

DIGITALISATION OF ENVIRONMENTAL MANAGEMENT IN LOCAL SELF-GOVERNMENT BODIES

HENNADII MAZUR¹, YURII YEFIMOV², VOLODYMYR SERVETNYK^{3*},
OLHA VASYLENKO⁴, MYKOLA ANDRUSHKO⁵

¹Department of Management and Administration, PHEE “Vinnytsia Academy of Continuing Education”,
Vinnytsia, Ukraine.

²State Environmental Inspectorate in Kharkiv Region, Kharkiv, Ukraine.

³Department of Public Administration, Educational Institute of Management, Economy and Finance,
Interregional Academy of Personnel Management, Kyiv, Ukraine.

⁴Department of Ecology and Geography, Faculty of Natural Sciences, Zhytomyr Ivan Franko State
University, Zhytomyr, Ukraine.

⁵Department of Plant Growing Technologies, Faculty of Agrotechnology and Environmental Protection,
Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine.

E-mail: ¹gennadii_mazur@ukr.net, ²yu.yefimov@gmail.com, ³volodymyr_servetnyk@eu-science.org,
⁴olga_vasylenko@ukr.net, ⁵andrushko@ukr.net

ABSTRACT

In the context of growing challenges related to environmental pollution, climate change and increased anthropogenic pressure on natural systems, the digitalisation of environmental management plays a key role. The study aims to identify key problems that limit the effectiveness of local self-government bodies and to determine ways to improve their institutional capacity to ensure an adequate level of environmental safety at the local level. The study applies a systematic approach and uses methods of comparative analysis, statistical evaluation of results, content analysis of regulatory and legal acts, and questionnaires. Data from 10 territorial communities in different regions of Ukraine, selected based on criteria such as digital maturity, population size, and environmental impact, were analysed. The results of the study showed that the key barriers are insufficient funding for environmental programmes and limited human resources. Large cities scored highly at 4.5 out of 5 in institutional readiness; medium-sized cities scored an average of 3.6; and small communities scored lower (3.1), compensating for limited resources with high public engagement. Institutional capacity (coefficient 0.12; $p = 0.009$) and the effectiveness of law enforcement agencies (0.085; $p = 0.01$) had a positive impact on the level of environmental security. A positive correlation was found between GDP per capita (0.05; $p = 0.013$) and foreign direct investment (0.04; $p = 0.027$). In contrast, the share of industry in the economic structure has a negative impact (-0.03; $p = 0.046$), caused by increased environmental pressure. The index of fiscal autonomy of communities was 0.06 ($p = 0.007$). A conceptual model of a digital ecosystem for environmental management of communities has been developed. The practical significance of the results lies in the potential to use the developed recommendations to improve local environmental safety strategies, optimise resource allocation, and establish an effective environmental monitoring system. Prospects for further research include analysing the possibilities for digitalising management processes.

Keywords: *Natural Resources, Agricultural Land, Digitalisation, Environmental Management, Multilevel Governance, Environmental Policy, Sustainable Development.*

1. INTRODUCTION

Environmental safety is a basic prerequisite for the sustainable development of society [1, 2]. Growing climate risks, urbanisation pressures, and the consequences of military action increase the demands placed on regional and local environmental

management systems [3, 4]. Local self-government (LSG) bodies play an important role in monitoring environmental conditions, managing natural resources and agricultural land, responding to environmental risks, and involving citizens in environmental decision-making. However, their ability to perform these functions depends on

institutional capacity, access to financial and human resources, the effectiveness of legal mechanisms, and the availability of reliable environmental information.

Digital technologies are increasingly being used to address these challenges. Artificial intelligence, big data, satellite monitoring, geographic information systems (GIS), Internet of Things (IoT) technologies, and digital platforms can improve environmental monitoring, risk forecasting, resource management, and the transparency of administrative decisions [1, 2]. International experience demonstrates that digitalisation is becoming an important component of regional environmental management. Leading countries are moving towards integrated digital-innovation models that combine technological, economic, and natural-resource factors to support long-term environmental sustainability [5]. For example, research on the United States shows that digitalisation, renewable energy development, and environmental innovations can contribute to improved environmental quality and reduced ecological pressure [5]. In EU countries, digital technologies, artificial intelligence, IoT, and GIS are actively used to control emissions, manage waste, and predict environmental risks, with northern countries demonstrating the best results thanks to high investment in science and green innovation [6]. At the same time, environmental management in Slovakia focuses on developing eco-innovations and digital solutions that underpin regional sustainable development strategies [7]. As international experience shows, the effectiveness of regional environmental policy increases with the introduction of open digital ecosystems that ensure transparency, public participation and the achievement of the UN Sustainable Development Goals by 2030 [8]. The use of intelligent algorithms, such as Quantile-on-Quantile Kernel-Based Regularised Least Squares (QKRLS), provides a more accurate assessment of the impact of innovation, globalisation and digitalisation on environmental indicators, creating the conditions for “smart” natural resource management.

In EU countries, priority is given to eco-innovation policy – for example, Slovakia’s experience shows active use of the Eco-Innovation Index [6]. This enables the identification of the strengths and weaknesses of regions, their comparison with EU-28 averages, and the development of targeted programmes to support the institutional and technological modernisation of local self-government (LSG) bodies [7]. At the same time, Scandinavian countries, particularly Sweden

and Denmark, are actively integrating AI and GIS to predict climate risks and monitor environmental pollution. In Central and Eastern European countries, digital tools are increasingly being used to create open environmental databases, electronic reporting systems, and to analyse sustainable development indicators [9]. These practices demonstrate the effectiveness of inter-municipal cooperation and partnerships between scientific institutions, businesses and territorial communities.

In the Ukrainian context, these trends are gradually being implemented through the digital transformation of environmental management in local government, the development of electronic services, the integration of GIS technologies into environmental monitoring, and the strengthening of institutional capacity in communities within the framework of decentralisation processes. Ukraine is adapting these approaches in line with European management standards, which creates the basis for the formation of sustainable, technologically advanced and environmentally responsible territorial communities. In Ukraine, the latest trends in regional environmental management are shaped by decentralisation and digital transformation. Following the signing of the Ukraine-EU Association Agreement, reforms aimed at increasing transparency, accountability, and citizen participation in environmental decision-making have been stepped up. Recent studies emphasise the key role of digitalisation in improving the effectiveness of management at the local self-government level [10, 11]. Territorial communities are implementing digital technologies for environmental monitoring, electronic services for natural resource management, and smart governance tools [12–14]. At the same time, challenges include insufficient institutional capacity of LSG bodies, a lack of personnel, and limited funding [15, 16]. Research shows that digitalisation is becoming a key tool for integrated and environmentally oriented management at the local level. To improve the efficiency of the management system in Ukraine, European public administration standards and the principles of the European Green Deal are being implemented, which provide for digitalisation, decarbonisation and the development of renewable energy sources [17, 18]. These processes contribute to the formation of a sustainable, environmentally oriented system of local self-government capable of effectively responding to the current challenges of sustainable development.

The scientific novelty of the study lies in the theoretical and methodological justification and

empirical assessment of digitalisation as a factor in improving the effectiveness of environmental management within LSG bodies. The research is based on the hypothesis that effective implementation of environmental safety policies in Ukrainian territorial communities requires continuous transformation of public management and administration systems at the strategic, tactical, and operational levels. This general hypothesis is examined through three specific hypotheses that assess the relationships between institutional capacity, law enforcement, economic conditions, digitalisation, and environmental safety. The study focuses on the capacity of local communities and cities in Ukraine to prevent environmental emergencies, respond to risks, and organise recovery processes.

The *aim* of the study is to identify the key factors that hinder the effectiveness of environmental management at the local level and to determine ways to strengthen the institutional capacity of LSG bodies through the introduction of digital technologies to ensure environmental safety and sustainable development of territorial communities. To achieve this goal, the paper sets out to solve the following *scientific tasks*:

- to analyse open databases, regulatory documents and scientific publications from the last 5 years on the current state of digitalisation of environmental management in LSG bodies in Ukraine and the EU;
- to justify the impact of digital technologies on enhancing the institutional capacity of territorial communities to ensure environmental safety;
- to develop a conceptual model of a digital ecosystem for community environmental management that integrates analytical, information and communication tools.

The study therefore combines the institutional, technological, legal, and social dimensions of environmental management and focuses on their interaction within the digital transformation of LSG bodies. The proposed approach is intended to contribute to the development of more effective local environmental governance and provide a basis for further assessment of digital maturity and the relationship between digital technologies and environmental indicators of territorial development.

Current research on environmental management in LSG bodies focuses mainly on several interrelated areas: strengthening community institutional capacity, digitising monitoring and

decision-making processes, increasing public participation, and improving legal mechanisms for environmental responsibility [19]. Recent studies confirm that digitalisation increases the efficiency of environmental monitoring, supports transparent governance and improves the management of natural resources in territorial communities. Researchers also emphasise the importance of digital tools for controlling the condition of agricultural land and reducing environmental risks at the local level. Digitalisation and innovation are key factors in improving the effectiveness of environmental management. Adebayo et al. [5] analysed the impact of innovations in solar energy, digitalisation and economic globalisation on the environment in the United States using the Quantile-on-Quantile Kernel-Based Regularised Least Squares method. The results showed that innovations in solar energy have a predominantly positive environmental impact. At the same time, digitalisation helps reduce the environmental footprint by improving the efficiency of environmental monitoring and resource management. In the European context, Adeshola et al. [6] explored the relationship between digitalisation, information and communication technologies (ICT), and environmental taxes, finding that digital tools, combined with environmental taxation, significantly reduce emissions and increase the environmental sustainability of economies. While in the US and Western European countries, digitalisation is increasingly being integrated into environmental management, Slovakia demonstrates another aspect of this process. Lesakova and Laco [7] used the Eco-Innovation Index to assess the dynamics of environmental innovation in the country, identifying strengths in the environmental performance of production but also highlighting structural weaknesses – in particular, insufficient public policy support and low levels of investment in research and development. The researchers emphasise the need for a comprehensive approach that integrates these components to ensure an effective and sustainable environmental management system in the context of sustainable development [2, 13]. Cvetković et al. [3] emphasise the need to enhance LSG bodies' capacity to manage environmental risks, while Darmi et al. [20] and Savchuk [21] highlight the vulnerability of rural territorial communities due to limited resources and a weak institutional framework. Similar conclusions are drawn by Buryk [4] and Zub [22], who note that without systemic organisational reform, financial

decentralisation and adequate staffing, achieving environmental security is unlikely. Some attempts to bridge this gap have been made using panel analysis methods [13]. In this context, digital technologies are seen as catalysts for transformational processes in environmental management – from the introduction of geographic information systems (GIS) to the use of big-data analytics and AI algorithms. Al-Hammouri et al. [1] demonstrate the potential of AI to improve the effectiveness of environmental monitoring, while emphasising the need for a clear regulatory framework for its safe and ethical use. The practical results of the digital transformation of local environmental management are highlighted in the works of Borodina and Trushkina [23], Chubar and Rusyn [24], Prikhno and Marchenko [25]. Similar observations are made by Nimko et al. [27], noting that e-governance can indeed increase transparency and reduce corruption risks, but only if digital services are open and accessible to citizens. Their effectiveness depends on institutional capacity, management culture, and social readiness for change [28]. Increased digitalisation also improves public communication about environmental initiatives. Regarding citizen participation, research by Kiss et al. [15] emphasises that involving the population in nature-oriented decisions increases the legitimacy and effectiveness of implementing nature-based solutions (NBS) [29]. However, several studies point to a problem: citizen participation in discussions of environmental issues is often declarative or fragmented, without formalised mechanisms for interaction [2, 30]. In the field of legal regulation and policy, several publications highlight regulatory approaches and their effectiveness. Herbedea et al. [31] and Klymenko [32] analyse the adaptation of national legislation to EU standards. They point to the need for harmonisation of rules, especially in the context of urbanisation and growing environmental risks. At the same time, legal studies [33] show that legal mechanisms are sometimes not flexible enough to respond to local challenges and also highlight problems in the law enforcement system. Methodologically, quantitative panel approaches and case studies dominate the literature, as well as practical experiments in ecosystem restoration [34] and impact modelling [35]. However, there is a methodological gap: many empirical studies either focus on technical aspects (e.g., methods of adsorption or migration of heavy metals – [36, 37]) or on administrative institutions. Rarely do

studies integrate these approaches into a single transdisciplinary model that combines technical, legal, and social dimensions of environmental safety management. This creates space for interdisciplinary research that combines eco-technologies, GIS analytics, and political-institutional dimensions [28, 35]. Another critical issue is the overall validity of results during crises: war, climate change shocks, and mass migration alter LSG bodies' priorities and affect the representativeness of samples [27]. Ukrainian studies [13, 38] reflect these circumstances well, but require more long-term panel data to analyse dynamics. Their effectiveness depends on the level of institutional readiness, access to investment capital, and the integration of digital technologies into decision-making processes. Summarising the results of the analysis, it can be noted that contemporary research in regional environmental management increasingly emphasises the decisive role of LSG bodies' institutional capacity as a key factor in ensuring the environmental security of territories [3, 13]. The digitalisation of management processes and the introduction of AI open new opportunities for monitoring, forecasting, and managing natural resources and agricultural land, but they also require adequate regulatory support and professional development [1, 23]. Active citizen participation and cross-sectoral cooperation contribute to greater transparency in decision-making and build trust in environmental policy [2, 15]. Despite significant achievements, there are still significant gaps in the literature, including a lack of integrated interdisciplinary approaches to waste management, a limited number of long-term panel studies, and insufficient adaptation of international environmental initiatives (in particular, resolutions on combating plastic pollution) to the national and local levels of governance [39]. Based on the reviewed studies, existing approaches provide valuable tools for environmental monitoring, institutional assessment, and public participation, but they are often applied separately. To address this limitation, the present study combines institutional, digital, legal, and social dimensions of environmental management within an integrated digital ecosystem for LSG bodies. This approach allows the study to assess institutional capacity, environmental safety, and the role of digital technologies in a common analytical framework. These aspects determine the directions for further scientific and practical developments in the field of digitalisation of

environmental management in the context of sustainable community development.

2. METHODOLOGY

2.1. Research Procedure

The study was conducted between 2023 and 2025 in three stages (Figure 1). Representatives of LSG

bodies, specialists in ecology and digital technologies, and civil society activists participated. The sample included ten territorial communities in Ukraine, selected based on their level of digital maturity, population size, and environmental impact indicators.

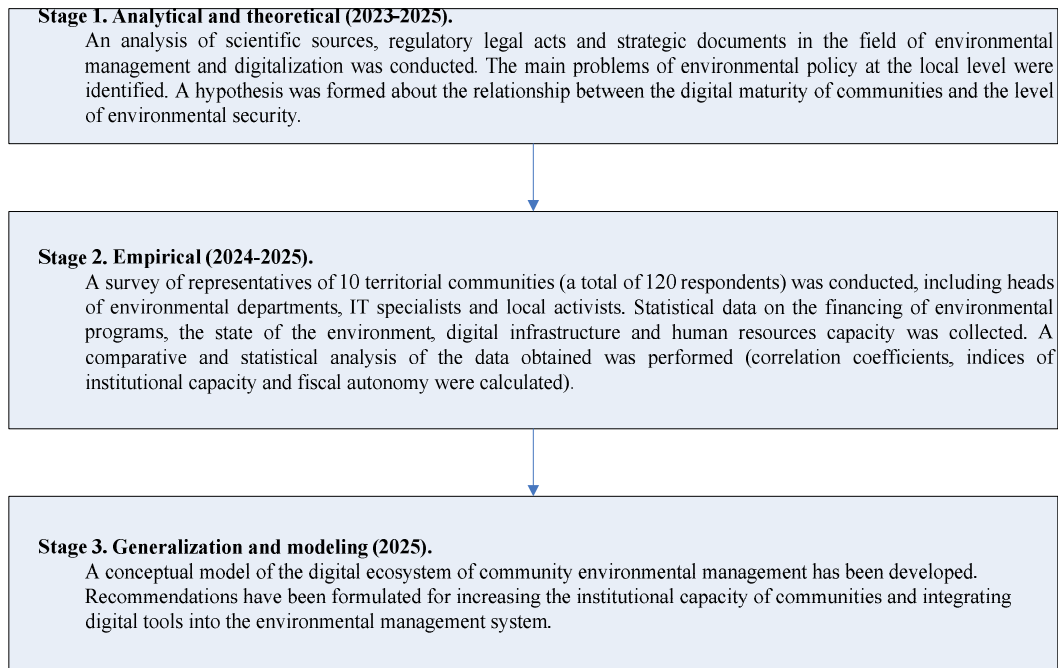


Figure 1: Research Procedure
Source: Compiled By The Author

2.2. Data Collection

The study used open data for 2024–2025 and surveyed territorial community leaders. The survey covered two target groups:

- mayors and heads of village/settlement councils responsible for coordinating environmental safety management activities at the territorial community level;
- officials of structural units of LSG bodies who work directly in the field of risk management and civil protection (120 respondents from 10 territorial communities of Ukraine).

The sample included communities of various types – from large cities of regional significance (Kyiv, Lviv, Dnipro, Kharkiv, Odesa, Zaporizhzhia) to medium-sized and small towns and rural communities (Lviv, Kamianske, Bilhorod-Dnistrovskiy, Vinnytsia, Lutsk, Myrhorod, Izium, Uman, Yaremche and Voznesensk).

Criteria for inclusion and exclusion of the sample.

- LSG bodies at all levels – urban, settlement and rural territorial communities that have approved or existing powers in the field of environmental safety and civil protection;
- officials directly involved in strategic planning, coordination, monitoring or implementation of community environmental policy measures;
- territorial communities from different types of regions (urban, rural, frontline, border, environmentally risky areas), ensuring the representativeness of the sample.

Exclusion criteria:

- communities that do not have structural units or designated persons responsible for environmental safety;
- communities that did not consent to participate in the study or returned incomplete/invalid questionnaires;
- officials who did not have at least one year of experience working in the civil service in the relevant position.

Survey of community leaders.

To this end, a questionnaire was developed with 12 questions covering four key dimensions of environmental safety management policy: strategic, organisational, resource and communication. Responses were collected using a Likert scale (1 – “strongly disagree”; 5 – “strongly agree”). Data collection was carried out using a combined method – through electronic distribution of questionnaires via official local government channels and individual interviews by telephone or online (Zoom, Microsoft Teams).

Between March 2024 and May 2025, responses were received from 86 of the 120 community leaders surveyed. The survey was conducted in two stages during 2024–2025.

In March 2024–May 2025, a survey was conducted among city, town and village heads ($n = 86$) from 120 territorial communities in Ukraine. In May 2025, the views and assessments of employees of the civil protection and environmental safety department within LSG bodies were studied. A total of 86 representatives from 10 territorial communities in 10 regions of Ukraine were involved in this part of the study.

A total of 86 interviews were analysed in the sample. To ensure the reliability and validity of the data, a pilot survey was conducted on a sample of 10 territorial communities. The results were checked for internal consistency using Cronbach's alpha coefficient (0.83), which confirmed sufficient reliability of the measurement tool.

Limitations:

1. The time horizon of the study, taking into account the analysed open data (2022–2025), covers a period of significant socio-economic changes and military actions in Ukraine, which could have influenced the priorities of local authorities in the field of environmental policy.

2. The self-reporting nature of the survey creates a risk of socially desirable responses, especially among officials who may overstate the level of institutional capacity.

3. The heterogeneity of territorial communities (in terms of size, economic potential and degree of urbanisation) complicates direct comparisons of results between regions.

4. The limited set of variables (IC_it ; ENF_it; GDP; FDI per capita; FiscalAut_it; α_0) in the constructed econometric model does not cover all

possible influencing factors, in particular natural-geographical and socio-cultural determinants.

5. The lack of panel data by year makes it impossible to fully track changes in the level of institutional capacity of communities.

The study used: the official website of the State Statistics Service of Ukraine (economy, demographics, emissions, waste); the official website of the Ministry of Environmental Protection and Natural Resources of Ukraine / State Environmental Inspectorate of Ukraine / EcoSystem; the official website of the State Emergency Service of Ukraine (emergency events and response); Community budget reports (open data portal, spending.gov.ua); air/water quality portals, local open data; the official website of the State Agency for Energy Efficiency (renewable energy sources, energy audits); patent databases (Ukrpatent / EPO CPC Y02 for “green” patents).

2.3. Data Analysis

A systematic approach was used to identify problems in the effectiveness of local environmental management and to determine ways to improve communities' institutional capacity to use digital technologies, employing methods such as comparative analysis, statistical assessment, content analysis of regulatory acts, and questionnaires.

Step-by-step analytical procedure

1. The data analysis was conducted in the following sequence:
2. Data collection and preparation: survey data from representatives of 10 territorial communities were combined with open statistical, environmental, budgetary and regulatory data.
3. Data reliability and validation: the survey instrument was tested using Cronbach's alpha. Correlation analysis and the Shapiro–Wilk test were used to assess the relationships and distribution of the variables.
4. Indicator calculation: institutional capacity and environmental safety indicators were calculated using the selected institutional, resource, organisational and environmental variables.
5. Comparative analysis: the institutional capacity of large, medium-sized and small communities was compared using the integrated institutional capacity index.
6. Statistical and econometric analysis: the relationships between institutional capacity, law

enforcement, economic indicators, fiscal autonomy and environmental safety were assessed using correlation analysis and regression estimation.

7. Hypothesis assessment: the estimated coefficients and their statistical significance were used to assess the proposed relationships between institutional capacity, environmental management and environmental safety.
8. Conceptual generalisation: the empirical findings were used to develop a conceptual model of a digital ecosystem for community environmental management integrating digital monitoring, analytical tools, e-governance and stakeholder interaction.

2.3.1. Research Method and Execution Protocol

The empirical analysis followed a predefined sequence of data processing and statistical evaluation. First, the survey and secondary data were organised into a common analytical dataset, with each observation assigned to the corresponding territorial community and observation period. Second, the variables were checked for completeness, consistency of coding and compatibility of measurement scales. Survey responses were converted into numerical values according to the predefined five-point Likert scale, while indicators obtained from administrative and statistical sources were retained in their original units until the calculation of composite indices.

Third, the prepared variables were screened for distributional properties and internal consistency before applying parametric statistical procedures. The reliability of the multi-item survey instrument was evaluated using Cronbach's alpha, while the Shapiro-Wilk test was applied to assess the distributional assumptions. Pairwise correlations were examined before regression estimation to identify potentially redundant explanatory variables and excessive multicollinearity.

Fourth, the institutional capacity and environmental safety indicators were calculated from the predefined groups of institutional, organisational, resource and environmental variables. The resulting indicators were used as analytical measures in the comparative and econometric stages of the study.

Fifth, the relationships between the dependent and explanatory variables were estimated using the specified regression model. For each estimated coefficient, the standard error, t-statistic and two-tailed p-value were calculated. A significance level

of 0.05 was used for statistical inference. The obtained coefficients were then interpreted in terms of the direction and statistical significance of the relationships hypothesised in the study.

Finally, the empirical results were synthesised with the findings of the comparative analysis to develop the conceptual model of the digital ecosystem for environmental management at the community level. The same processing sequence was applied to the analytical dataset to ensure consistency of calculations and comparability of the results.

2.4. Model and Generally Accepted Hypothetical Assumptions

The basic model for calculating the institutional capacity of LSG bodies in the field of environmental safety is presented in formula (1):

$$ESI_{it} = \alpha_0 + \alpha_1 IC_{it} + \beta^T X_{it} + \mu_i + \tau_t + \varepsilon_{it}, \quad (1)$$

where: i – community/city/district (panel unit), t – year; ESI_{it} (Environmental Safety Index) – integral index of environmental safety management results/effectiveness; IC_{it} – institutional capacity of LSG bodies in the field of environmental safety; X_{it} – vector of control variables; μ_i – individual (spatial) effect; τ_t – time effect; ε_{it} – error.

Hypothesis H1: $\alpha_1 > 0$. Higher institutional capacity of LSG bodies increases the level of environmental safety/effectiveness of its management [37].

Mediation through environmental management tools can be represented as follows:

$$\begin{aligned} ENF_{it} &= \delta_0 + \delta_1 IC_{it} + \theta^T X_{it} + \mu_i + \tau_t + u_{it}, \\ ESI_{it} &= \alpha_0 + \alpha_1 IC_{it} + \alpha_2 ENF_{it} + \beta^T X_{it} + \mu_i + \tau_t + \varepsilon_{it}, \end{aligned} \quad (2)$$

where ENF_{it} is the intensity of enforcement/law enforcement (number of inspections, sanctions imposed, proportion of violations eliminated).

Hypothesis H2 considers a possible indirect effect through environmental management instruments (ENF), assuming that part of the effect is realised through strengthened enforcement and control.

Hypothesis H2:

$$IC \rightarrow ENF \rightarrow ESI. \quad (3)$$

Interactions (heterogeneity)

$$ESI_{it} = \dots + \gamma_1 (IC_{it} \times Urban_i) + \gamma_2 (IC_{it} \times FiscalAut_{it}) + \gamma_3 (IC_{it} \times Shock_{it}) + \dots \quad (4)$$

Urban $_i$: urban/rural community;

FiscalAut_{it}: fiscal autonomy index; Shock_{it}: military/climate shocks.

Hypothesis H3 tests the *contextual variability* of the α_1 effect, according to which the impact of institutional capacity increases in communities with higher levels of fiscal autonomy and decreases under the influence of external shocks (military or climatic).

Hypothesis H3: The *IC* effect is higher in communities with greater fiscal autonomy and outside areas experiencing acute shocks.

Dynamics / inertia:

$$ESI_{it} = \rho ESI_{i,t-1} + \alpha_1 IC_{it} + \dots + \mu_i + \tau_t + \varepsilon_{it} \quad (5)$$

Baseline estimation: two-way fixed effects with SE clustering by *i* (or Driscoll–Kraay SE for spatio-temporal dependence) [20, 37].

The problem of endogeneity: possible feedback between $ESI \leftrightarrow IC$.

Tools (2SLS/IV-FE): transfer lags to ecology, statistical density of eco-departments, distance to regional centres/Eco-Inspection, “waves” of grant programmes.

in the FE model, Event Study around the launch of programmes/reforms.

Model robustness: alternative *ESI* and *IC* constructs (different weights/PCA); exclusion of megacities/militarily active territories;

Example of interpreting coefficients:

$\alpha_1 = 0.12$: an increase in *IC* by 0.1 (10 index points) is associated with an increase in *ESI* by 0.012 standard deviations (or 1.2 points on a scale of 0–1).

$\alpha_2 > 0$ in the mediation model: part of the *IC* effect is realised through stronger enforcement of *ENF* law enforcement.

2.5. Statistical Evaluation of Results

The results were evaluated using the Ordinary Least Squares (OLS) method and by calculating Cronbach’s alpha coefficient, which assesses the degree of interdependence between items on the scale that measure the same characteristic.

The calculation was performed using the following formula:

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^n \sigma_i^2}{\sigma_t^2} \right) \quad (6)$$

where: *k* is the number of variables, σ_i^2 is the variance of each variable, σ_t^2 is the total variance of the aggregate indicator.

$\alpha = 0.83$ indicates high internal consistency of the scale (threshold 0.7). The absence of multicollinearity ($r < 0.85$) and the normal distribution of the data (Shapiro–Wilk, $p > 0.05$) allow the use of parametric methods. The instrument is reliable and valid, ensuring the results are reliable. Additionally, a correlation analysis was performed, which confirmed the absence of excessive multicollinearity ($r < 0.85$). Checking the normality of the data distribution using the Shapiro–Wilk criterion showed compliance with normality ($p > 0.05$), which allowed the use of parametric methods for further analysis.

Standard errors, t-statistics, and p-values were calculated in Microsoft Excel. For each parameter, the standard error was obtained from the diagonal elements of the estimated covariance matrix $\hat{\sigma}^2(X^T X)^{-1}$, the t-statistic as the ratio of the coefficient estimate to its standard error, and the p-value as the two-tailed probability under the t-distribution with $n - k$ degrees of freedom [36].

3. RESULTS

3.1. Assessment of the Institutional Capacity of LSG Bodies in the Field of Environmental Safety

Based on data from the Ministry of Digital Transformation of Ukraine, several indices of digital transformation and regional institutional capacity were developed [40]. The digital transformation index was introduced in 2021, but it has not been published for all regions of Ukraine. The institutional capacity index values were published in 2024. The average digital transformation index for Ukraine’s regions was 0.593 out of a possible 1. The result indicates a moderate level of digitisation of LSG bodies. As of 2024, the penetration index for basic electronic services was 0.759; institutional capacity: 0.687; Internet development: 0.686. The sub-index “Implementation of a paperless regime” had the lowest result, which was 0.421. Key factors for the effectiveness of digitalisation at the regional and local levels include a regional digital transformation strategy and the development of regional and local informatisation programmes. Priority funding for digitalisation measures and the formation of structural units for digital development in LSG bodies and executive authorities are also important. The results of the analysis are presented in Figure 2.

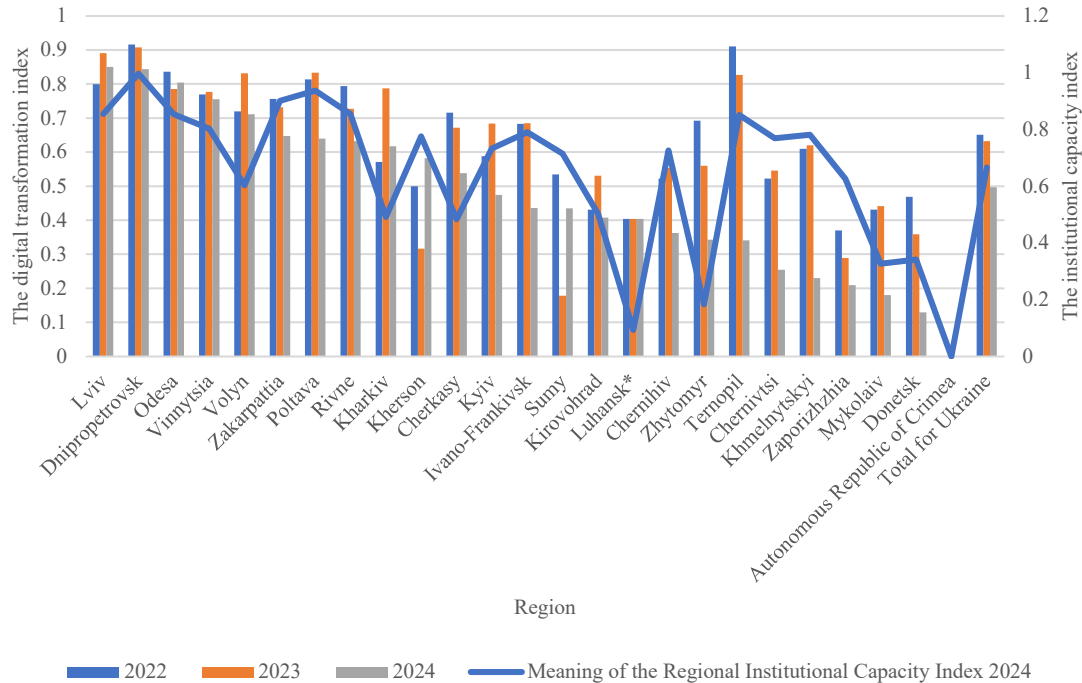


Figure 2: Key findings from the respondent survey

Source: own research based on [40]

According to the results presented in Figure 2, Ukraine's lowest Digital Transformation Index score was recorded in 2024. It was 0.497 out of a possible 1. The highest sub-indices were: penetration of basic e-services – 0.759; institutional capacity – 0.687; internet development – 0.686. The lowest sub-index was the implementation of a paperless regime – 0.421, indicating the need to intensify work in this area.

The results indicate a steady trend towards the digitalisation of regional and local governance, particularly in the field of environmental management. The gradual strengthening of institutional capacity contributes to the more effective implementation of e-services, environmental monitoring systems and digitalisation programmes. The comparative assessment of the institutional capacity of LSG bodies in environmental safety management is presented in Table 1.

Table 1: Comparative Characteristics Of The Institutional Capacity Of LSG Bodies In Environmental Safety Management (Example Of Ukraine)

Type of community	Strategic planning in the field of environmental safety	Resource provision (personnel, finances, equipment)	Coordination with environmental services, the State Emergency Service and scientific institutions	Involvement of the public and business in eco-projects	Overall institutional capacity
Large cities (500,000+)	High – existing environmental strategies, climate change adaptation plans, integration with the European Green Deal	High – specialised departments, access to international grants, modern monitoring equipment	High – regular joint activities with state bodies, scientific institutions, and international partners	Average – public participation limited to pilot programmes	4,5 / 5

Medium-sized cities (50,000–500,000)	Average – individual programmes exist, but there is no comprehensive strategy	Average – limited funding, lack of environmental specialists, insufficient laboratory facilities	Average – interaction is situational, depends on available projects	High – active environmental NGOs, local eco-initiatives	3,6 / 5
Small towns and rural communities (<50,000)	Low – strategic documents are absent or are declarative in nature	Low – dependence on regional structures, lack of own monitoring infrastructure	Medium – interaction with regional services and volunteer networks	High – communities actively participate in cleaning, greening, and restoring ecosystems	3,1 / 5

Note: Assessment on a five-point scale based on an integrated institutional capacity index

Source: own research

The results show clear differences in institutional capacity among communities of different sizes. Large cities demonstrated the highest capacity (4.5/5), while medium-sized and small communities scored 3.6/5 and 3.1/5, respectively.

The assessment demonstrates that large cities possess stronger institutional and technological capacities for digital environmental management due to the availability of specialised departments, modern monitoring infrastructure and access to international funding. At the same time, smaller communities demonstrate higher levels of public participation in environmental initiatives, including activities related to the protection of

natural resources and agricultural land. Medium-sized cities occupy an intermediate position, combining moderate institutional capacity with active involvement of local environmental organisations.

The survey results additionally indicate that large cities have a high level of institutional readiness but require broader community involvement in environmental decision-making. Small communities compensate for limited financial and technical resources through active civic engagement; however, they remain more vulnerable to environmental risks because of insufficient monitoring infrastructure and limited administrative capacity (Figure 3).

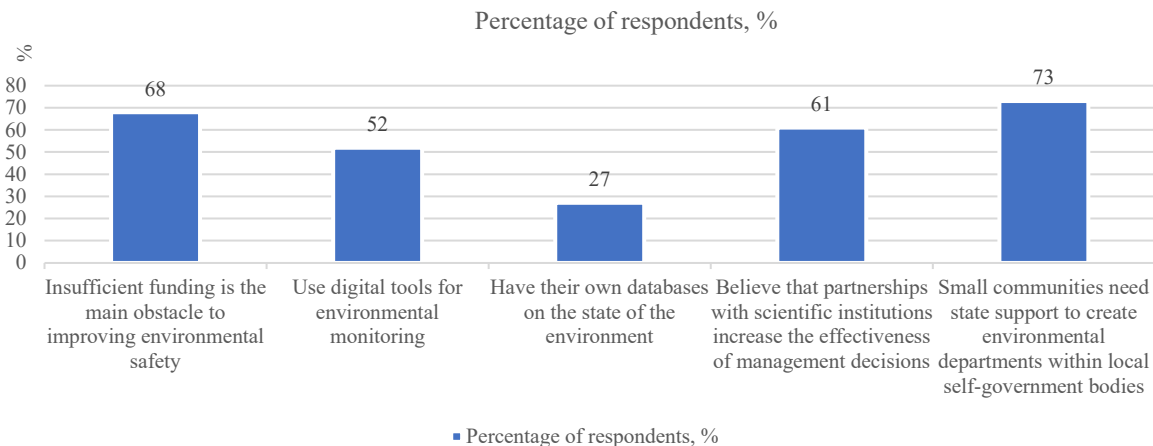


Figure 3: Key Findings From The Respondent Survey

Source: Own Research

Figure 3 reflects key issues related to communities' institutional capacity. The results show that the spread of digitalisation has a positive but still insufficient momentum. It has been

established that most communities rely on external or state information resources. The survey confirms the importance of scientific and expert support for local government and the need to implement

centralised programmes to support digital and human resource capacity. The results of calculating the institutional capacity indices of local

communities according to models (1)-(5) are presented in Table 2.

Table 2: Results Of The Conditional Assessment Of The Model Of Institutional Capacity Of LSG Bodies In The Field Of Environmental Safety

Variable	Coefficient	Standard error	t-statistics	P-value
IC_it (institutional capacity)	0.12	0.045	2.67	0.009
ENF_it (law enforcement)	0.085	0.032	2.65	0.01
Gross regional product (GRP) per capita	0.05	0.02	2.5	0.013
Share of industry	-0.03	0.015	-2.0	0.046
FDI per capita (foreign direct investment per capita)	0.04	0.018	2.22	0.027
Fiscal autonomy index FiscalAut _{it}	0.06	0.022	2.73	0.007
Constant (α_0)	0.5	0.08	6.25	0.0

Source: own research

Table 2 presents the results of a conditional econometric assessment of the model measuring the impact of LSG bodies' institutional capacity on environmental safety levels. Institutional capacity (IC_{it}) has a positive and statistically significant impact on the environmental safety index (coefficient 0.12, $p = 0.009$), indicating that improvements in organisational and administrative capacity are associated with better environmental outcomes. This confirms hypothesis H1: an increase in institutional capacity by 0.1 index units is associated with an increase in ESI by approximately 0.012 units.

Law enforcement (ENF_{it}) also has a positive impact on environmental safety (coefficient 0.085, $p = 0.01$), consistent with the mediation hypothesis H2 – part of the IC effect is transmitted through increased inspections and controls. It suggested that institutional capacity is more effective when supported by inspections, control and enforcement mechanisms. GDP per capita and foreign direct investment per capita have a positive and statistically significant impact, indicating the role of economic development in improving environmental performance. The share of industry in GRP has a negative effect (coefficient -0.03 , $p = 0.046$), which may reflect increased environmental pressure in more industrialised communities. This difference can be explained by the additional environmental pressure generated by industrial activity.

The fiscal autonomy index proved to be a significant positive factor ($p = 0.007$), confirming hypothesis H3 that communities with greater financial independence are more effective at ensuring environmental safety. This indicates that communities with greater financial independence have better opportunities to implement environmental measures. The constant (α_0) indicates that even when all variables are zero, the baseline level of environmental security remains moderately high (0.5 on a 0–1 scale). The results are consistent with the theoretical model: institutional capacity is a significant driver of environmental security, both directly and through enhanced law enforcement. At the same time, the structure of the economy (the share of industry) can weaken this effect. Therefore, economic capacity alone does not guarantee better environmental outcomes; its effect depends on the structure of the local economy and the ability of local institutions to manage environmental risks.

3.2. Conceptual Model of a Digital Ecosystem for Community Environmental Management

Figure 4 presents a conceptual model of a digital ecosystem for community environmental management, reflecting the systemic interactions among institutional actors, digital tools, and environmental outcomes, to improve the effectiveness of environmental management and ensure environmental safety at the local level.

The upper part of the model presents digital platforms for environmental monitoring of natural resources and agricultural land. Which include GIS systems, IoT sensors, mobile applications, and online dashboards. The data is consolidated into centralised environmental hubs or open databases that contain information on air, water and waste conditions, and is enhanced by analytical and AI-based forecasting and risk-assessment systems.

Digital coordination is carried out through e-Governance platforms that serve as intermediaries among various participants in the ecosystem. At this level, partnerships are formed between public authorities, businesses, civil society and scientific institutions:

- business structures are implementing GreenTech solutions and public-private partnership models.
- local authorities act as coordinators of environmental policy;
- public and scientific institutions provide crowdsourced data and integrate research results into decision-making practices.

The interaction between digital and management elements results in the formation of a stable digital ecosystem of local governance, which provides:

- increasing the transparency of environmental monitoring;
- prompt response to environmental challenges;
- optimisation of resource allocation;
- strengthening environmental security and achieving sustainable development goals.

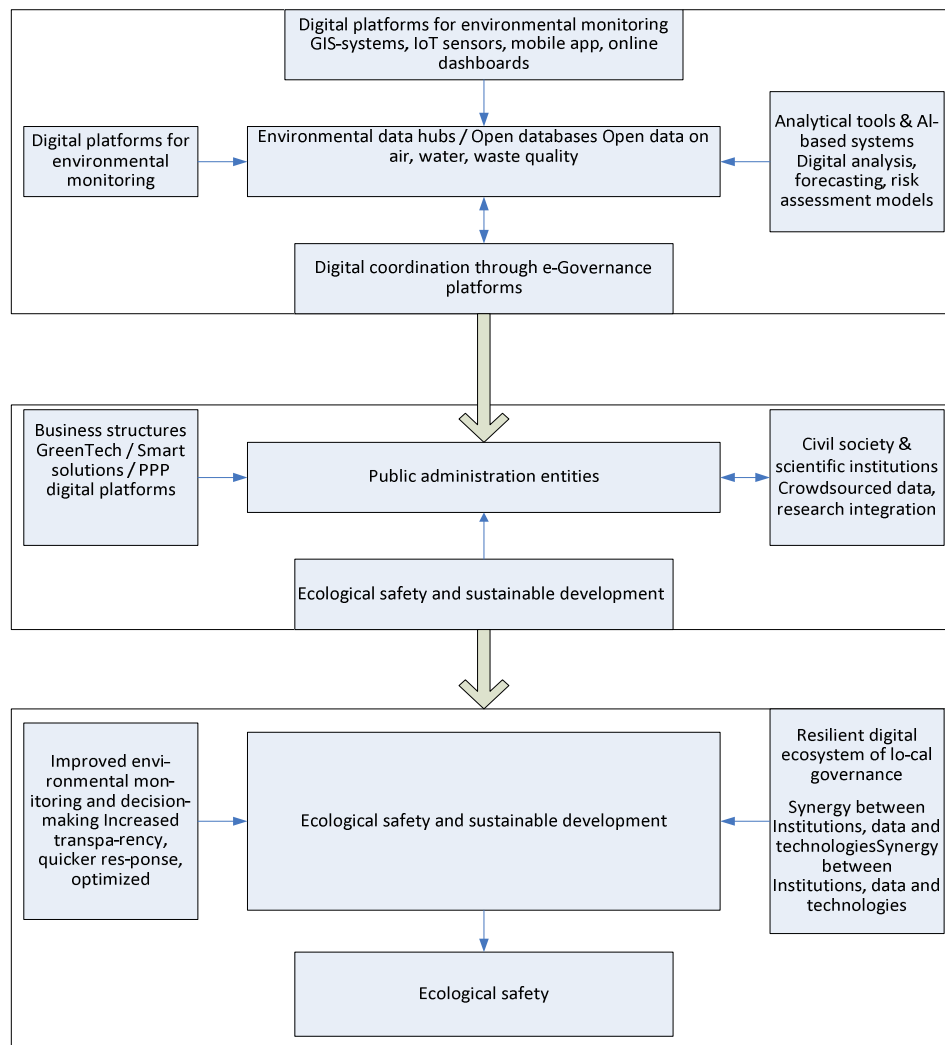


Figure 4: Conceptual Model Of A Digital Ecosystem For Community Environmental Management
Source: Own Research

Thus, the model demonstrates that the digitalisation of environmental management not only modernises monitoring and control processes but also creates synergies among institutions, data, and technologies, enhancing the institutional capacity of communities and promoting the transition to environmentally sustainable and innovative local governance. The model supports transparent governance, sustainable use of natural resources and effective monitoring of agricultural land at the local level.

4. DISCUSSION

The results confirm that the digitalisation of environmental management is a system-forming factor in the institutional capacity of local and regional authorities. It shapes a new digital ecosystem for environmental management, combining digital platforms, public-private interaction, analytical monitoring tools and mechanisms for public engagement. According to the conceptual model, the interaction among administrative structures, businesses, scientific institutions, and citizens creates synergies that ensure sustainable environmental development.

The results are consistent with the findings of Bisogno et al. [2] and Samiotis et al. [33], who argue that the introduction of digital technologies in public administration is a prerequisite for achieving the SDGs. It has been confirmed that the quality of digital infrastructure and officials' digital competence directly affect the effectiveness of environmental policy. This is consistent with the findings of Cvetković et al. [3], who emphasise that local authorities must have the technological capabilities to manage risks. At the same time, differences in results may be related to varying levels of digital maturity, financial resources, specialised personnel and digital infrastructure. An important finding is that smaller communities, despite lower institutional capacity, can partly compensate for limited technical and financial resources through higher public participation.

As noted by Darmi et al. [20] and Sridharan et al. [41], even small communities can achieve high results in environmental safety by implementing analytical and sensor systems. In our study, 52% of respondents reported using digital monitoring tools, while only 27% had their own databases, indicating that digitalisation remains fragmented. This finding suggests that the availability of individual digital tools does not necessarily imply an integrated digital management system. The results of the study also confirm the position of Al-Hammouri et al. [1] and Vynohradenko et al. [38] that the introduction of AI

and automated analytical systems increases the transparency and accuracy of environmental control, but requires a regulatory framework.

This partly correlates with the conclusions of Butynska [19], who emphasises the need for a systematic approach to the digitalisation of legal relations in the environmental sphere in Ukraine.

Ukrainian researchers such as Khvesyk et al. [13] and Buryk [4] note that institutional support for digital processes is a key determinant of the effectiveness of environmental policy. Our study confirms that digital tools enhance transparency, accountability and public participation, which is consistent with the findings of Kiss et al. [15] on the role of electronic platforms in shaping nature-oriented decisions. At the same time, Kostrubiec et al. [30] and Klymenko [32] emphasise the need to harmonise Ukrainian legislation with European e-governance standards, which is a prerequisite for the effective implementation of the conceptual model of a digital ecosystem developed. Similarly, Koval et al. [18], Honcharuk [29] and Korol [42] stress that digitalisation must be combined with the development of environmental thinking among managers and with improving digital literacy.

The results of the study demonstrate that the digitalisation of environmental management can serve as a key tool for enhancing communities' institutional capacity. The identified differences in digitalisation levels between communities indicate the need to account for socio-economic, infrastructural, and managerial factors when implementing digital solutions. In practical terms, integrating digital technologies into environmental management processes contributes to the coordination of actions among all participants, enhances coordination, and creates the conditions for sustainable and safe community development in the digital age. The integration of digital tools into environmental management improves coordination among authorities, businesses and communities in the protection of natural resources and agricultural land.

4.1. Recommendations

1. Institutional level: establishment of permanent departments or coordination councils on environmental safety within local authorities to ensure the integration of environmental objectives into local development policies.

2. Digitalisation of management: introduction of unified digital platforms for monitoring

environmental risks and community reporting using GIS technologies and open data.

3. Financial decentralisation: expanding the fiscal autonomy of local budgets to establish sustainable sources of funding for environmental projects. Additional financial support is needed to ensure effective digital monitoring of natural resources and sustainable management of agricultural land.

4. Staff training: conducting systematic training and programmes for officials in the field of environmental management and emergency response.

5. Further research: application of panel or spatial econometric analysis to study regional differences, as well as expansion of the model by adding social and technological indicators.

5. CONCLUSIONS

The relevance of the study is due to the growing need to develop a digital ecosystem for environmental management capable of ensuring timely monitoring of the state of the environment, improving the effectiveness of management decisions by local self-government (LSG) bodies and strengthening the environmental security of territorial communities in the context of climate challenges and decentralisation. The study confirmed that the digitalisation of environmental management is a decisive factor in improving the effectiveness of LSG bodies' environmental safety activities. The results of the study showed that the main obstacles to effective environmental management remain insufficient funding for environmental programmes and limited human resources in local government bodies. An analysis of institutional readiness showed that large cities achieved high scores (4.5 out of 5 points), medium-sized communities demonstrated an average level (3.6). In contrast, small communities scored lower (3.1) but partially offset this with higher levels of active public participation. Econometric analysis confirmed the positive impacts of institutional capacity ($\beta = 0.12$; $p = 0.009$) and law enforcement effectiveness ($\beta = 0.085$; $p = 0.01$) on environmental safety. A statistically significant positive correlation was found between GDP per capita ($r = 0.05$; $p = 0.013$) and foreign direct investment ($r = 0.04$; $p = 0.027$), indicating a relationship between economic development and environmental indicators. At the same time, the share of industry in the economy harms the environmental condition of territories ($\beta = -0.03$; $p = 0.046$), due to increased anthropogenic pressure. The index of fiscal autonomy of

communities, which was 0.06 ($p = 0.007$), underscores the importance of financial independence for implementing sustainable environmental policies. The results confirmed the generally accepted hypothesis H_1 that digital technologies enhance responsiveness to environmental risks and strengthen the interaction among government, business, and the public through e-participation mechanisms. The results indicate the need to strengthen the digital competencies of local government officials, develop digital infrastructure, and create uniform standards for electronic environmental management. The implementation of these tasks will ensure more rational use of natural resources and agricultural land, reduce environmental risks, and achieve balanced regional development. Prospects for further research lie in developing integrated methodological approaches to assess the level of digital maturity of LSG bodies in environmental management. Another important area is modelling the impact of digital technologies on environmental indicators of regional development. The results obtained can be used to improve local government digital transformation strategies, shape regional environmental policies, and enhance the effectiveness of state environmental safety regulation. Future research should focus on developing integrated approaches for assessing the digital maturity of LSG bodies in environmental management and on modelling the effects of digital technologies on regional environmental indicators. Further studies could also examine the proposed framework across communities with different levels of digital infrastructure and institutional capacity to assess its applicability under different territorial conditions.

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