in Ukraine happened due to the war, which the Russian Federation started in 2022. It caused many ecological risks and threats for Ukrainians and future generations. The post-war renovation of the affected areas will cost at least 1 trillion USA dollars, and it is important environmental restoration and ecological modernization will be taken into account as well. For instance, it is essential to introduce renewable energy if rebuilding the energy infrastructure. Reforestation should be carried out simultaneously with forest extra-protection. New build-

ings have to be constructed keeping the European energy efficiency standards and using waste-free and recycling technologies. In other words, the future of Ukraine should be as green as possible.

Restoration of roads, bridges, energy infrastructure and water supply networks should be managed by the Government at the expense of loans and foreign financial assistance. Private companies instead will finance water purification in small rivers where pieces of military equipment fell into. Also business entities are nice in

the recovery of natural parks and reserves since authorities usually are too slow in solving local challenges associated with communities and ecosystems.

The cooperation can be particularly efficient for the restoration of ecosystems. That is because ecosystems usually are very vulnerable to the consequences of military actions and do not get much attention and funds from the national environmental agencies. The Ministry of the Environment of Ukraine estimated the corresponding damage at over 1 trillion hryvnias. Damage from air pollution cost 923 billion hryvnias, and 138 billion hryvnias to soil and land. The nature has no borders. As 40 oil depots have been destroyed in Ukraine, over 499.000 tons of toxic substances were released into the atmosphere. Because of the explosions, more than 46 million tons of pollutants got into the air.

Literature review

Environmental consequences of the war in Ukraine are described and estimated by many Ukraine's and foreign academicians [1, 5]. Usually, they discover the current situation and prospects and also study supplying points like social aspects of the recovery [3] and the urban space scenarios [6]. Many researchers make proposals on how Ukraine can go "green" on the post-war recovery path [2]. Some economists and environmentalists study impact of the warfare on certain elements of the environment like rivers [4], soils for agri-industry [7], and solar energy for households and communities [9].

In the post-war reconstruction course, Ukraine should not rely on foreign experience only. The situation, starting points, circumstances, and effects are unique a lot. It is worthy to apply the national experience of grassroots cooperation and involve donors, volunteers, non-profit organizations, and local businesses [10, 11]. Taking into account the European aspirations of Ukraine, it seems that the academicians make more efforts to discover how the circular economy's ideas can be applied in Ukraine on the way to integration into the EU in order to direct sustainable management [8].

Results

Recovery of the environment in Ukraine means the opportunity to restructure the national system of planning and management of the nature use accompanying the implementation of short- and long-term environmental policy measures. The environmental restoration measures are diverse in directions, spheres of the nature use, scale and complexity. The measures include elimination of the warfare consequences, assessment, and verification of the environmental damage and losses, development of technical plans for the environment's restoration, fundraising, the plans' implementation, and follow-up monitoring. Compared to the pre-war time, the measures listed above will need much more effort and funds. Still, there is not enough relevant experience.

In the open warfare zones all the nature's components suffered: waters, lands, forests, nature reserves, air, landscapes, and animals. The damage was caused also to entire ecosystems. In order to reduce the damage the environment should be restored completely on the affected area and as soon as possible. It includes reforestation planting fast-growing tree species, bringing plantations closer to natural forests, implementing technologies improving water filtration and purification, cultivating lands and soils with poly-crops and organic farming, introducing endangered biological species, and recovering their habitat.

Sometimes the environment should be restored even if the war battles did not hit the area. Usually, warfare results ordinal the nature protection measures are not carried out in time. Mainly it concerns forest restoration and care, ongoing repairs of water infrastructures, and land cultivation. Taking it longer usually causes the deterioration of natural resources and degradation of the environment.

Dependence of the world on Ukrainian grain definitely will raise the value of arable lands and add to the domestic agri-industry's output. It should take place together with the agricultural and environmental policy approximation to the EU *acquis communautaire*. In order to provide full-scale agricultural production in Ukraine, it is necessary to inspect the quality of soils in the hurt areas. It will help to prevent cultivating crops on contaminated soils. Additionally, as a

candidate country for the EU, Ukraine has to implement the EU Biodiversity Strategy until 2030, which declares the enlargement of protected areas, stimulus to organic agriculture, reduction of pesticide application, and protection of free-flowing rivers. The Forestry Strategy of the EU until 2030 announces the same goals.

Concurrent tasks of environmental restoration and approximation to legislation of the EU will be both an advantage and a difficulty for Ukraine in the post-war time. Since it is planned to turn Europe into a climate-neutral continent by 2050, the mitigation of climate change will continue. The intention to refuse the import of Russia's oil and gas will smooth the way for the development of green energy in Ukraine and Europe. It will impact into reduction of greenhouse gas emissions. The Ministry of the Environment estimated the direct damage caused by Russia to the climate up to 31 million tons of emissions.

Perfection of the areas' planning system is one more important task for environmental restoration. After-war targeting of the areas not always will be the same as before the war. In some cases, it will be better to afforest agricultural lands or, conversely, use areas of dead forests for agri-industry. The better way of land use means reduction of arable land share and enlargement of forests. Some attention should be paid to the restoration of areas inside or near towns and villages. It is better to apply landscape design techniques and turn destroyed areas into green parks. At the same time, ecologically valuable land should be conserved in order to prevent construction on coastal areas and damage to floodplains.

After the war, many natural resources will be extracted and used for the national economy's recovery. It means economic needs should be matched with ecological goals, and all the sustainable development components like ecological (restoration of the environment), economic (reconstruction of the national economy), and social (social support to people) should be well-adjusted. And one more element has to be added. That is consolidation of territorial communities and their involvement in the management of nature. The administration and management of ecosystem services will change drastically. Particularly, digital tools will be widely applied.

According to the Environmental Performance Index, even before the Russian invasion in February 2022, air quality, biodiversity and ecosystem health in Ukraine were poor. After the war started, the environmental situation has been getting worse and worse. Ukraine is the fourth in Europe by the number of deaths caused by air pollution. That is why combatting air pollution is an urgent task. In 2021 15.5% of urbans and 6.2% of rurals considered coal dust and other environmental issues like smog, unpleasant smells, polluted water, etc. as the urgent problem. At the same time, 9.1% of urban residents and 3.3% of villagers noted noise pollution (noise caused by neighbors, and outdoor noise like traffic, enterprises, and so on bothered them a lot).

Since the environmental situation worsened a lot because of military actions like fires at oil depots, explosions at chemical enterprises, it is important to introduce modern technologies for cleaning gas emissions from chemical, petrochemical, and other harmful substances. In 2020 emissions of methane, sulfur dioxide, and carbon monoxide constituted over 400 thousand tons each. The situation with wastewater is similar: 3.316 cubic meters of wastewater were dumped into surface water bodies without processing. So, it will be necessary to adopt new standards for air emissions and wastewater.

In order to raise the necessary finances for environmental restoration measures it is worth reforming the Environmental Fund of Ukraine, separate the Fund's administrative body, and transform it into a Fund for the environment's restoration. Expectedly, the fund will get finances from Russia as compensation for the environmental damage. Another optional source of the financing is selling of carbon certificates. Hopefully, after the war Ukraine will be more attractive for investments, and environmental requirements for investment projects will be strictly observed. In order to consolidate communities and support civil society's entities, public agencies, private enterprises, local authorities, and NGOs should get access to foreign grants for environmental restoration. Primarily it concerns local projects and grassroots initiatives.

A special agency or sub-division at the Ministry of the Environment should be established in order to provide rapid and overall restoration of the environment. An agency has to join efforts of various experts, academicians, and stakeholders.

One of the tasks will be to monitor and control the efficiency of the recovery measures. Instead, businesses have to co-implement the recovery measures. Consequently, national authorities will respond to elimination of pollutants, public and private enterprises will carry on afforestation, local authorities will reproduce steppe ecosystems, and public organizations will restore parks and green sites. Hopely, we will find opportunities in difficulties and after the war, Ukraine will get a chance to implement many innovations to restore the ruined environment.

Forests

Around 3 million hectares of forests are affected by the war in Ukraine. Death of flora and fauna will have long-lasting effects, and it may happen earlier biodiversity will be recovering in centuries. Sharp termination of international biodiversity conservation projects has a negative influence on the forests. Frequently it happens because territories are mined and a staff has no safe access to forests. The redirection of the responsible forest services like forest firefighters to the front line also caused forest areas to become more vulnerable to any emergency cases.

However, many countries have positive experiences of reforestation under the same situation. In Germany, an appropriate demining method was applied. It means constrained firing in forests with special equipment. Forests are specially fired up to the floor and mineral layers of the soil in order to detect ammunition remnants. In order to escape wildfires the method should be used only in early spring and with no wind. Unfortunately, the method is not appropriate in the case of anti-tank mines, which usually hide deeper than a mineral soil's layer. And the worldwide experience reveals that forests frequently stay partially or completely mined and the visits are prohibited. Those forests get special status and turn into exclusion zones.

Until February 24, 2022, in Ukraine, forests contaminated with ammunition were located only in some areas of Luhansk and Donetsk regions. However, those forests had not got any special category or a regime. Today, according to the UN, Ukraine is one of the most mined countries in the world. Over 80.000 square km of the country's areas have to be cleared from explosive remnants. The situation with forests

in Chornobyl zone is even harder. In 2022, the worst fires happened in the zone. It proves the damage of the war to the environment is huge and long-lasting. The very point is all vegetation in forests is flammable.

Lands

Since 2014 in Ukraine around 150–180 thousand square km have been contaminated because of the warfare. It is up to 25–30 % of the entire area of the country. Places where people live have been polluted and 25.000 square km of arable land were damaged and contaminated with ammunition. Experts who clear areas from explosive remnants argue it is not possible to clear from ammunition more than 2.500 square m of arable lands in a day. It means 10 million people should be involved in order to eliminate the pollution. At a cost of 200 euros per day, complete elimination will cost up to 2 billion euros.

After an explosion, a part of the chemical substances becomes gaseous and another part falls down onto the soil as sulfur. When it rains, the sulfur comes into contact with water and turns into oxide or highly dangerous sulfuric acid. Most of the sulfur releases into the air, evaporates, or comes to the ground waters. Additionally, heavy metals contaminate the ground waters.

Because of the war in Ukraine thousands of hectares were bombed; hundreds of thousands of hectares were burned along with a harvest. Additionally to economic losses areas have been polluted with chemicals and explosive damages. As a result of explosions soil breaks and compactions happen, vegetation and soil fauna die. Consequently, the hydrolytic regime changes, the soil structure is destroyed, and erosion and desertification happen. Sometimes normal restoration of lands takes hundreds of years.

Usually, filling deep sinkholes and potholes (more than 0.5 m) up with soil is too expensive. The restored soils should be similar to normal areas, and the upper layer (20–30 cm) should be the most fertile. If an area was filled up chaotically, it results in low yield production. So, additional measures should be applied like organic fertilizers, pesticides, melioration, etc. One can leave an area and allow it to recover normally or be afforested. If there is no vegetation in a dam-

aged area, soil erosion usually occurs. In order to ensure the use of soils in the agri-industry, preliminary soils have to be demined and roughly reclaimed. Expectedly the restoration of the soil fertility will take decades depending on an area. It also will need substantial funding.

Water and rivers

Because of the warfare over 6 million of Ukrainians have no or limited access to clean water. Even before 2014 13 regions of Ukraine had water shortage. At the standards, a person should get about 2.000 cubic m of water per year. In Ukraine, the indicator varies from 1.000 to 1.700. In the war the water shortage becomes vital and in a few cases causes human and environmental disaster. For instance, many water supply systems were damaged in Mariupol because of massive shelling. Biological remains and discharges to sewages fell into rivers and the Sea.

Additionally to breaks of water supply, the water's deterioration occurred. Evidently, water purification facilities did not operate in Chernihiv, Mariupol, Mykolaiv, Rubizhny, Skadovsk, Slovyansk, and Vasylivka. Wastewaters discharged into the Dnipro River in Vasylivka and Mykolaiv. Sometimes water facilities were used for military or political purposes. For instance, on February 24, 2022, Kakhovska hydropower plant was captured. The goal was to control the North Crimean Canal, which is the primary source of water supply for the Crimea peninsula.

Since water supply is vital for civilians, its destruction, damage, or violation of the standards pose serious threats to the lives and health of people, as well as to the environment.

National parks and reserves

This caused destructive consequences for 900 protected areas with an area of 1.2 million hectares. That is about a third part of all the protected areas in Ukraine. Now 14 wetlands of international importance (397.7 thousand hectares), over 200 sites of the Emerald Network (2.9 million hectares), and 4 UNESCO biosphere reserves (123 thousand hectares) are endangered. Mine clearance usually results in craters appearing because of explosions, ecosystems deteriorating or dying. Also, the warfare means no environmental protection measures have been provided. Currently, the Ministry of the Environment

and Nature Protection estimates the damage to nature reserves from UAH 6 million to UAH 38 billion depending on the area and depth of the effect. Not all the species will be revitalized. Protected areas can recover either normally (with no human efforts) or with the establishment of new natural reserves in order to get back at least some part of the lost animals and plants.

The global experience proves the rationality of conserving and transforming lands into national parks if areas cannot be used for agricultural purposes. Castel National Park in Israel was created shortly after the end of the War for Independence. The Mediterranean forests having a special protective status still have trenches and bunkers of wartime. Currently, the park employees make tours in the forests and organize exhibitions in order to tell about the War and its price for the people. Gauja National Park in Latvia is very popular for tourists and visitors. The park is the largest one in the country, and it belongs to the Natura 2000 network. The park's area also includes sites of past liberation battles being important locations for cultural tourism and excursions. Thus, nature parks preserve not only biotopes, flora, and fauna, but also the memory of important historical events.

Currently, it is important to define a future strategy on the natural areas in Ukraine. It would be proficient to keep a normal work of the areas or use them in agri-industry. At the same time it is reasonable to conserve the areas in order to enable their natural recovery. The other approach is to protect the areas as sites of historical heritage and install memorial signs on sites where crucial battles happened. Battles reconstruction, regular excursions, and thematic festivals would impact a lot into both the local economy and the national memory of historic events.

The Parliament of Ukraine adopted the Law additionally protecting the state border and expanding the border strip up to two kilometers. The Law approves the procedure for withdrawing those areas from the Nature Reserve Fund of Ukraine. The fact is that the northern border areas are usually wild forests, swamps, and wetlands, which are a natural obstacle to the advance of the enemy's military equipment. So, the preservation of the natural areas is a point for national security. Currently, the two-kilometer strip along the northern and eastern state border of Ukraine has 120.000 hectares of the nature reserve lands,

and over half of these areas are objects of the Emerald network. The Polissia area along the Pripyat River is of high importance for the Central European climate regime. There are uninhabited and hard-to-reach places with most wild natural ecosystems to be protected.

Conclusions

The war in Ukraine caused the deterioration of waters, lands, forests, nature reserves, air, landscapes, and animals. In order to reduce the damage the environment should be restored. It means reforestation, preservation of natural forests, better water filtration and purification, cultivating lands and soils, introduction of endangered species, and recovering their habitat. Sometimes the environment needs to be restored even if the war battles did not affect the area, because the necessary environmental protection measures were not carried out in time due to military operations. Lands have been polluted with chemicals and explosive damage. As a result of explosions soil breaks and compactions happen, vegetation and soil fauna die. Consequently, the hydrolytic regime changes, the soil structure is destroyed, and erosion and desertification happen; thus, additional measures like organic fertilizers, pesticides, and melioration have to be provided. Since water supply is vital for civilians, its destruction, damage, or violation of the standards pose serious threats to the lives and health of people, as well as to the environment.

Protection of the destroyed natural reserves needs extra effort. Definitely, it is better to conserve areas that cannot be used for agri-industry. In that way, nature parks preserve biotopes, flora, and fauna, and sometimes natural areas are important locations for cultural tourism and excursions. Currently, it is important to define a future strategy on the natural areas in Ukraine. It would be proficient to keep a normal work of the areas or use them in agri-industry. It the same time it is reasonable to conserve the areas in order to enable their natural recovery. The other approach is to protect the areas as sites of historical heritage and install memorial signs on sites where crucial battles happened. Battles reconstruction, regular excursions and thematic festivals would impact a lot into both the local economy and the national memory of historic events.

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Напрями та ресурсне забезпечення післявоєнного відновлення довкілля в Україні

Війна в Україні завдала суттєвих збитків та шкоди навколишньому природному середовищу; вартість його повоєнного відновлення вже зараз оцінюється експертами у понад 1 трильйон доларів США. При цьому важливо, аби відновлення довкілля відбувалося одночасно з адаптацією природоохоронного законодавства до європейського, з екологічною модернізацією та впровадженням інновацій. Це, наприклад, більш широке впровадження відновлюваних джерел енергії під час відбудови енергетичної інфраструктури; будівництво житлових приміщень з дотриманням європейських стандартів енергоефективності та з використанням безвідходних і переробних технологій; проведення лісовідновлення з одночасними заходами додаткового захисту лісів.

Ще одним важливим завданням є удосконалення системи розподілу фінансів, відповідальності та зусиль між залученими сторонами та відомствами. Так, відновленням доріг, мостів, енергетичної інфраструктури, мереж водопостачання мають здійснюватися за рахунок кредитів та зовнішньої фінансової допомоги та під керівництвом центральних органів виконавчої влади. Натомість приватні компанії можуть фінансувати заходи з очищення малих річок та відновлення природоохоронних територій — адже центральна влада зазвичай занадто повільно вирішує локальні проблеми, пов'язані з повсякденним життям громад та щоденними умовами їх життя.

Відновлення навколишнього природного середовища в Україні означає також можливість суттєвої перебудови й удосконалення національної системи управління природокористуванням. Умови, наслідки та виклики, що стоять перед суспільством в частині відновлення довкілля, є безпрецедентними. Тому під час післявоєнної відбудови варто спиратися не лише на міжнародний досвід, але й на вітчизняні розробки щодо удосконалення механізмів використання природних ресурсів. Також варто застосувати вітчизняний досвід соціальної взаємодії, передбачивши широке залучення донорів, волонтерів, неприбуткових організацій та підприємців. Адже майбутні природовідновлювальні та природоохоронні заходи будуть різноманітними за напрямками, сферами природокористування, масштабом реалізації та складністю. Це, зокрема, заходи з ліквідації наслідків бойових дій, оцінки та верифікації шкоди і збитків навколишньому середовищу, розробки та виконання планів відновлення довкілля.

Ключові слова: природний ресурс, навколишнє природне середовище, екосистема, природоохоронна територія, природний резерват