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PROSPECTS OF USING SYNTHETIC-APERTURE RADAR IMAGES IN UKRAINE

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Ukraine is going through hard times because of the Russian invasion today. But the history of the 20th century has many examples of post-war «economic miracles». So, Ukraine also has new opportunities for post-war development. One of them is access to the use of SAR satellite images. This opportunity arose after the Serhiy Prytula Foundation purchased a satellite and access to the ICEYE database for a year. Scientific works (Miskiewicz, 2018; Jafarzadeh et al., 2019; Dźwigoł, 2021) prove that the study of new methods of scientific research is relevant today. The use of SAR time series can become a new method of solving many problems in Ukraine. Therefore, we set ourselves the goal of investigating the prospects of synthetic-aperture radar images in Ukraine.

First, let's explain the basic definition. Synthetic-aperture radar is a type of radar that collects data about an object by emitting energy in the range of electromagnetic waves and recording the amount of reflected energy after interacting with the Earth's surface. Usually, radars of this type are installed on aircraft, including satellites, spacecraft, or airplanes.

Unlike optical satellites, satellites using SAR technology can receive a clear image around the clock and under any weather conditions. However, processing the information received from SAR satellites is much more complicated. In general, it requires the following steps: applying the orbit file, radiometric calibration, de-bursting, multilooking, speckle filtering, and terrain correction (Meyer, 2019). The complexity of this process, the high cost of research, and the lack of free access by the world academic community made SAR an unpopular and ineffective technology for most fields for a long time. Due to the reduction of the costs of launching and maintaining satellites, the development of information technology, which greatly simplified the process of data pre-processing, the policy of the European Space Agency to provide satellite data for free use, and the increase of competition in the market of SAR satellites, this technology has become much more popular during the last decades.

Likely, the ease of analyzing and simplifying the processing of SAR data will attract more actors to the field in the future. Also, the relevance of SAR, as a unique means of prevention and response to changes in the environment, will greatly increase due to global warming and other environmental problems in the world.

According to a market report from Mordor Intelligence, the global SAR market was valued at \$3,3 billion in 2020 and is expected to reach \$6,5 billion by 2026, representing a compound annual growth rate (CAGR) of 11.6% during the period 2021-2026 (Mordor Intelligence, 2021).

Ukraine is not an exception to the global trend. As Andrii Kolesnyk, a former adviser to the head of the State Space Agency of Ukraine said in an interview with the BBC: «Ukraine was buying satellite images even before the full-scale invasion of Russia. About 30 – 35 million hryvnias per year were allocated for this» (Ковалевська, 2022). But he also said that it was mostly data from Chinese and Israeli optical satellites. Most of the companies that provided Ukraine with informational support in the form of access to satellite images after February 24, including Maxar Technologies and Planet Lab, also own mostly optical satellites. Therefore, the acquisition by the Serhiy Prytula Foundation of access to the ICEYE company database for a year and the capabilities of one of the satellites during its time in orbit had a significant impact on the volume and quality of satellite information for Ukraine. First, Ukraine can now receive data collected by SAR satellites, the advantages of which we have already talked about earlier. Secondly, due to the absence of intermediaries, the speed of obtaining information from satellites increases, which is important for quick decision-making.

Currently, Ukraine's Main Directorate of Intelligence owns the data from the satellites. Therefore, SAR satellite images are used mainly in the military sector. SAR images from satellites help the military to map the territory and detect objects on the surface of the earth (for example, to find buildings, logistics routes, missile sites, camouflaged equipment, etc.) It is most likely that this direction of using SAR images will be the most relevant in the short term for Ukraine. But the acquired satellite of the ICEYE company will remain at the disposal of Ukraine throughout the entire period of its operation, which makes more opportunities for the use of SAR images in Ukraine in the future. We consider promising to use images from SAR satellites in Ukraine in many directions. Let's describe the main ones.

1. Insurance. SAR satellite images can be a reliable source for assessing damage and destruction caused by natural disasters or military actions (this is currently very relevant for Ukraine), monitoring the activities of entities, etc. Thus, the automation of property and loss assessment becomes less time-consuming, which allows insurance companies to free up human resources. Effective management of human resources is an important topic for many studies (Hanić et al., 2020; Ziabina et al., 2021; 18. Oleksich et al., 2021; 19. Mamay et al., 2021;). A successful example of this application of SAR imaging abroad is the study of the consequences of the flood in the Darbhanga area (India) in 2017. According to the authors of the study: «These findings are crucial ... to assess flood impacts» (Tripathi et al., 2020).

2. Land use analysis and soil condition monitoring. Analysis of time series of SAR satellite images allows timely detection of fluctuations, subsidence, landslides,

etc. Previously, such changes in the early stages were often imperceptible and could lead to significant destruction and injuries. But today the SAR startup Synspecive, through the analysis of soil deformation carried out in Guatemala City (Republic of Guatemala) during 2018-2021, has proven that the application of SAR technology can be a solution to this problem.

3. Monitoring of urban development. This area is particularly relevant for Ukraine, due to the need to rebuild cities that suffered from the Russian invasion. Satellite SAR images help analyze the state of cities and their rapid expansion and change in near real-time. This makes it possible to assess the state of the territory during social and economic changes. This use of SAR can provide answers to many research questions. For example, SAR images can help assess the impact of Covid-19 on city activity (Boronos et al., 2020) or analyze the long-term dynamics of the economy (Brown et al., 2020; Ramli et al., 2022; Rosokhata et al., 2022). An example of the real use of SAR in this area is the study of changes in land use in the city of Hangzhou (China) from 2000-2003, in which the use of SAR technology made it possible to create an accurate map of the city, reflecting its rapid pace of economic growth and development.

4. Energy and mining industry. As mentioned earlier, SAR satellite images allow for soil condition monitoring. This opportunity is important for the energy and mining industry. The territory of Ukraine is rich in deposits of oil, gas, coal, etc. So, we could use SAR images to conduct geological exploration operations, prevent accidents at the mining site, and control large-scale construction or production works. This use of SAR images can increase Ukraine's energy security, the importance of which is emphasized by V. Panchenko (Panchenko, 2020).

5. Agricultural business. There are many possibilities for using images from SAR satellites in the agricultural field. For example, SAR time series can help with crop inventory, crop cycle monitoring, plant biophysical changes, etc. Research aimed at creating long-term inventories of crop types has already been conducted in Ukraine (in the Belotserkivskiyi district of the Kyiv region). According to the authors of this study: «It allows one to monitor compliance of crop rotation rules, which are necessary for the preservation of soil degradation. In particular, violations of winter wheat, winter rapeseed, sunflower and maize were identified» (Kussul et al., 2018). Continuation of research in this field can increase the efficiency of the use of land resources in Ukraine.

6. Analysis of the state of the country's infrastructure. SAR satellite images, which have high resolution, allow monitoring of the state of the road surface, subsidence, and displacement of the soil over a large area, and analyze the situation with problematic areas of infrastructure. Successes in this area would help Ukraine solve problems with infrastructure quality monitoring and increase the country's logistical attractiveness and convenience. But according to American scientists: «SAR-based methods are useful as a complementary tool rather than a replacement

for current technologies and practices, specifically in the sense of state of good repair» (Ozden et al., 2016).

7. Hydrological research and monitoring of water resources. Hydrological research has always required considerable training and a large amount of equipment. With the use of SAR satellite images, mapping and monitoring the state of surface water bodies has become much easier and cheaper. This can help solve the problem of dumping waste into rivers and improper disposal of waste by enterprises, the relevance of these topics for Ukraine is described in studies (Chygryn et al., 2020; Mishenin et al., 2020). Also, satellite images are often used to track boats (including poaching). For example, SAR satellite images have helped to assess the impact of the Covid-19 crisis on the frequency of ships entering French Mediterranean waters in 2020.

8. State sphere. Obtaining accurate and up-to-date information about the state of large areas is extremely important for decision-making in the public sector. The SAR satellite is one of the most effective tools that have such capabilities. In particular, SAR satellites' images can help Ukrainians detect crimes: illegal construction, extraction of natural minerals (in particular, amber), deforestation, fishing, etc. Exposing such types of illegal businesses can be one of the tools for solving the problem of the shadow economy in Ukraine. Many Ukrainian scientific works are devoted to the search for a solution to the problem of the shadow economy (Levchenko et al., 2018; Tiutiunyk et al., 2019; Tiutiunyk et al., 2021), which proves the relevance of research on this topic.

In conclusion, SAR is an effective tool for collecting large arrays of data about objects and processes on the Earth's surface. The uniqueness of the technology lies in the possibility of round-the-clock use in any weather conditions and the high resolution of modern radars. SAR images in combination with modern technologies and methods of working with data allow you to get an incredible amount of accurate information for making effective decisions. SAR has significant prospects for use in Ukraine, including in the areas of military intelligence, insurance, energy and mining industry, agricultural and public sectors, hydrological research, soil condition monitoring, and urban and infrastructure development. In our opinion, the effective use of SAR by state structures and businesses can make Ukraine more attractive for investment and contribute to the development of international cooperation, the importance of which for the country is described in scientific works (Nelson, 2017; Gentle, 2022). Therefore, conducting further research on the practical application of SAR images is very promising for the Ukrainian academic community and society.

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