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IDENTIFICATION OF DESTRUCTION AREAS OF RECLAMATION SYSTEMS AND EVALUATION OF IRRIGATED AGRICULTURE BY THE REMOTE SENSING DATA

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Abstract. *The article analyzes the results of using the decision-making support system to identify the destruction areas of reclamation systems and evaluates the state of irrigated agriculture by the remote sensing, as well as proves its ability to form and provide the user with preliminary information about the state of reclamation infrastructure. Most of the relatively new and functioning irrigation systems are currently out of the control of the Government of Ukraine due to the occupation of the Kherson and Zaporizhzhia regions by the Russians. Irrigation and drainage systems, over which control was restored and which were in the zone of direct hostilities, were in a destroyed state, and the undermining of the Kakhovska HPP by the occupiers makes it impossible to further use the irrigation systems of both the occupied and unoccupied parts of Ukraine, which were provided with water directly from the Kakhovska reservoir. To provide a rapid visual identification of destruction areas of reclamation systems for evaluating damage to irrigation and drainage infrastructure in 2023, the capabilities of the information system developed at the Institute of Water Problems and Land Reclamation of the National Academy of Agricultural Sciences of Ukraine have been expanded. On the example of the Odesa region, based on basic information about pumping stations of reclamation systems and available information using ACLED technology about hostilities, explosions, artillery attacks, etc., as a result of Russian aggression, a synthesized image was formed, which can be used for visual evaluation of the impact of hostilities on reclamation systems in both individual areas and the whole country. The information system was used for zoning regions by the intensity of military impacts and expected damage to the infrastructure of irrigation and drainage systems. The evaluation of indirect damage zones was carried out using remote sensing data by the NDVI index, which indicates a decrease in the accumulation of biomass in the areas of irrigation systems. The forecast for the further use of irrigated land is based on a statistical analysis of the data on the conclusion of contracts for special water use, which proved a four-fold decrease in water demand, planned for 2022.*

The study results can be used to evaluate the damage caused to Ukraine as a result of the war and confirm the devastating impact of the war on the irrigation and drainage sectors.

Key words: *remote sensing of the Earth, irrigation, information system, damage, irrigation management, special water use, irrigation*

The relevance of the research. Since 2022, because of the full-scale armed aggression of the Russian Federation in the territory of Ukraine, the agricultural sector of our country has been suffering from a significant negative impact of war. According to the FAO report [1], agriculture is of crucial importance for the economy of Ukraine. Before the war, it produced about 20 percent of the country's GDP and more than 40 percent of the total revenue from exports, and its decline in the first year of the war amounted to more than 30 % [2]. The war is expected

to continue to have far-reaching consequences for Ukraine's economic growth and affect global food security.

The war damaged agriculture and its infrastructure across the country, affecting irrigation, crop storage and processing facilities, machinery and equipment, port storage and transport infrastructure, greenhouses, livestock, etc. The carried out analysis indicates that as of July 2022, preliminary losses to the agricultural sector amount to 4.3–6.4 billion US dollars [3], that is 15–22 percent of the total value of the country's agriculture before the war, estimated at 29 billion US dollars. The actual figures are likely to be much higher, as the above estimates do not include the potential damage to the agricultural capital of smallholders located in war-affected areas, who on average produce about 40 percent of Ukraine's total agricultural production, which inevitably indicates a much greater losses in the sector.

Unfortunately, it is currently impossible to identify the real areas of damage caused by military actions and to calculate the actual damage on reclaimed systems due to a number of restrictions, in particular, due to active hostilities and the occupation of part of the territory. In this case, a remote sensing approach is the only possible way to estimate damage, especially on a larger scale – from point, regional to national scales. This approach is considered cost-effective and time-efficient, as a single image can be used to estimate damage over a large area [4].

This work is part of research conducted by the Institute of Water Problems and Land Reclamation of the National Academy of Agricultural Sciences of Ukraine to evaluate the damage and local needs experienced by reclamation systems and producers on these lands. For this purpose, territories that were unoccupied, de-occupied, and free of active hostilities as of January 31, 2023 were specifically studied. A general methodology, which included four key components: (1) surveys at the state and local levels of owners and producers on reclamation systems, (2) interviewing of territorial communities, (3) mapping and analysis of remote sensing data, (4) working with databases on armed conflicts and statistics published in the ACLED database for the period 24.02.2022–31.01.2023.

The result of processing a large amount of information was an economic evaluation of the losses suffered by reclamation systems and the producers working on reclaimed lands since the beginning of full-scale aggression. In this article, the authors present a part of the materials and methodology that were used to identify the areas of destruction of reclamation systems and evaluate the state of irrigated agriculture by the remote sensing data.

Analysis of recent research and publications. For the rebuilding of Ukraine, the "Plan for the post-war reconstruction of Ukraine" was developed, and the UNITED24 fundraising platform was established for cooperation with charitable foundations, partners, donors and public figures around the world. The World Bank (WB) together with the government of Ukraine, based on a joint evaluation of the ministries using the RDNA (Rapid Damage Need Assessment) method, evaluated the damage caused to Ukraine as a result of military operations. The results of this evaluation were approved by the Government of Ukraine [5].

In the first report made by the World Bank, the Government of Ukraine and the European Commission [5] on the evaluation of damage and recovery needs for Ukraine, the total amount of damage and recovery needs of the irrigation and water sector was estimated as $8 billion as of June 1, 2022. This amount partially includes the damages caused to water management infrastructure in the amount of $0.2 billion, and provides for the reconstruction of the irrigation and drainage sector by the principle of reconstruction at a qualitatively new level "We will rebuild better [than it was]", "Build Back Better", which is valued at $7.5 billion.

Based on the data of the Ministry of Agrarian Policy and Food, the Ministry of Environmental Protection and Natural Resources and the State Water Agency, as the balance keeper, a rapid damage, loss and needs assessment (RDNA) was conducted in the irrigation and drainage sector.

The Ministry of Agrarian Policy and Food deals with recording losses in the irrigation and drainage sector at the local level. In view of recording the effects of the war, this ministry is responsible for recording losses in the sectors of agriculture, land reclamation, and fisheries. The Ministry of Environmental Protection and Natural Resources of Ukraine and the State Water Agency record the damages to the surrounding natural environment, water resources, including damages to water management infrastructure. The State Environmental Inspection deals with the formation of a list of all breaches in the field of environmental protection (including water resources) during the war.

The ministries have developed and approved at the legislative level the methods of damage evaluation along with relevant cases [6]. These methods assume that the damage to objects in the country is caused by an entity or person

who operates or resides in the country in a legal manner. Damage to the infrastructure by the developed methods involves the assessment of assets by a residual book value. Methods for calculating the amount of environmental damage and compensation for damages (direct or indirect) are currently adopted taking into account the so-called "war coefficients", that is, costs for environmental damage to the object are calculated according to the methods in force in Ukraine for its citizens and multiplied by a certain coefficient, which may be subject to doubt during the consideration of cases in international courts.

The evaluation of damage to the irrigation and drainage system is constantly carried out by the Ministry of Environmental Protection and Natural Resources along with the State Water Agency using the inventory method, but currently contains only separate/fragmentary estimates of the financial value of the damage to the irrigation and drainage sector as well as water resources that was caused to Ukraine as a result of hostilities. Information about recorded violations in the field of environmental protection and infrastructure is placed on interactive maps [7, 8].

The purpose of the research is to identify the state, scale of destruction, areas of possible damage, and calculate actual damages on reclaimed territories caused by military actions by applying the methodology of using data from remote sensing of the Earth and information technologies.

Research conditions. The research was conducted during 2022-2023 on the lands of the unoccupied part of the territory of Ukraine. The identification of risk zones of potential destruction of reclamation systems and infrastructure was carried out using the information system for supporting decision-making in agriculture, developed at IWPLR [9]. A detailed analysis was carried out for the territory of the Odesa region, the results were scaled to the entire territory of Ukraine.

Research methods and materials. Data on actual damage in the territories were obtained using the ACLED methodology [10] for the period 24.02.2022–31.12.2023 (The Armed Conflict Location & Event Data Project (ACLED) – real-time databases on locations, dates, parties to the conflict, casualties and types of all registered events of political violence and protests around the world, including Ukraine. Evaluation of indirect damage to agriculture on irrigated lands was carried out in 2019–2022, when comparing irrigated massifs by the NDVI index, as well when using statistical methods.

To clarify the direct and indirect losses, the variety of crops was evaluated, and the recognition of crops was verified using the data of remote sensing of the Earth and the Hydrosolution software complex [11].

To evaluate the intensity of agricultural production on irrigated lands, permits for special water use issued for irrigation on the territory of Ukraine were analyzed.

Research results. The reports on damage evaluation in the irrigation and drainage sector are obviously not final, given the ongoing nature of the war and the lack of access to the areas, which temporarily are not controlled by Ukraine. The lack of inventory materials at the state level regarding the state of the irrigation and drainage system, the lack of data on private infarm infrastructure, which is an important part of the lost asset base, also delay damage evaluation. Another cost item not estimated in the described documents is the damage to private irrigation systems, which are generally smaller in size.

At the same time, at the local levels, there is no integrated monitoring of damage evaluation, in particular to water resources, integrated irrigation and drainage systems, and there is no economic assessment of the effects of the war on the production process of agricultural products.

As evidenced by the data of IWPLR [12, 13] and World Bank [13], even before the war started, the irrigation and drainage sector as well as the water management sector had been in a transition period. Some irrigation systems were already unviable, and the irrigated areas of others were significantly reduced. A number of systems were identified for reconstruction and/or modernization. There is a clear need to improve the operation of irrigation and drainage systems and to combine rehabilitation and reconstruction efforts with ongoing institutional reform. The Irrigation and Drainage Strategy sets a medium-term goal of restoring irrigation on the area of 810,000 hectares with possible further expansion to 1.5 million hectares and restoring drainage systems, taking into account 3 million hectares of already drained areas with the possibility of restoring the irrigation functions on such systems in the area of 1 million hectares.

To carry out a rapid visual evaluation of damage to the irrigation and drainage infrastructure, the capabilities of the information system have been expanded this year [14, 15]. The following software solutions were used for data preparation:

- geoinformation system QGIS;
- postgresql database (with PostGIS extension module);
- QGIS geoinformation system;

• Python programming language for developing scripts;

• Pandas, Folium and Leaflet library for data processing and visualization.

To fulfill the task of identifying the destruction areas of reclamation systems, in the current year the work with databases has been supplemented with new possibilities when using the PostGIS module, namely an extension of the PostgreSQL object-relational DBMS. This module helps to store geographic data in the database and facilitates the work with such data. PostGIS includes support for R-Tree/GiST spatial indexes and geodata processing functions.

PostGIS is a geographic information system, or GIS, implemented as an extension to PostgreSQL. GIS enables to store spatial or geographic data, such as points, broken lines, and polygons, perform various operations including efficient searches using them. During the work, the database was connected to QGIS. Layers with pumping stations can serve as an example for analyzing potential damage due to military actions (Fig. 1).

Based on the example of the Odesa region, using the basic information on the pumping stations of reclamation systems and available information about hostilities, explosions, artillery attacks, etc., as a result of Russian aggression in this region, a synthesized image was made, which can be used for a rapid visual evaluation of the impact of military actions on the reclamation systems of the Odesa region. Of course, such information can and should be clarified in the future. A fragment of the inventory database of the reclamation systems as of 2019 is shown in Fig. 2.

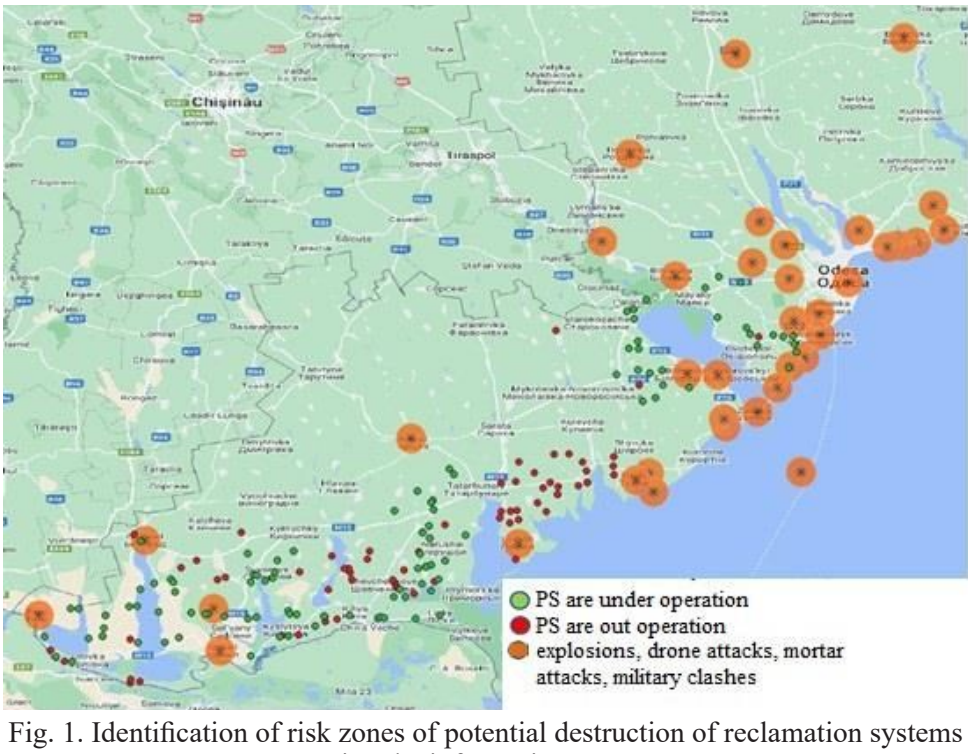
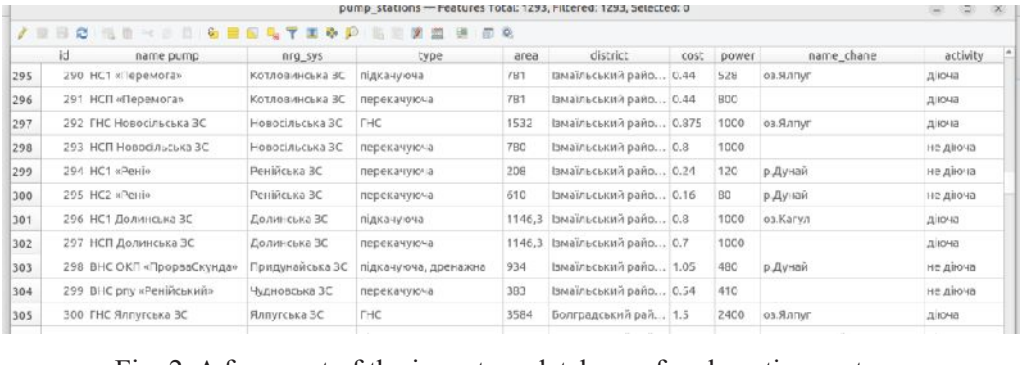


Fig. 1. Identification of risk zones of potential destruction of reclamation systems using the information system



	id	name_pump	irg_sys	type	area	district	cost	power	name_chane	activity
295	290	НСП «Перемога»	Котловинська ЗС	підка-чуюча	781	Ізмаїльський райо…	0.44	528	оз.Ялпуг	діюча
296	291	НСП «Перемога»	Котловинська ЗС	перекачуюча	781	Ізмаїльський райо…	0.44	800		діюча
297	292	ГНС Новосільська ЗС	Новосільська ЗС	ГНС	1532	Ізмаїльський райо…	0.875	1000	оз.Ялпуг	діюча
298	293	НСП Новосільська ЗС	Новосільська ЗС	перекачуюча	780	Ізмаїльський райо…	0.8	1000		не діюча
299	294	НС1 «Рені»	Ренійська ЗС	перекачуюча	208	Ізмаїльський райо…	0.24	120	р.Дунай	не діюча
300	295	НС2 «Рені»	Ренійська ЗС	перекачуюча	610	Ізмаїльський райо…	0.16	80	р.Дунай	не діюча
301	296	НС1 Долинська ЗС	Долин-ська ЗС	підка-чуюча	1146,3	Ізмаїльський райо…	0.8	1000	оз.Кагул	діюча
302	297	НСП Долинська ЗС	Долин-ська ЗС	перекачуюча	1146,3	Ізмаїльський райо…	0.7	1000		діюча
303	298	ВНС ОКП «ПрорваСкунда»	Придунайська ЗС	підка-чуюча, дренажне	934	Ізмаїльський райо…	1.05	480	р.Дунай	не діюча
304	299	ВНС рпу «Ренійський»	Чьдновська ЗС	перекачуюча	383	Ізмаїльський райо…	0.54	410		не діюча
305	300	ГНС Ялпугська ЗС	Ялпугська ЗС	ГНС	3584	Болградський рай…	1.5	2400	оз.Ялпуг	діюча

Fig. 2. A fragment of the inventory database of reclamation systems

After analyzing the territory using the ACLED database, which collects real-time data on the locations, dates, parties to the conflict, casualties and types of all recorded events of political violence and protests worldwide, including Ukraine, the military impacts that can affect the functioning of irrigation and drainage systems are mapped.

The thematic map (Fig. 3) shows the territory of Ukraine with territorial communities and hydrotechnical facilities according to the State Water Agency's inventory data (green symbols on the map). Red symbols indicate military intervention on the territory of Ukraine, which could potentially negatively affect the efficiency of irrigation and drainage systems. Data for the period 02.24.2022 – 02.01.2023 were used to make this map. The damaged infrastructure in the occupied regions was evaluated by the distance to the site of hostilities or explosions recorded in the ACLED database [10].

Using the available information in the database, a rapid evaluation of damage and needs was carried out within the territory controlled by Ukraine. Working and non-working pumping stations, hydrotechnical structures and recorded explosions, drone attacks, mortar attacks, combat clashes, as well as the risk zones of potential destruction of reclamation systems and infrastructure facilities were identified on the map (Fig. 3).

For the period since the beginning of the full-scale invasion (24.02.2022) and till January 31, 2023, the areas were classified by the intensity of hostilities, where the most intense color indicates more than 16,000 documented cases of enemy damage to the territory, namely explosions, drone attacks, mortar attacks, combat clashes, which could potentially affect the operation of irrigation and drainage systems, while the least intense color indicate less than 100 cases. It is obvious that in these areas the intensity of damage to the irrigation and drainage infrastructure at different levels will be distributed accordingly.

Regions were zoned by the intensity of military impacts (Fig. 4), where the color scheme indicates the number of military events within the regions. It is obvious that in these regions the intensity of damage to the irrigation and drainage infrastructure at different levels will be distributed accordingly.

Explosions, remote impacts such as artillery and drone attacks, and direct combat operations in the territories are considered as potential sources of destruction.

The refined methodology for determining the destruction will be based on the automatic determination of the components of reclamation systems, in particular the pumping stations and the reclamation network, which are in the area of negative impacts (explosions, hostilities, etc.), and further actual research of these zones. In fig. 5 there is the ranked infrastructure of the reclamation network in the Odesa region depending on the distance to the places of explosions (from 0 to more than 40 km).

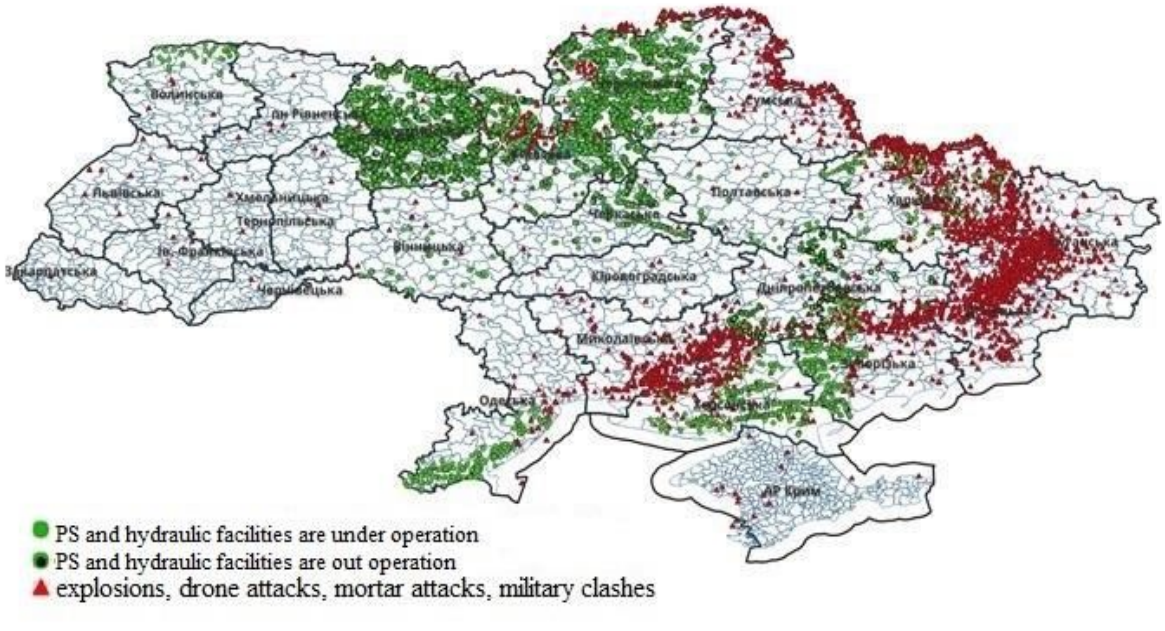


Fig. 3. Synthesized image of the state of reclamation systems in the Odesa region and the risks of the impact of military operations in the period 24.02.2022–31.01.2023

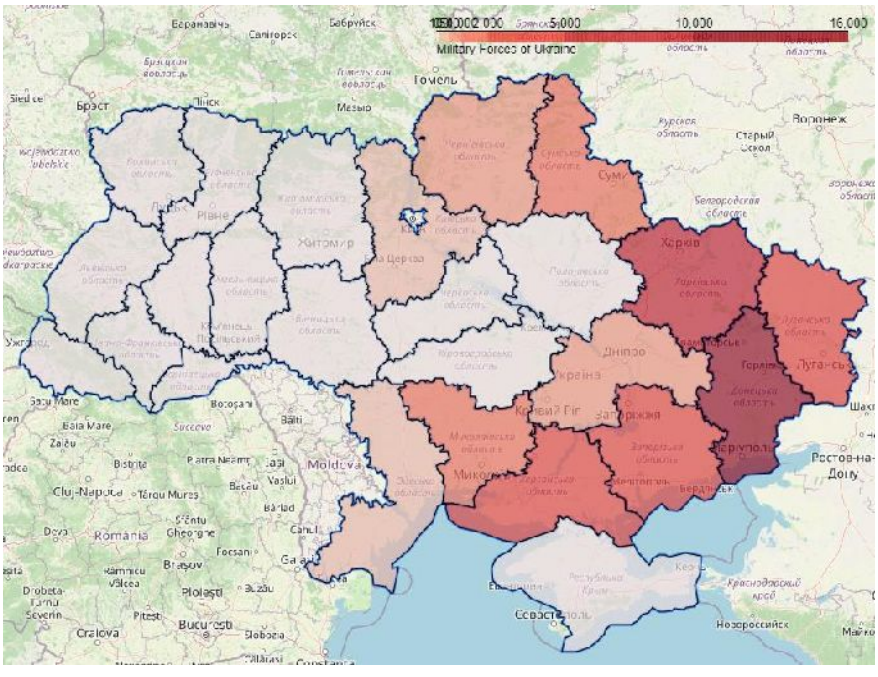


Fig. 4. Zoning of the territory of Ukraine depending on the number of military impacts and the intensity of hostilities

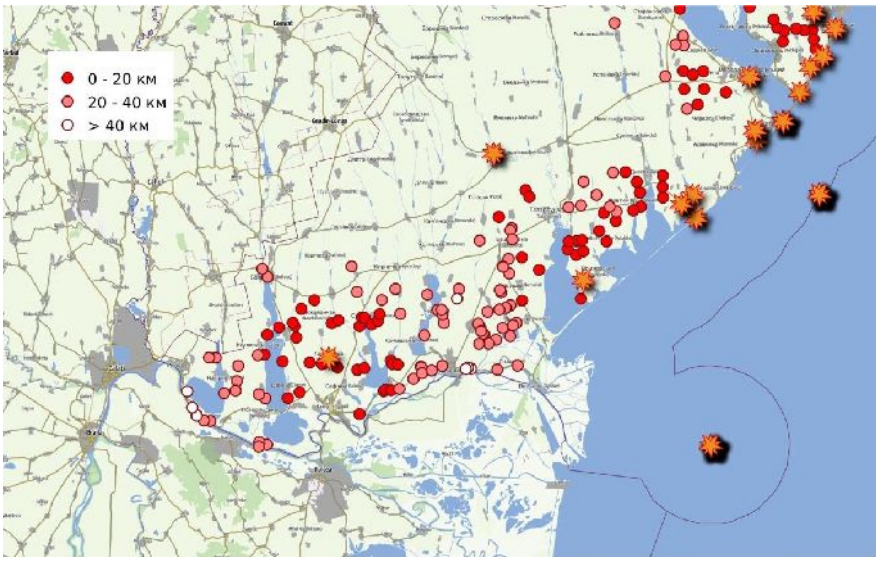


Fig. 5. Identification of potential destruction zones of reclamation systems based on the database of the information system

The identification of potential destruction zones of reclamation systems was carried out on the online platform developed and placed on the IWPLR server [9]. This approach enables to identify the risk zones of potential destruction of reclamation systems and infrastructure objects, to prioritize the restoration of infrastructure across the country and in the Odesa region in particular by the distance to hostilities or places of explosions using the data from constantly updated sources. Remote sensing data, in particular the NDVI index (Normalized Difference Vegetation Index) [16, 17], were used to evaluate the indirect losses and confirm the reduction in production intensity. The irrigated massifs in the Kherson region, in particular in the Chaplynsky district, where field research was already conducted in last years by the authors of this paper [18], were taken as the main area for comparison.

NDVI can be a useful tool for evaluating the condition of vegetation and identifying patterns in its growth, but accurate yield forecasting requires the use of more complex models that combine many factors, including weather conditions, soil quality, agricultural technology, etc. To confirm the fact of a decrease in the intensity of farming in 2022, data on a decrease in the accumulated biomass were used. This change was estimated using the NDVI index, which was specified in the period from 2019 to 2022 for selected irrigated areas in the Kherson region.

Special attention should be paid to the significant decrease in the NDVI index values in the zone where intense hostilities took place. This testifies to the significant impact of military actions on vegetation and agricultural land in this region and emphasizes the need to take measures to restore the agricultural infrastructure and the infrastructure of irrigation systems in this area (Fig. 6).

For a detailed evaluation of damages to agriculture and clarification of direct and indirect damages in terms of changes in the types of cultivated crops, the diversity of crops was evaluated according to the methodology [11]. The study of the accuracy of machine learning algorithms was carried out by the authors from IWPLR and "Hydrosolutions" as part of a joint research (Fig. 7).

Verification of crop recognition using machine learning algorithms was carried out at 287 observation points by the authors. The accuracy of the algorithms was estimated to be 93.4 %.

Based on the developed technologies, it is possible to further specify the amount of direct and indirect damage caused to the irrigation and drainage sector using remote monitoring [19].

The analysis of the concluded contracts for special water use, where irrigation is defined as the purpose of taking water from surface or underground sources, also testifies the losses in the irrigation and drainage sector (Table 1). The set obtained from the open data portal [20] contains a list of issued permits for special water use, including the information provided in the permit form. In particular, the obtained tables included the number, date of issue, status of

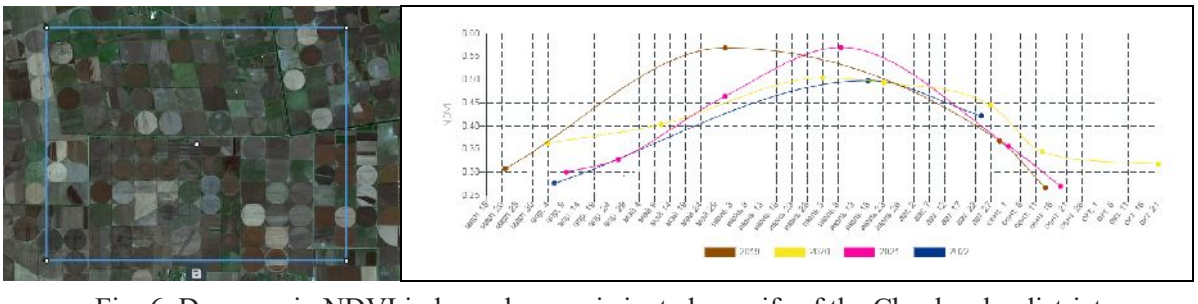


Fig. 6. Decrease in NDVI index values on irrigated massifs of the Chaplynsky district of the Kherson region in 2022

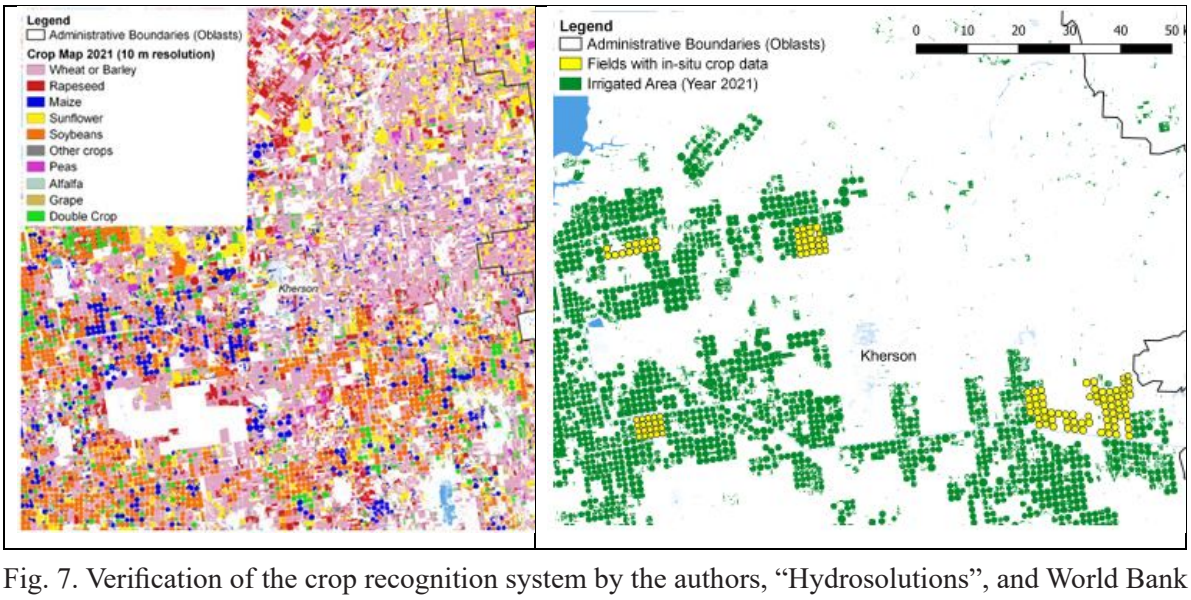


Fig. 7. Verification of the crop recognition system by the authors, "Hydrosolutions", and World Bank

1. The established limit of water intake for irrigation, by the Register of issued permits for special water use in general in Ukraine, thousand m³/year

Regions	2021	2022	2023	2022 compared to 2021
	thousand m³	*thousand m³*	*thousand m³*	*%*
Vinnytska	2531,2	1006,2	50,6	40 %
Volynska	757,2	0		0 %
Dnipropetrovska	63 158,6	6662,5	9,0	11 %
Donetska	4167,7	8183,2		196 %
Zhytomyrska				
Zakarpatska	110,1	177,8		161 %
Zaporizhska	140 975,9	22 951,1		16 %
Ivano-Frankivska	33,1	109,5		331 %
Kyivska	2638,9	246,7	59,8	9 %
Kirovogradska	13 910,3	3308,1	40,7	24 %
Luhanska				
Lvivska	412,8	447,9		108 %
Mykolaivska	79 188,8	10 328,6	1277,0	13 %
Kyiv city				
Odeska	168 697,8	35 794,8		21 %
Poltavska	9750,0	3228,8		33 %
Rivnenska	96,0	405,5		422 %
Sumska	40,8			0 %
Ternopilska	513,0			0 %
Kharkivska	6901,8	148,8		2 %
Khersonska	1 270 640,0	310 600,2		24 %
Khmelnytska	2491,6	723,2		29 %
Cherkaska	19 681,8	17 924,4		91 %
Chernivetska	207,9	70,0		34 %
Chernihivska	688,6			0 %
In total	1 787 593,9	422 317,1	1437,1	24 %

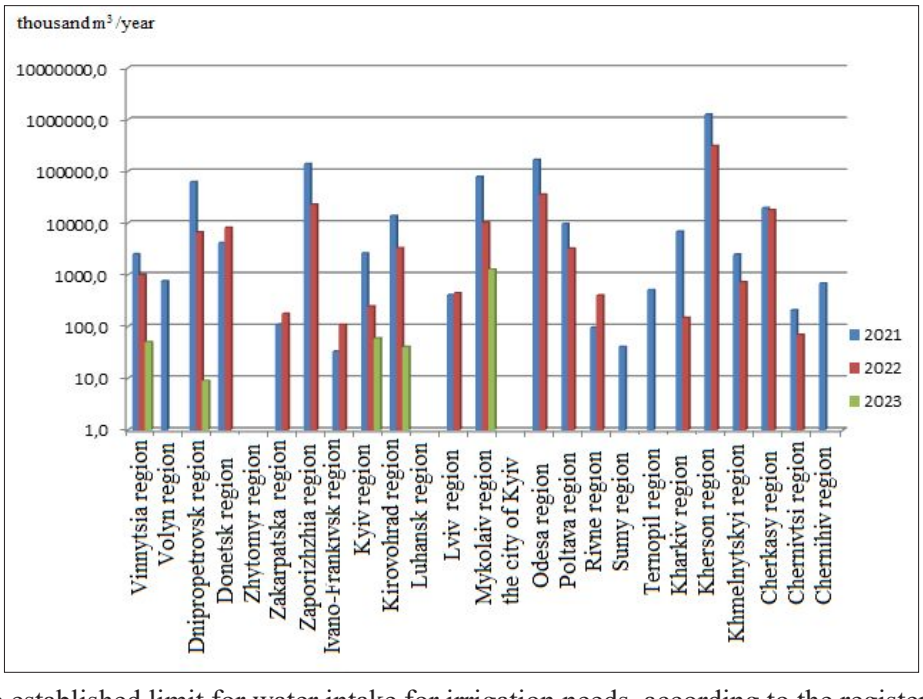


Fig. 8 The established limit for water intake for irrigation needs, according to the register of issued permits for special water use in Ukraine, thousand m³/year

the permit, name and code of the water user's USREOU, validity period of the permit, purpose of water use, limits of water intake and use, volumes of water intake, transfer and discharge by various categories of water users, and others.

The authors analyzed the permits for special water use, where the purpose of water use is specified as "irrigation", issued during the years of 2021–2023, as they indicate the intensity of water use and irrigation intentions.

Since the permitting process is statistically evenly distributed over the years, the number of permits issued annually is roughly the same. With the growth of production on irrigated lands in 2020–2021, the number of issued permits tended to increase. The last column in Table 1 shows the percentage of the actual volume of planned limits for water intake for irrigation needs in thousands of cubic meters by the issued permits in 2022 compared to 2021.

The actual volume of water planned for irrigation in 2022 in total for the country is 24 % of the planned in 2021. That is, the decrease in the intensity of consuming water for irrigation is 76 %. To visualize the data in Table 1, a diagram of the distribution of water intake limits for irrigation by regions for three years was built (Fig. 8).

The data for 2023 are given only until January 31, 2023, so it is appropriate to compare the intensity of obtaining permits in January with previous years (Table 2).

2. Month-by-month comparison of established water intake limits for irrigation needs, according to the register of issued permits for special water use in Ukraine, thousand m^3/year

	January 2021	**January 2022**	**January 2023**
Permit limits, thousand m^3	58427	60637	1437

The analysis of issued permits month-by-month, at the beginning of the year, also testifies the future reduction of water intake for irrigation needs in 2023 and a decrease in the intensity of water use for irrigation.

Discussion. Given the scale and intensity of damage to the infrastructure of reclamation systems as a result of military operations, as well as the difficulty in specifying the actual performance of irrigation and drainage systems, there is a need for re-evaluation and analysis based on data that will be available after the end of hostilities.

Identification of the destruction areas of reclamation systems by the remote sensing data requires a mandatory verification at the local level when performing field surveys. Such studies are particularly relevant, since the correct identification of the areas of the destruction of reclamation systems and reclaimed lands is important in the development of economic assessments, policies and practices aimed at their restoration. It is clear that during the war conflict, an independent monitoring system becomes important, which will allow timely obtaining the information on the state of reclamation systems and infrastructure in war conditions.

In view of the significant scale of damage to the territories, appropriate measures are needed to solve this problem. The complexity of the processes of reclamation systems destruction and deterioration of territory conditions require a combination of various data sources and approaches for proper interpretation.

In conclusion, further areas of research should be the development of a strategy for restoration and improvement of the state of reclamation infrastructure on the principle of better than it was, identification of needs, science-based planning of restoration and international cooperation to ensure the sustainable functioning of reclamation systems.

Conclusions. Large areas of regions, UTCs bordering the territories where the active hostilities take place, are often minded and subject to periodic artillery fire, so there is actual physical destruction of irrigation and drainage infrastructure there. So, there is a need of a rapid expert evaluation of damage to the functionality of the irrigation and drainage infrastructure. The developed methodology for the use of remote sensing data of the Earth and information technologies to identify the areas of possible damage to reclamation infrastructure in the decision support information system in agriculture allows making preliminary conclusions about its malfunction and identifying probable areas of direct destruction and, accordingly, damage. To identify indirect damages, an analysis of received permits for special water use was carried out, which testified that the total amount of water intended for irrigation needs by the issued permits in 2022 amounted to only 23 % compared to 2021. That is, a decrease in the intensity of concluding the contracts for special water use for irrigation needs in 2022 was about 77 %. To visualize the obtained results, mapping and analysis of the studied areas were made by the ACLED methodology. Thematic maps containing the layers of territorial communities and hydrotechnical structures were made based on the data of the State Water Agency's

inventory. The maps also show the types of military impacts on the territory of Ukraine that could potentially negatively affect the efficiency of irrigation and drainage systems. To evaluate in details the damages to agriculture, namely to clarify direct and indirect damages to cultivated crops, crop diversity during the cultivation was evaluated and crop recognition was verified using machine learning algorithms, which allows analyzing the change in the structure of crops and profitability. Identification of the destruction areas of reclamation systems by the remote sensing data requires a mandatory verification at the local level when performing field surveys. These measures are particularly relevant, as the correct identification of the destruction areas of reclamation systems and reclaimed lands is important for economic assessments, policies and practices aimed at their restoration.

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ІДЕНТИФІКАЦІЯ ЗОН РУЙНУВАНЬ МЕЛІОРАТИВНИХ СИСТЕМ ТА ОЦІНКА ЗРОШУВАНОГО ЗЕМЛЕРОБСТВА ЗА ДАНИМИ ДЗЗ

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Анотація. *У статті проаналізовано результати використання системи підтримки прийняття рішень для ідентифікації зон руйнувань меліоративних систем та проведено оцінювання стану зрошуваного землеробства за даними дистанційного зондування Землі та підтверджено її здатність формувати і надавати користувачеві попередню інформацію про стан меліоративної інфраструктури. Більшість відносно нових і функціонуючих систем зрошення наразі знаходиться поза контролем Уряду України через окупацію Херсонської і Запорізької областей. Зрошувальні та дренажні системи, над якими відновлено контроль і які перебували в зоні безпосередніх бойових дій, опинилися в зруйнованому стані, а підрив окупантами Каховської ГЕС робить неможливим подальше використання зрошувальних систем окупованої і неокупованої частини України, що брали воду безпосередньо з Каховського водосховища.*

Для проведення швидкої візуальної ідентифікації зон руйнувань меліоративних систем для оцінювання збитків зрошувальної і дренажної інфраструктури в 2023 році розширені можливості інформаційної системи, розробленої в ІВПіМ НААН. На прикладі Одеської області на основі базової інформації про насосні станції меліоративних систем та доступної інформації за технологією ACLED про бойові дії, вибухи, артилерійські атаки тощо внаслідок російської агресії сформовано синтезоване зображення, за яким можна провести візуальну оцінку впливу військових дій на меліоративні системи як окремих областей, так і здійснити таку оцінку в межах країни. За інтенсивністю військових впливів за допомогою інформаційної системи проведене зонування областей за кількістю військових впливів і очікуваного ушкодження інфраструктури систем зрошення і дренажу. Оцінку зон непрямих збитків проведено з використанням даних дистанційного зондування за індексом NDVI, який свідчить про зниження накопичення біомаси на території зрошувальних систем, прогноз подальшого використання зрошуваних земель наведено на основі статистичного аналізу даних про укладання договорів на спецводокористування, який засвідчив зниження в чотири рази обсягів води, запланованих для використання в 2022 році.

Результати можуть бути використані для проведення оцінки збитків, нанесених Україні в результаті воєнних дій та підтвердження руйнівного впливу війни на сектори зрошення і дренажу.

Ключові слова: *дистанційне зондування Землі, дощування, інформаційна система, збитки, управління зрошенням, спецводокористування, зрошення*