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ALGORITHM FOR THE USE OF GEOINFORMATION TECHNOLOGIES FOR THE PURPOSE OF GEOECOLOGICAL MONITORING OF TERRITORIAL COMMUNITIES

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Abstract. *The article discusses the role and capabilities of modern geoinformation technologies in the process of geo-ecological monitoring of territorial communities. The growth of anthropogenic pressure, climate change and active development of land resources necessitate the introduction of innovative tools for timely detection, analysis and forecasting of the state of the environment. Geoinformation systems ensure the integration of different types of spatial data, their modelling and rapid visualisation, which enables local authorities to make scientifically sound management decisions on the use of natural resources, spatial planning and environmental safety at the local level.*

The study analyses the main functional capabilities of geographic information systems, in particular spatial analysis, geostatistics, risk modelling and scenario forecasting. Particular attention is paid to the use of remote sensing of the Earth to assess the dynamics of natural processes such as soil degradation, changes in vegetation cover, water balance and pollution detection. Examples are given of the application of integrated geoinformation solutions in communities for monitoring land

conditions, analysing environmental sustainability and monitoring compliance with environmental protection standards.

The results of the study prove that the introduction of geoinformation technologies into the geo-ecological monitoring system is a key condition for improving the efficiency of natural resource management at the level of local communities. The use of integrated geospatial data allows for more accurate assessment of environmental threats and the development of sound sustainable development strategies. Thus, geoinformation systems serve as the basis for the creation of modern monitoring systems that meet the requirements of adaptive management in the environmental sphere.

Keywords: *geoinformation systems, geo-ecological monitoring, territorial community, land resource management, land use planning, rational land use.*

Actuality. The rapid development of information technologies in general and artificial intelligence in particular is causing structural changes in many industries and areas. In this context, the relevance of using geoinformation technologies in geo-ecological monitoring of territorial communities is determined by a complex of modern environmental, socio-economic and managerial challenges. In the context of martial law, constant growth of anthropogenic pressure, intensification of economic activity and climate change, there is a need to create a system of operational, reliable and scientifically sound control over the state of the environment at the local level using modern geoinformation systems and technologies. Amalgamated territorial communities, as the basic link in land resource management, need accurate and effective tools to identify negative environmental processes, assess their consequences and plan for sustainable development.

Geographic information systems enable the integration of diverse spatial data, combining the results of remote sensing, field research, and statistical observations. This allows for a comprehensive picture of the state of land, water, and biotic resources, tracking their dynamics and predicting potential threats. In today's world, where environmental processes are developing rapidly and often have a localised nature,

geoinformation technologies are becoming an indispensable tool for timely management decisions.

Equally important is the ability of geoinformation systems to maintain the transparency and openness of environmental information, which contributes to increasing the environmental responsibility of the population and involving the public in monitoring the state of the environment.

Thus, research into the use of geoinformation technologies in geo-ecological monitoring of local communities is extremely relevant, as it meets the current needs of digital transformation, provides a basis for effective natural resource management, and forms a reliable toolkit for communities to adapt to environmental risks.

Analysis of the latest scientific research and publications. Durova, N. V., Kondratyuk, D. Yu. and Pershko, L. O., researching the use of geoinformation technologies by local communities in the context of digitalisation, came to the conclusion that the implementation of geoinformation technologies in local communities is a complex task that requires the resolution of numerous technical, economic, social, organisational and legal issues, and solving these problems requires a comprehensive approach that includes investing in infrastructure and training, engaging stakeholders, developing standardised protocols, and complying with the regulatory framework [1].

Researchers I. Yasinetska and I. Mushenik in their work [2] note that "today, GIS are an indispensable tool for researching tasks related to spatially distributed information, including the input and storage of source information, effective processing of spatial data, visual and geostatistical analysis, as well as the preparation of various types of source cartographic and other documents." And "remote sensing technologies provide a wide range of opportunities for agricultural land use, such as: identification and accounting of crop areas; forecasting crop yields; assessing the condition of crops; determining crop areas; identification of areas requiring fertilisers and agrochemicals; control of crop rotation and the quality of agrotechnical measures; determination of crop frost damage areas; pasture areas; analysis of subsidy results; assessment of snow cover and moisture; identification of affected areas and much more."

Thus, most scientists address issues related to the use of geoinformation systems in the management of community land resources and agriculture, but research on their application in the geo-ecological monitoring of territorial communities is relatively new and understudied.

The aim of the study is to provide scientific justification for the use of geoinformation technologies in geo-ecological monitoring of territorial communities.

Materials and methods of scientific research. The methodological basis of the study was the use of geographic information system tools for the integration, storage, analysis, and visualisation of spatial data. Data processing was carried out in modern geographic information technology environments, which made it possible to combine traditional geographic information methods with modern computational geography algorithms.

Comparative analysis was used to form a classification of geo-ecological monitoring of territorial communities; system analysis to determine the relationships between natural, anthropogenic and management factors; the monographic method to generalise theoretical approaches and assess the state of scientific developments; structural-logical modelling methods to develop a geo-ecological monitoring algorithm.

The tools used provided a comprehensive and multi-level approach to assessing the environmental status of local communities, allowing spatial patterns of potential threats to be identified and directions for optimising the monitoring system to be determined.

Research results and their discussion. Geo-ecological monitoring of local communities is a comprehensive system of observation, assessment and forecasting of the state of the natural environment at the local level to identify negative changes and develop management decisions. It includes monitoring air, water, soil, waste and natural processes using both traditional and modern technologies such as GIS and satellite data. The aim is to ensure sustainable development, environmental safety and transparency in community management.

In general, geo-ecological monitoring can be classified according to various factors: by object of observation, by methods, by nature of impact, by purpose, and by frequency of implementation (Fig. 1).

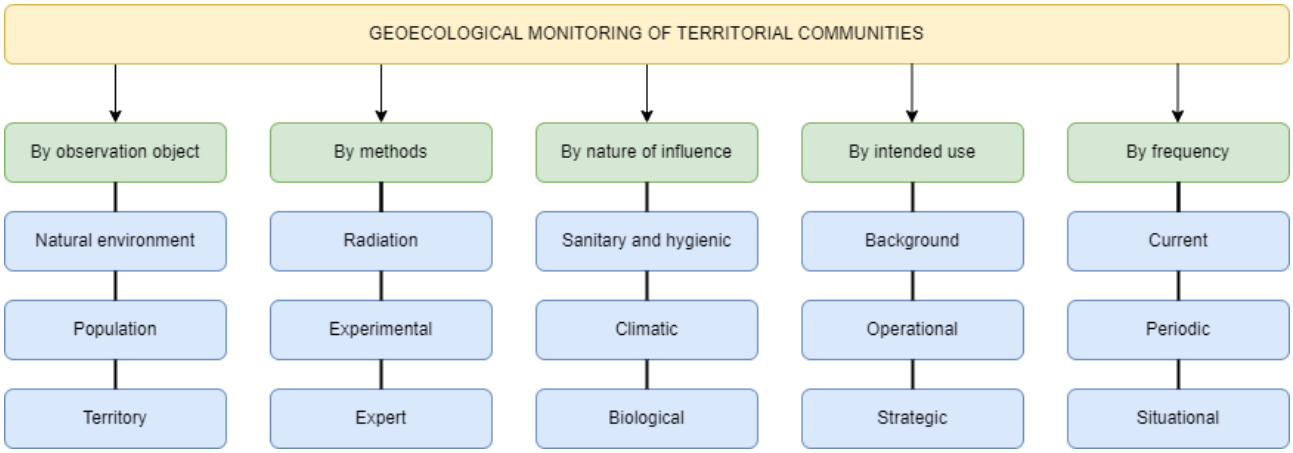

Fig. 1. Classification of geo-ecological monitoring of territorial communities

Having analysed the definitions of monitoring among contemporary researchers, we can note the scientific work of O.M. Kanivets, who defines monitoring of land use by territorial communities as "the use of land by united territorial communities, where the main focus is on the formation of spatial, urban planning, environmental and socio-economic support based on the creation of a quantitative basis for integrated assessment, mathematical modelling, and the use of geoinformation tools to identify imbalances in the land relations system and establish prospects for their development" [3].

GIS technologies and remote sensing are effective tools for monitoring land use changes, enabling detailed spatial analysis and forecasting. The use of satellite imagery in combination with GIS allows for the rapid identification of urban expansion, changes in vegetation cover and soil degradation. Machine learning and deep learning algorithms significantly improve the accuracy of land use change analysis by providing automated classification of territories. Remote sensing methods combined with geospatial analysis are promising for optimising land resource management in the context of urbanisation and climate change. Improvement of methods for integrating GIS data with remote sensing data to increase the accuracy of land use change analysis. Research into the possibilities of using drones to increase the detail of cartographic

data. Implementation of machine learning models for forecasting territorial changes, taking into account socio-economic factors. Development of interactive GIS platforms for real-time land use monitoring [4].

Based on the results of the analysis of scientific works by researchers and the functional capabilities of geoinformation systems, in particular spatial analysis, geostatistics, risk modelling, scenario forecasting, and the use of remote sensing of the Earth to assess the dynamics of natural processes, an algorithm for geo-ecological monitoring of territorial communities was developed (Fig. 2)

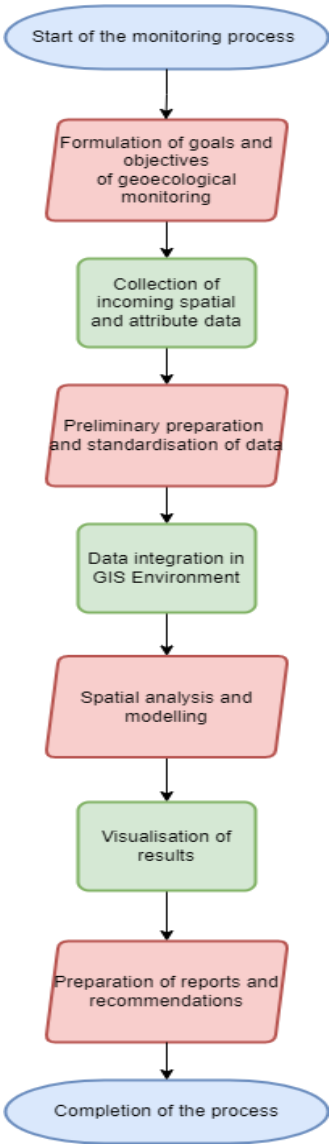

Fig. 2. Algorithm for geo-ecological monitoring of territorial communities based on the application of geoinformation technologies

In Fig. 2, the algorithm diagram divides the blocks into three categories, where oval-shaped blocks show the beginning and end of the algorithm execution process,

rhombus-shaped blocks show key functional stages, and rectangular blocks show actions related to the input-output and visualisation of geospatial data for geo-ecological monitoring.

Thus, the algorithm for geo-ecological monitoring of territorial communities with the widespread use of geoinformation systems and technologies includes:

Formulation of monitoring objectives and targets

- determining the type of monitoring (in accordance with the classification in Fig. 1);
- establishing observation objects (air, soil, forest and water resources, vegetation cover, landscapes, etc.);
- agreeing on criteria for assessing the state of the environment and impact indicators.

Collection of incoming spatial and attribute data

- remote sensing data (satellite images, aerial photographs, UAVs);
- topographic and cadastral layers;
- data from observation points (air, water and soil quality control stations);
- socio-economic and statistical data on the local community;
- geophysical, climatic and sanitary-hygienic indicators.

Preliminary preparation and standardisation of data

- georeferencing and coordinate transformation;
- creation of a unified geodatabase structure;
- cleaning data of errors, duplicates, etc.;
- normalisation of attribute tables.

Data integration into the GIS environment

- loading all layers into GIS (ArcGIS, QGIS, GeoServer);
- building base maps: relief, land use, hydrographic network, road infrastructure, sources of pollution;
- overlaying dynamic and thematic monitoring layers.

Spatial analysis and modelling

• buffer analysis to determine the areas of influence of industrial facilities, transport corridors, etc.;

• cross-analysis of layers to assess environmental risk;

• interpolation (IDW, Kriging) to create pollution surfaces;

• modelling of water flows and erosion sensitivity;

• calculation of indices for assessing the condition of vegetation and land;

• detection of changes based on time series.

Візуалізація результатів у ГІС

• creation of thematic maps: atmospheric pollution maps, heat island maps, aquatic ecosystem status maps, soil degradation maps, natural hazard maps (landslides, floods), cumulative environmental load maps;

• generating 3D models and analytical profiles;

• creating interactive web maps for the community (via ArcGIS Online, Leaflet, GeoNode).

Preparation of reports and recommendations

• generalisation of spatial and statistical results.

• preparation of analytical conclusions on the ecological state of the territory.

• development of recommendations (prevention of pollution and thermal anomalies, optimisation of land use, land reclamation, environmental management).

Conclusions and perspectives. The study confirms that geoinformation technologies are a key tool for ensuring effective geo-ecological monitoring of local communities. Thanks to the integration of various types of spatial data, the use of spatial analysis tools, geostatistics, remote sensing of the Earth, and machine learning methods, GIS technologies ensure a high level of accuracy, efficiency, and validity of environmental assessment of territories.

The results obtained prove that the use of GIS in combination with satellite and aerial survey data creates opportunities for comprehensive monitoring of natural processes – soil degradation, changes in vegetation cover, urbanisation pressure, and the formation of environmental risks. This, in turn, enables communities to respond to

environmental threats in a timely manner, improve the efficiency of land and natural resource management, ensure transparency in management decision-making, and develop sustainable development strategies.

The study also shows that further modernisation of geo-ecological monitoring systems is relevant through the introduction of automated classifiers, integrated web GIS platforms, the use of UAVs to increase the detail of spatial data, and the development of predictive models based on artificial intelligence. The development of such tools will contribute to the formation of a comprehensive adaptive environmental management system capable of ensuring the ecological safety and sustainability of territorial communities in the face of modern challenges.

Thus, geoinformation technologies not only enhance the analytical capabilities of geo-ecological monitoring, but also create a reliable basis for sustainable nature management, environmentally sound planning, and improved quality of land management at the local level.

References

1. Durova, N. V., & Pershko, L. O. (2024). Heoinformatsiini tekhnolohii terytorialnykh hromad v umovakh didzhytalizatsii [Geoinformation technologies of territorial communities in the context of digitalization]. *Akademichni vizii*, (32), 1–14.
2. Yasinecka, I., & Mushenyk, I. (2021). Vykorystannia heoinformatsiinykh system i system dystantsiinoho zonduvannia dlia potreb zemelnoho kadastru, zemleustroiu ta upravlinnia zemelnymy resursamy [Use of geoinformation systems and remote sensing systems for land cadastre, land management, and land resources administration]. *Pryrodnychi nauky*, 2, 55–66.
3. Kanivets, O. M. (2023). Formuvannia monitorynhu vykorystannia zemel obiednanykh terytorialnykh hromad [Formation of monitoring of land use in united territorial communities] (Doctoral dissertation, KhNUMG im. O. M. Beketova).
4. Braslavska, O. (2025). HIS-tekhnolohii ta dystantsiine zonduvannia u monitorynhu zmin zemlekorystuvannia [GIS technologies and remote sensing in

monitoring land use changes]. *Mistobuduvannia ta terytorialne planuvannia*, (89), 472–487. DOI: https://doi.org/10.32347/2076-815x.2025.89.472-487

5. Bricker, S., Jelenek, J., van der Keur, P., et al. (2024). Geoscience for Cities: Delivering Europe'sSustainable Urban Future. Sustainability, 16, 2559. DOI: https://doi.org/10.3390/su16062559.

6. Hölscher, K., Frantzeskaki, N., Collier, M.J., et al. (2023). Strategies for maistreaming nature-basedsolutions in urban planning in the European cities. Urban Sustainability, 3 (54). DOI:https://doi.org/10.1038/s42949-023-00134-9.

7. Kovalchuk, I., Ivanov, Y., & Pylypovych, O. (2024, October). Geoecological Analysis of the Urban System: Structure, Algorithms, Principles of Monitoring. In International Conference of Young Professionals «GeoTerrace-2024» (Vol. 2024, No. 1, pp. 1-5). European Association of Geoscientists & Engineers.

8. Koroso, N., & Zevenbergen J. (2024). Urban land management under rapid urbanization: Exploringthe link between urban land policies and urban land use efficiency in Ethiopia. Cities, 153,105269. DOI: https://doi.org/10.1016/j.cities.2024.105269

9. Azimov, O. T., Shevchuk, O. V., & Azimova, K. O. (2020). Geoinformation systems in the investigations of the environment pollution drivers within the catchment areas of landfills: current state and trends. Geoinformatics (Ukraine), 2(74), 69-88.

10. Tsatsaris, A., Kalogeropoulos, K., Stathopoulos, N., Louka, P., Tsanakas, K., Tsesmelis, D. E., ... & Chalkias, C. (2021). Geoinformation technologies in support of environmental hazards monitoring under climate change: An extensive review. ISPRS International Journal of Geo-Information, 10(2), 94.

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Алгоритм використання геоінформаційних технологій з метою геоекологічного моніторингу територіальних громад

Анотація. *У статті розглядається роль та можливості сучасних геоінформаційних технологій у процесі геоекологічного моніторингу територіальних громад. Зростання антропогенного навантаження, зміни*

клімату та активне освоєння земельних ресурсів зумовлюють необхідність упровадження інноваційних інструментів для своєчасного виявлення, аналізу та прогнозування стану довкілля. Геоінформаційні системи забезпечують інтеграцію різнотипних просторових даних, їх моделювання та оперативну візуалізацію, що дає змогу органам місцевого самоврядування приймати науково обґрунтовані управлінські рішення щодо використання природних ресурсів, планування територій та екологічної безпеки на місцевому рівні.

У межах дослідження проаналізовано основні функціональні можливості геоінформаційних систем, зокрема просторовий аналіз, геостатистику, моделювання ризиків і сценарне прогнозування. Особливу увагу приділено використанню дистанційного зондування Землі для оцінювання динаміки природних процесів, таких як деградація ґрунтів, зміна рослинного покриву, водний баланс і виявлення забруднень. Наведено приклади застосування комплексних геоінформаційних рішень у громадах для моніторингу стану земель, аналізу екологічної стійкості та контролю за дотриманням природоохоронних норм.

Результати дослідження доводять, що впровадження геоінформаційних технологій у систему геоекологічного моніторингу є ключовою умовою підвищення ефективності управління природними ресурсами на рівні територіальних громад. Використання інтегрованих геопросторових даних дозволяє підвищити точність оцінювання екологічних загроз та формувати обґрунтовані стратегії сталого розвитку. Таким чином, геоінформаційні системи виступають основою для створення сучасних моніторингових систем, що відповідають вимогам адаптивного управління у сфері довкілля.

Ключові слова: *геоінформаційні системи, геоекологічний моніторинг, об'єднана територіальна громада, управління земельними ресурсами, землеустрій, раціональне використання земель.*