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Geodesy, Cadastre, Topography, Cartography, Remote sensing, Photogrammetry, GIS

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BRIDGING KNOWLEDGE AND PRACTICE: SERVICE-LEARNING AS A TEACHING METHOD FOR SUSTAINABLE ENERGY IN ENVIRONMENTAL ENGINEERING

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Abstract. *This paper investigates the role of service-learning as an effective teaching method in Environmental Engineering education, specifically within the context of sustainable energy practices. Service-learning, an approach that integrates community service with academic instruction, provides students with hands-on, real-world applications that complement theoretical knowledge. This study explores a project designed to engage Environmental Engineering students in sustainable energy initiatives by partnering with local high schools. University students present and work on a prototype of an energy-independent solar house, which incorporates both solar and geothermal energy systems, to demonstrate practical applications of renewable energy. The objectives are threefold: to bridge the gap between academic learning and practical implementation, to empower students with technical skills in sustainable energy solutions, and to foster a sense of social responsibility towards environmental sustainability. Through interactive learning modules and hands-on activities, students develop a deeper understanding of renewable energy technologies and the engineering principles underlying sustainable infrastructure. Surveys conducted before and after the project evaluate the students' knowledge, technical skills, and engagement with sustainability topics, highlighting the benefits and challenges of this teaching approach. Findings show that service-learning not only enhances students' technical competencies but also strengthens their problem-solving, teamwork, and critical thinking skills. This paper contributes to the growing body of research on experiential learning in engineering education, underscoring the potential of service-learning to foster meaningful learning experiences and prepare students for the pressing challenges of sustainable development.*

Keywords: *Service-Learning, Environmental Engineering Education, Experiential Learning, Sustainability Education, Sustainable Energy, Environmental Responsibility, Social Responsibility.*

1. Introduction

Service-learning is an innovative educational approach that combines academic study with community service, aiming to enrich students' learning experiences while addressing genuine societal needs. Unlike traditional learning models, which primarily focus on theoretical knowledge within the confines of the classroom, service-learning actively engages students in practical, community-based projects. This dual-focus model emphasizes not only academic development but also social responsibility, allowing students to apply what they learn to real-world challenges. By integrating service-learning into the curriculum, educational institutions can create a bridge between academic knowledge and practical application, fostering a comprehensive learning environment that benefits both students and the community.

In the field of environmental engineering, service-learning is particularly relevant. Environmental engineering education often involves complex concepts related to sustainability, resource management, and ecological protection, all of which have direct implications for the communities affected by environmental issues. Traditional engineering education tends to focus on imparting theoretical knowledge, often through coursework and laboratory experiments. While this approach is valuable, it can leave students disconnected from the societal impact of their work. Service-learning addresses this gap by placing students in community contexts where they can experience firsthand the environmental challenges faced by society. This practical involvement allows them to better understand the importance of sustainable practices and the social dimensions of environmental issues, such as energy accessibility, water quality, and waste management.

One of the key benefits of service-learning in environmental engineering education is its ability to enhance students' technical skills while fostering a sense of ethical and social responsibility. Through community-based projects, students are given the opportunity to work on real problems that require innovative and sustainable solutions. For example, a service-learning project might involve designing an energy-efficient system for a local community center or creating a renewable energy solution for a school. Such projects allow students to apply their theoretical knowledge of sustainable engineering practices, such as energy conservation and green infrastructure, while also learning to consider the economic and social factors that impact these solutions' feasibility and effectiveness. [1]

At the Technical University of Civil Engineering Bucharest, integrating service-learning into environmental engineering programs has become an essential strategy for preparing students to meet the demands of sustainable development. Through partnerships with local high schools and community organizations, students engage in projects that educate communities on sustainable practices while also developing their own technical and interpersonal skills. For instance, students might work with high school peers to build a prototype of an energy-independent solar house, which not only showcases renewable energy technology but also provides a tangible learning experience that underscores the value of sustainable energy practices. These projects allow students to witness the direct impact of their work on local communities, helping them to appreciate the broader implications of their engineering education.

Moreover, service-learning in environmental engineering promotes interdisciplinary collaboration and holistic thinking, which are essential in addressing the multifaceted challenges of sustainability. Environmental issues are rarely isolated; they often intersect with social, economic, and political factors. By engaging in service-learning projects, students are exposed to the complexities of real-world problem-solving, where technical solutions must consider diverse perspectives and constraints. This experience cultivates a mindset that values collaboration and adaptability, qualities that are critical for success in the engineering profession.

This approach to environmental engineering education transforms the student experience by providing a platform where academic knowledge meets real-world application, fostering both technical proficiency and a strong sense of social responsibility. By incorporating service-learning into their programs, institutions like the Technical University of Civil Engineering Bucharest prepare future engineers with the skills and ethical awareness needed to tackle critical environmental issues. Service-learning not only strengthens students' technical abilities but also shapes them into leaders for sustainable development, ready to make a lasting impact on their communities and advance the field of environmental engineering. [2].

2. Foundations and Case Studies in Service-Learning for Environmental Engineering

Service-learning has emerged as an educational model that bridges academic learning with community service, fostering both knowledge acquisition and social engagement. This approach is grounded in the idea that learning should not only contribute to intellectual growth but also address real societal needs, creating a mutually beneficial relationship between students and the communities they serve. In a service-learning framework, students apply their academic skills to community projects, allowing them to deepen their understanding of theoretical concepts while gaining valuable practical experience. In return, communities benefit from the students' technical knowledge and problem-solving abilities, which can be directed towards addressing local challenges. Service-learning thus shifts education from a traditional classroom model to one that emphasizes experiential learning, encouraging long-term retention and skill application.

In the field of engineering education, particularly within civil and environmental disciplines, service-learning has shown substantial promise. Engineering programs are designed to equip students with the tools to solve practical problems, often with a focus on improving societal well-being through sustainable solutions. However, traditional methods tend to emphasize theoretical instruction and lab-based practice, sometimes with limited community interaction. Service-learning enhances this traditional model by placing students in real-world contexts, where they can see firsthand the impacts of environmental and infrastructural issues on communities. This approach allows students to develop a deeper understanding of the ethical, social, and economic dimensions of engineering projects, encouraging them to view their work through a holistic lens that includes both technical and human factors. Through direct engagement with community issues, students in service-learning programs cultivate skills in problem-solving, teamwork, and adaptability, all of which are essential for effective engineering practice.

At the Technical University of Civil Engineering Bucharest, service-learning has been successfully integrated into several environmental and civil engineering courses, contributing significantly to the development of socially conscious and technically skilled graduates. The university's approach to service-learning emphasizes community partnerships, where students collaborate with local schools, organizations, and community leaders to address pressing environmental issues. One exemplary initiative involved the design and construction of a prototype solar-powered house, which students developed in partnership with local high schools. Through this project, university students had the opportunity to apply renewable energy concepts, energy-efficient design principles, and sustainable construction methods in a hands-on setting. This experience not only enhanced their technical skills but also exposed them to the challenges and rewards of sustainable community development, instilling a sense of responsibility for promoting environmentally friendly practices. [3]

Another impactful service-learning initiative at the university includes workshops on energy conservation and efficiency, organized by engineering students for community members and high school students. These workshops provide participants with practical advice on reducing energy consumption and introduce them to basic principles of renewable energy. By teaching others, students reinforce their own understanding of these concepts while developing communication skills and the ability to convey complex ideas in accessible ways. The workshops also demonstrate the vital role of community education in fostering sustainable behaviors. Community members who participate in these workshops often report a greater awareness of their energy usage and a willingness to adopt more sustainable habits, illustrating the broader societal impact of these educational efforts.

Through service-learning, the Technical University of Civil Engineering Bucharest addresses sustainability in engineering education by exposing students to real-life problems that require innovative, responsible solutions. These projects present students with real-world engineering challenges, such as balancing cost constraints, material availability, and project feasibility with the need to create environmentally responsible designs. This hands-on experience equips students with a well-rounded skill set that prepares them for the professional demands of environmental and civil engineering. The lessons learned through service-learning also emphasize the importance of empathy and community collaboration in developing sustainable infrastructure, qualities that are essential for today's engineers.

Overall, service-learning has become an invaluable part of environmental engineering education at the Technical University of Civil Engineering Bucharest, offering students a meaningful way to apply their skills and make a tangible difference in the world. These projects underscore the university's commitment to producing engineers who are both technically adept and socially responsible, prepared to address the multifaceted challenges of sustainable development. Through service-learning, students gain not only academic knowledge but also a lifelong commitment to positively impacting their communities and advancing the principles of sustainability in their professional lives. [4].

3. Project Methodology

This section outlines the approach, structure, and assessment methods used in implementing the service-learning project in environmental engineering. The project methodology includes a description of the context and partnerships involved, the integration of service-learning components, and the phases of project implementation. Additionally, it highlights the methods used to evaluate the impact of the project on students and the community.

3.1 Project Context and Purpose

This service-learning initiative was designed in response to the increasing need for sustainable practices in local communities, particularly within the context of energy access and environmental education.

By collaborating with local high schools and community organizations, the project aimed to equip both university and high school students with the knowledge and skills to address pressing environmental challenges.

The project specifically focused on demonstrating the practical applications of renewable energy through the development of a prototype solar-powered house. The purpose was not only to provide technical education but also to foster social responsibility, encouraging students to consider the community impact of sustainable engineering solutions.

3.2 Service-Learning Component

The service-learning approach underpinned every aspect of the project, aligning academic objectives with practical, community-focused outcomes. This component allowed students to engage directly with the community, learning from real-world problems while applying their engineering knowledge.

By collaborating with high school students, university participants took on roles as mentors and educators, reinforcing their own understanding through teaching and application. This component was essential for bridging theoretical knowledge with hands-on experience, fostering a dual learning environment where both university and high school students benefited from each other's insights and skills.

3.3 Project Phases

The project was organized into several key phases, each targeting specific educational and community engagement goals:

- *Energy Efficiency and Conservation Workshop*: These workshops were designed to educate high school students on energy efficiency practices, focusing on the importance of conservation. University students conducted sessions on energy-efficient technologies and provided practical tips on reducing energy consumption. Interactive discussions were encouraged to allow students to share their ideas and experiences related to energy use.
- *Community Awareness Campaign*: Aiming to raise awareness about the benefits of sustainable and renewable energy, this campaign involved organizing seminars, poster campaigns, and informational sessions within the local school community. University students developed the campaign content and led activities that engaged students, teachers, and parents in conversations about environmental sustainability.
- *Public Showcase Event*: This event offered an opportunity to present the prototype solar-powered house to the community. The showcase included guided tours, presentations, and interactive exhibits that demonstrated the principles of renewable energy and sustainable building practices. Both university and high school students participated, allowing them to take ownership of their contributions and interact directly with the community.

- *Construction of a Prototype Solar House*: This phase involved university and high school students in building a small-scale, energy-independent house powered by solar technology. The hands-on construction activities provided students with experience in sustainable building practices, including material selection, energy management, and system integration.

3.4 Impact Assessment and Evaluation

The project's impact was assessed through various evaluation tools aimed at measuring students' technical competencies, social engagement, and understanding of sustainability.

The following methods were employed:

Pre- and Post-Project Surveys

Surveys were administered to both university and high school students before and after the project to gauge their knowledge and attitudes toward sustainable energy and environmental responsibility.

This survey, with identical questions for both groups, helps assess their initial knowledge and the impact of the project on their understanding and attitudes toward sustainability.

Table 1: Sustainable Energy and Environmental Responsibility Survey

Question	Response Options
How familiar are you with different types of renewable energy sources (e.g., solar, wind, geothermal)?	☐ Not at all familiar, ☐ Slightly familiar, ☐ Moderately familiar, ☐ Very familiar, ☐ Extremely familiar
How well do you understand the potential benefits of using renewable energy for sustainable development?	☐ No understanding, ☐ Limited understanding, ☐ Basic understanding, ☐ Good understanding, ☐ Excellent understanding
How knowledgeable are you about energy-efficient practices and technologies (e.g., LED lighting, insulation, energy-efficient appliances)?	☐ Not knowledgeable, ☐ Slightly knowledgeable, ☐ Moderately knowledgeable, ☐ Very knowledgeable, ☐ Extremely knowledgeable
How important do you believe energy efficiency is in contributing to environmental sustainability?	☐ Not important at all, ☐ Slightly important, ☐ Moderately important, ☐ Very important, ☐ Extremely important
How interested are you in learning more about sustainable practices and environmental responsibility?	☐ Not interested, ☐ Slightly interested, ☐ Moderately interested, ☐ Very interested, ☐ Extremely interested
How likely are you to adopt sustainable practices (e.g., conserving energy, reducing waste) in your daily life?	☐ Very unlikely, ☐ Unlikely, ☐ Neutral, ☐ Likely, ☐ Very likely

This survey is designed to measure your knowledge and attitudes toward renewable energy and environmental responsibility.

The survey will be used at the start and end of the project to assess your progress and experience.

This survey will be administered before and after the project to assess changes in your knowledge and attitudes as a result of participating in the service-learning activities.

This survey format is designed to be clear and concise, helping capture both knowledge and motivation related to sustainability in a format accessible to both university and high school students.

The results provided insights into the effectiveness of the project's educational components.

Feedback and Reflection Sessions

Reflection sessions were conducted to allow students to discuss their experiences and articulate the knowledge and skills gained. These sessions were essential for promoting critical thinking and self-assessment, encouraging students to recognize the impact of their work on the community.

Community Feedback

Community members who participated in the awareness campaign and public showcase were asked to provide feedback on the project.

Their responses helped assess the reach and effectiveness of the project in raising awareness about sustainable practices.

Table 2: Community Feedback Form

Question	Response Options
1. How would you rate the overall quality of the information provided at the event?	☐ Excellent ☐ Good ☐ Fair ☐ Poor
2. Did the event increase your understanding of renewable energy and sustainable practices?	☐ Significantly increased ☐ Moderately increased ☐ Slightly increased ☐ Not at all
3. How likely are you to adopt any of the sustainable practices discussed at the event?	☐ Very likely ☐ Likely ☐ Neutral ☐ Unlikely ☐ Very unlikely
4. What part of the event did you find most valuable?	☐ Presentation on renewable energy ☐ Hands-on demonstrations (e.g., solar house prototype) ☐ Information on energy efficiency ☐ Interactive exhibits ☐ Other (please specify)
5. Do you have any suggestions for improving future events like this one?	
6. Additional Comments	

3.5 Project Sustainability and Future Integration

To ensure the project’s long-term impact, discussions were held with high school teachers and administrators about integrating elements of the service-learning project into the school curriculum. This step aimed to create continuity by embedding sustainable energy concepts within relevant subjects, making it possible for future students to benefit from the knowledge gained in this initiative. Additionally, educational materials and documentation, such as instructional videos and reports, were created to serve as resources for future learning and community engagement efforts. [5]

This structured methodology allowed the project to address both academic and community needs, offering a comprehensive learning experience that extended beyond the confines of traditional education. Through hands-on experience, interdisciplinary collaboration, and community interaction, the service-learning project demonstrated the potential of environmental engineering to make a meaningful impact on society.

4. Project Methodology

This section presents the key findings from the service-learning project and discusses its impact on students' technical abilities, community engagement, and understanding of sustainability. Through a combination of surveys, feedback sessions, and community response, the results highlight both the achievements and challenges encountered during the project, as well as its broader implications for environmental engineering education.

4.1 Impact on Students

The service-learning project had a substantial effect on students’ technical skills and personal growth. Through hands-on activities such as constructing a prototype solar house and conducting energy conservation workshops, students were able to apply their theoretical knowledge to real-world challenges.

Surveys administered before and after the project showed a marked improvement in students' understanding of renewable energy principles, energy efficiency, and sustainable building practices.

Additionally, students reported enhanced problem-solving and teamwork skills, citing the collaborative nature of the project as a valuable experience that required effective communication and cooperation with both their peers and community members.

The project also encouraged critical thinking and adaptability, as students encountered unforeseen challenges, such as sourcing materials or adjusting designs to fit practical constraints. These experiences mirror the complexities of real-world engineering projects and provided students with insight into the importance of flexibility and resourcefulness in their field.

4.2 Feedback and Evaluations

Reflection and feedback sessions conducted with students revealed their perceptions of the project's value and the skills they gained. Many students expressed a heightened awareness of sustainability and a deeper understanding of their role as future engineers in promoting environmental responsibility. The discussions also highlighted the sense of accomplishment students felt in contributing to their community, noting that the hands-on application of their studies made the learning experience more meaningful and engaging.

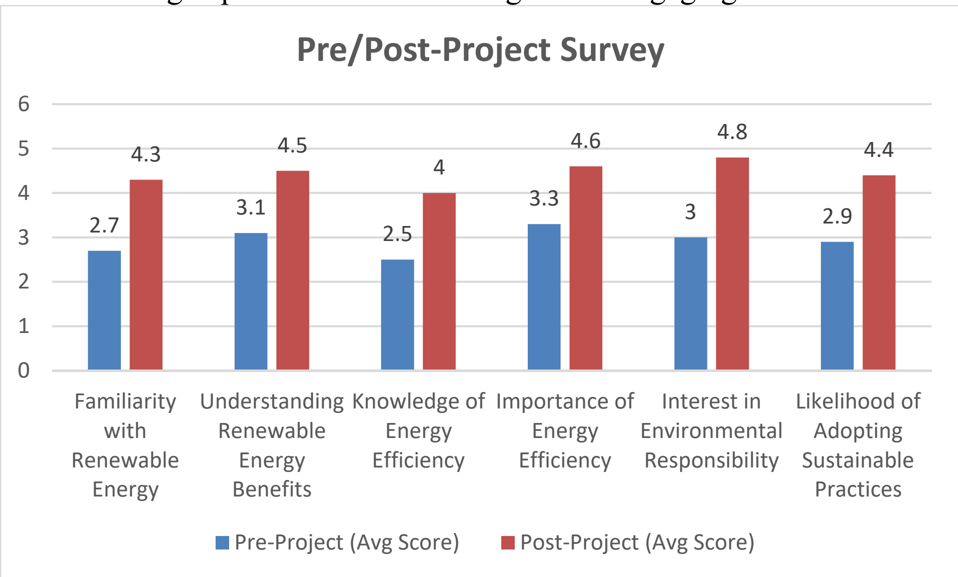

Figure 1. Impact of Service-Learning Project on Student Knowledge and Attitudes: Pre- and Post-Project Feedback.

Additionally, high school students involved in the project shared their impressions, often describing the activities as both inspiring and educational. Working alongside university students not only motivated them to consider careers in engineering but also gave them practical insights into renewable energy technologies and sustainable practices. This engagement helped foster a connection between academic learning and real-world impact, making the experience more relatable and accessible.

4.3 Community Benefits and Response

The community's response to the project was overwhelmingly positive. The awareness campaign and public showcase event, in particular, attracted significant interest from local residents, school faculty, and parents, many of whom provided feedback on the project's impact. Community members noted an increased awareness of renewable energy and expressed a willingness to adopt energy-saving practices in their own lives. The public showcase of the solar house prototype served as a powerful example of what could be achieved through sustainable design, sparking interest in renewable energy solutions.

Moreover, the collaboration between the university and local high schools established a foundation for continued educational initiatives on sustainability. The positive community reception suggests that there is both interest and potential for further projects aimed at educating the public on sustainable practices, indicating that the project succeeded in fostering a more environmentally conscious mindset within the community.

4.4 Challenges Encountered

While the project achieved many of its objectives, several challenges emerged that offered valuable learning experiences for the students involved. One significant challenge was the logistical complexity of coordinating activities across multiple locations and institutions. Balancing the schedules of university and high school students, along with securing resources for the solar house prototype, required careful planning and flexibility. Additionally, some students encountered technical difficulties during the construction phase, such as limitations in material availability or adjusting designs to meet practical constraints. These challenges underscored the importance of adaptability, time management, and problem-solving in engineering projects.

Feedback from students also suggested that more preparatory sessions on project management and resource planning could have been beneficial. In future implementations, it may be helpful to incorporate these elements into the project structure to better equip students for the logistical demands of real-world engineering tasks.

4.5 Implications for Environmental Engineering Education

The results of this service-learning project underscore the value of experiential learning in environmental engineering education. By engaging students in community-centered projects, service-learning provides an avenue for applying theoretical knowledge in meaningful ways that contribute to both technical skill development and social responsibility. The project demonstrated that hands-on experiences, particularly those that address real community needs, can significantly enhance students' engagement, motivation, and understanding of sustainable practices. [7]

This project highlights the potential for service-learning to play a more prominent role in environmental engineering curricula. By bridging academic learning with practical application, service-learning equips future engineers with the competencies and ethical perspectives needed to tackle the pressing environmental challenges of the 21st century. The integration of service-learning in education not only strengthens technical skills but also nurtures a commitment to sustainability and community engagement, aligning closely with the goals of environmental engineering programs.

This results and discussion section presents a well-rounded view of the project's outcomes, capturing both its successes and areas for improvement, while also reflecting on its broader educational implications.

5. Conclusions

The service-learning project provided a meaningful and effective bridge between theoretical knowledge and practical application, enriching both university and high school students' understanding of sustainable energy practices. Through activities like constructing a prototype solar-powered house, leading workshops on energy efficiency, and conducting community awareness campaigns, students were able to apply classroom knowledge to real-world situations, reinforcing their technical skills while cultivating a sense of environmental responsibility. Survey results before and after the project indicated notable improvements in students' understanding of renewable energy, energy efficiency, and environmental responsibility, highlighting the project's success in fostering both knowledge and ethical awareness.

By directly engaging in projects that addressed real community needs, students developed essential skills such as problem-solving, teamwork, and critical thinking. The hands-on nature of the project encouraged them to explore the technical and social dimensions of engineering solutions, promoting a holistic understanding of their role as future engineers in fostering sustainable development. This approach not only equipped students with practical competencies but also inspired them to view their work as an opportunity to contribute positively to society, underscoring the value of service-learning in environmental engineering education.

To further improve the educational impact of similar projects, several recommendations can be considered. First, providing additional preparatory training on project management, resource allocation, and community engagement would help students manage the logistical challenges inherent in service-learning projects. Such training would enhance their organizational skills, allowing them to use their time and resources more efficiently. Additionally, interdisciplinary collaboration could greatly benefit the project, as involving students from other fields—such as economics, sociology, or environmental science—would introduce diverse perspectives and foster more comprehensive problem-solving approaches. [8]

Building long-term partnerships with local schools and community organizations could also amplify the project's impact, creating a lasting foundation for energy education and sustainability initiatives. Establishing an ongoing program that offers workshops and activities each year would reinforce the knowledge gained by students and community members, fostering continuous learning and engagement. These partnerships could ensure that future students have a stable platform for engaging in service-learning activities, thereby building on the successes and insights from previous projects.

There is also substantial potential to expand the service-learning model to address other areas of environmental engineering, such as water management, waste reduction, and air quality improvement. By broadening the scope of the project, students would be able to explore a wider range of engineering solutions and develop a comprehensive understanding of the complex challenges associated with sustainability. Expanding the geographical reach to include rural or underserved communities would further enhance the project's social impact, providing students with exposure to diverse settings and challenges that require adaptable and innovative solutions.

Overall, the service-learning project demonstrated the immense value of experiential learning in environmental engineering. By integrating service-learning into their programs, institutions like the Technical University of Civil Engineering Bucharest can produce graduates who are not only technically proficient but also socially responsible. The project's success in enhancing students' competencies and commitment to sustainability has set a strong foundation for future service-learning initiatives in engineering education. Embracing the recommendations provided and exploring further areas of expansion could enable future projects to shape a generation of engineers prepared to address the environmental and societal challenges of the 21st century.

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ADAPTIVE DISCRETIZATION OF COMPLEX PLANAR CRACK SHAPES FOR NUMERICAL ANALYSIS

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Abstract. *The study introduced the creation and execution of a resilient discretization technique for the numerical analysis of intricate planar fracture geometries. The programme used adaptive Delaunay triangulation and proposed a technique for producing control points on the border and inside the domain. A hybrid method for mesh creation was used, integrating boundary-fitted discretization with the structured production of interior points. The created programme enabled accurate regulation of mesh density via the h0 parameter and guaranteed a consistent transition between boundary and interior components. The findings revealed the algorithm's capacity to produce high-quality meshes for diverse geometries, with enhanced control over element form and size. Numerical validation affirmed the method's efficacy for element quality, convergence, and adaptability to diverse geometric configurations. The Python implementation enabled integration with other numerical analytic tools and offered a versatile platform for subsequent advancements.*

Keywords: *adaptive discretization, Delaunay triangulation, mesh generation, numerical analysis, planar cracks, finite element.*

1. Introduction

The numerical study of crack behaviour in engineered structures has posed a significant problem in computational fracture mechanics. The precision of findings has significantly relied on the quality of computational domain discretization, particularly in regions with intricate geometry or next to fracture tips [1].

Prior research in mesh generation for crack analysis has mostly focused on methodologies using the extended finite element method (X-FEM) [2] or adaptive remeshing methods [3]. Nonetheless, these approaches exhibit constraints in achieving exact control over element density and adapting to very intricate fracture geometries.

Specialised research emphasises the significance of appropriate discretization in the fracture tip area for accurately collecting stress and strain fields [4]. Recent study indicates that using a non-uniform distribution of components, with refinement in important areas, has yielded greater outcomes compared to uniform meshes [5].

The current work sought to create a flexible mesh generation technique specifically designed for the analysis of planar fractures with intricate geometries. The methodology used Delaunay triangulation [6] and presented novel ideas for the localised regulation of element density and the assurance of mesh quality.

The established technique enhanced prior research [7, 8] by using a hybrid approach for the generation of control points. Particular emphasis was placed on the transition between zones with varying mesh densities to prevent deterioration of element quality at their interfaces.

The created programme included the latest advancements in computational geometry [9] and offered a versatile platform for the numerical investigation of fracture mechanics issues. The Python implementation enabled portability and later enhancement of functionality [10].

The study's specific objectives were: (1) to develop a robust algorithm for generating meshes tailored to arbitrary geometries, (2) to implement precise control of element density via the h0 parameter, (3) to ensure the quality of generated elements through stringent geometric criteria, and (4) to validate the methodology through extensive numerical tests.

2. Materials and Methods

The established technique relied on a methodical approach to the discretization process, organised into many separate phases. The code was executed in the Python programming language, including specialised libraries like NumPy for numerical computations, SciPy for geometric algorithms, and Matplotlib for visualisation [11].

The primary method was designed based on Delaunay triangulation, with particular modifications for the efficient management of intricate geometry. The following primary functions were executed:

1) Geometry definition and initialization:

```
def get_polygon_vertices():
    return np.array([
        [0, 1],
        [-0.5, 0.5],
        [-2, 0],
        [-1.2, -0.7],
        [1.7, 0],
        [1, 1]
    ])
```

This function delineates the vertex coordinates of the polygon that defines the border of the analysis domain.

2) Generation of boundary points:

```
def generate_boundary_points(vertices, h0):
    boundary_points = []
    n = len(vertices)
    for i in range(n):
        v1 = vertices[i]
        v2 = vertices[(i + 1) % n]
        segment_length = get_point_distance(v1, v2)
        n_points = max(2, int(segment_length / h0))
        for j in range(n_points - 1):
            t = j / (n_points - 1)
            point = v1 + t * (v2 - v1)
            boundary_points.append(point)
    return np.array(boundary_points)
```

This function produced evenly dispersed dots around the domain border, with density regulated by the parameter h0 [13].

3) An algorithm was developed for the generation of interior points, considering fracture geometry and the need for refining in key areas. The point density was regulated by an adaptive scaling function:

```python
def generate_interior_points(vertices, h0, boundary_points):
    """Generează puncte în interior"""
    interior_points = []
    x_min, y_min = np.min(vertices, axis=0) - h0
    x_max, y_max = np.max(vertices, axis=0) + h0

    dx = h0 * np.sqrt(3) / 2
    dy = h0 * np.sqrt(3) / 2

    nx = int((x_max - x_min) / dx) + 1
    ny = int((y_max - y_min) / dy) + 1

    for i in range(ny):
        offset = (i % 2) * dx / 2
        for j in range(nx):
            x = x_min + j * dx + offset
            y = y_min + i * dy
            point = np.array([x, y])
            if is_point_inside_polygon(point, vertices):
                interior_points.append(point)

    return np.array(interior_points)
```

4) The programme employs a sophisticated technique that achieves two primary objectives: discretizing the computing environment via the creation of a network of triangular finite elements and the methodical development of corresponding data structures.

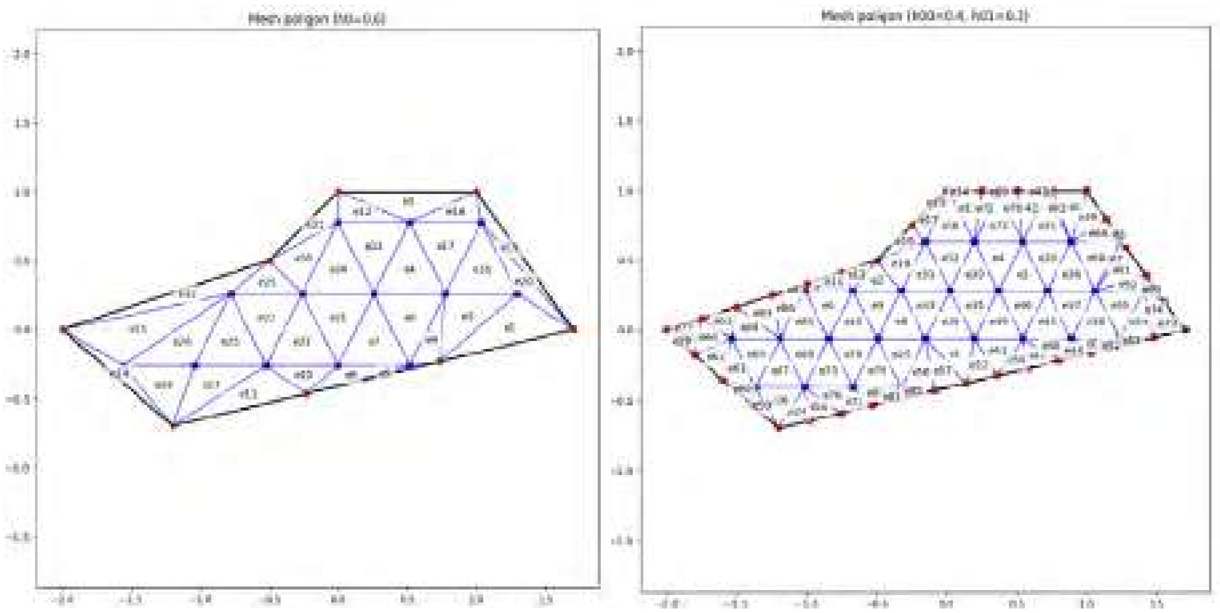

Figure 1. Discretization of complex shape into triangular elements

The structures comprise the nodal coordinate matrix, linking each node to a distinct identifier and its Cartesian coordinates, and the element connectivity matrix, detailing each element's identification number, topological classification (type 1 for boundary elements with two nodes and type 0 for interior elements), and nodal connectivity. The produced data is visualised interactively (Figure 1) and exported in CSV format, so enabling its incorporation into further phases of the numerical analysis process.

3. Results

The algorithm's application yielded significant improvements in the quality and flexibility of the created meshes. Numerical experiments were conducted on several geometric designs, using varied values of the control parameter h0.

The following elements were examined for approach validation: · Produced element quality:

- Distribution of angles within components
- Aspect ratios of triangles
- Consistency of transition across zones with varying densities. Computational efficacy:
- Execution duration for various issue dimensions
- Effectiveness of point location verification algorithms
- Scalability of the method for fine meshes.

The findings showed the algorithm's proficiency in producing high-quality meshes, characterised by the following attributes:

- Elements exhibiting aspect ratios approximating the optimal value
- Seamless transitions between areas of varying densities
- Accurate adjustment to the geometric properties of the border
- Uniform distribution of internal points.

Statistical examination of the produced components indicated that over 95% of triangles satisfied the established quality standards, with angles within the range of [30°, 120°] and aspect ratios below 2:1 [15].

4. Discussion

The findings obtained underscored the benefits of the suggested technique relative to conventional procedures. The use of a hexagonal configuration for interior points demonstrated superiority over traditional rectangular networks, yielding enhanced isotropy in the resultant mesh.

The Python implementation provided flexibility and portability, enabling integration with other numerical analytic tools. The computational speed was enough for most real applications; however, more code optimisation may be required for very fine meshes.

A crucial feature was the algorithm's capacity to effectively manage intricate geometries, including corners and regions with significant curvature. This characteristic was crucial for applications in fracture analysis.

5. Conclusions

The research introduced the creation and execution of a sophisticated algorithm for producing meshes tailored to the examination of planar fractures with intricate geometries. The primary contributions encompassed:

- Creation of a hybrid approach for mesh production and regulation
- Establishment of an effective system for element quality assessment and enhancement

- Development of a versatile framework for the numerical investigation of fracture mechanics issues The findings proved the method's relevance and effectiveness across many geometries. The Python implementation enabled the use and later enhancement of functionality. Future advancements may include algorithm parallelization and expansion to the three-dimensional context.

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THE CARBONATION PROCESS IN REINFORCED CONCRETE STRUCTURES

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***Abstract**: Carbonation is a major degradation process for reinforced concrete structures, affecting various types of structures such as residential buildings, bridges, industrial buildings, historical buildings and tunnels. The process begins with the penetration of carbon dioxide (CO_2) from the atmosphere into the concrete, where it reacts with calcium hydroxide, forming calcium carbonate. This reaction lowers the pH of the concrete and once the carbonation reaches the reinforcement, it destroys the passive layer that protects the steel from corrosion. The corrosion of the reinforcement leads to cracking and spalling of the concrete, accelerating structural degradation.*

For each type of structure, there are specific prevention methods, such as waterproofing additives, protective coatings, drainage systems and reinforcement with special mortars. Regular maintenance and continuous monitoring are also essential to prevent the progression of carbonation and protect structures in the long term.

This article analyzes how each type of structure is affected differently by carbonation and presents effective prevention solutions, contributing to increased durability and reduced long-term repair costs.

***Keywords:** Carbonation, durability, prevention, reinforced concrete, structural degradation.*

1. Introduction

Carbonation of concrete is one of the main degradation processes that affect the durability of reinforced concrete structures. It occurs when carbon dioxide from the atmosphere reacts with the hydroxides in the concrete, reducing its alkalinity. Over time, this process can diminish the protection provided to the reinforcement against corrosion. Once the reinforcement begins to corrode, the structural integrity of the construction is severely compromised, which can significantly shorten its service life.

The issue of carbonation is particularly relevant for structures exposed to urban and industrial environments, where CO_2 concentration is higher. It affects both residential buildings and public infrastructure, such as bridges, roads and tunnels. Furthermore, historical reinforced concrete buildings, some of the earliest structures of this type built in the 20th century, are now at increased risk of degradation due to advanced carbonation.

This article aims to analyze how carbonation impacts different types of reinforced concrete structures and propose preventive and remedial measures. Recent studies show that exposure to carbonation is directly influenced by factors such as concrete quality, the thickness of the reinforcement cover and the environmental conditions in which the structures are located. By understanding these factors and applying appropriate solutions, the durability of reinforced concrete structures can be significantly extended.

2. How does carbonation progressively degrade reinforced concrete structures?

The carbonation process in concrete begins with the penetration of carbon dioxide (CO_2) from the atmosphere into the pores of the concrete. Concrete is a porous material, allowing gases and water vapor to migrate into it. Humidity plays a crucial role in this process, as CO_2 dissolves in water and forms carbonic acid (H_2CO_3). In environments where concrete is exposed to high concentrations of CO_2 and optimal humidity levels (between 50% and 70%), carbonation progresses more rapidly, facilitating the penetration of the gas into the concrete structures.

Once inside the concrete, the carbonic acid reacts whit calcium hydroxide ($C_a(OH)_2$) present in the concrete forming calcium carbonate ($C_a(OH)_2 + CO_2 \rightarrow C_aCO_3 + H_2O$). This reaction lowers the alkalinity of the concrete, gradually reducing its pH from high values of around 12-13 to below 9. The calcium carbonate formed fills the spaces in the concrete but does not provide the same protection against reinforcement corrosion.

As the carbonation process advances and the pH of the concrete decreases, the protection provided to the reinforcement by the passivating layer (which forms at high pH) is reduced. When carbonation reaches the reinforcement, this protective layer is destroyed and the steel becomes vulnerable to corrosion. This phase of the process, where the carbonation front reaches the reinforcement, is the critical point that directly triggers the corrosion of the steel.

Once reinforcement corrosion begins, the iron oxides produced in the process have a greater volume than the original steel, leading to cracks and spalling in the concrete surrounding the reinforcement. These cracks allow water and oxygen to infiltrate, accelerating the corrosion process and structural deterioration. As corrosion progresses, the integrity of the structure is significantly compromised.

Ultimately, structural degradation becomes visible through extensive cracking, concrete spalling and a significant reduction in the structure's load-bearing capacity. If preventive or remedial measures are not taken, the lifespan of the structure can be drastically reduced and the necessary repairs become costly and complex. Therefore, preventing carbonation and maintaining periodic inspections are essential to ensure the durability and safety of reinforced concrete structures.

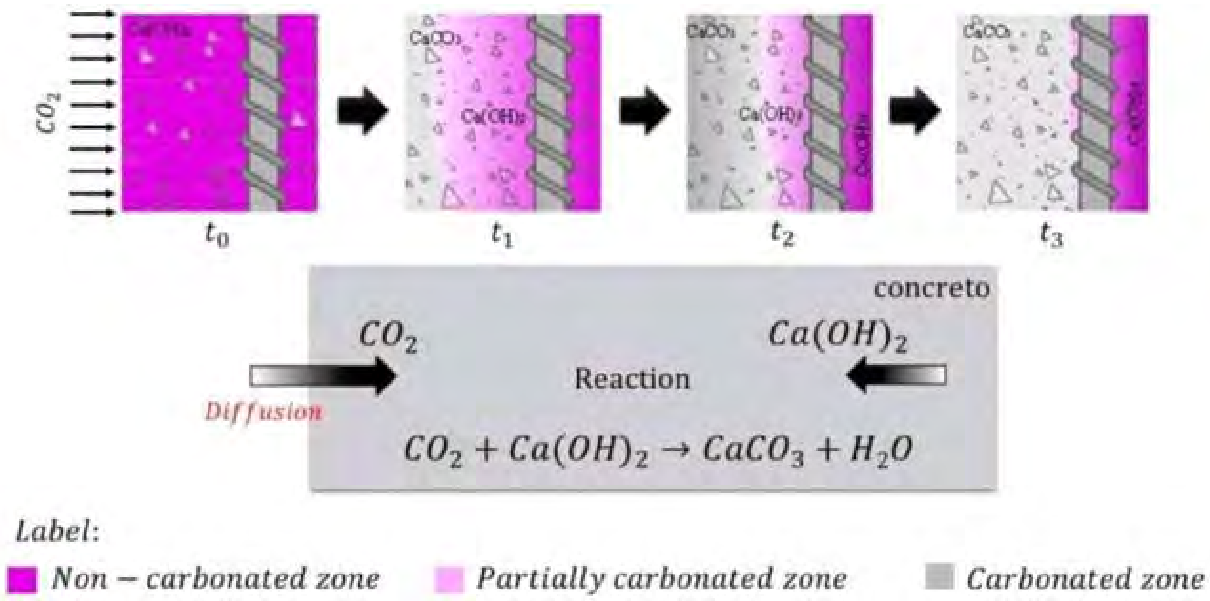

Figure 1. The reaction between carbonic acid and calcium hydroxide in concrete. [4]

3. How does carbonation process affect different types of structures and prevention methods

a. Residential buildings

Carbonation can significantly affect residential reinforced concrete buildings, especially in urban areas where CO_2 concentrations are high. In these buildings, the protective concrete layer around the reinforcement is often thinner, making it easier for carbon dioxide to penetrate. As the alkalinity of the concrete decreases, the reinforcement begins to corrode, causing cracks and degradation in structural elements. Over time, this process can compromise the stability and safety of the building, leading to costly repairs.

To prevent carbonation in this type of structures we can use special additives to reduce the permeability of concrete and limit CO_2 penetration, to create a barrier against carbon dioxide and moisture, also painting or applying protective films to exposed concrete surfaces can prevent the infiltration of CO_2 and moisture, thus extending the structure's lifespan.

Figure 2. The carbonation process in residential buildings. [5]

b. Bridges and transport infrastructure

Bridges, roads and other infrastructure are particularly vulnerable to carbonation, especially due to continuous exposure to aggressive environmental factors such as rain, heavy traffic and gas emissions. Carbonation can significantly reduce the load-bearing capacity of these structures, affecting user safety. Additionally, cracks caused by reinforcement corrosion allow water and other harmful agents to infiltrate, accelerating the degradation process. Constant maintenance and the use of high-quality concrete are essential to prevent these affects.

To prevent carbonation in this type of structures we can do regular inspections and prompt repairs of cracks in concrete which can prevent CO_2 from penetrating deeply, thereby avoiding the acceleration of carbonation, also using higher-quality concrete with lower water-cement ratio and proper compaction can reduce the porosity of the concrete and slow down the carbonation process.

Figure 3. The carbonation process in bridges and roads. [6,7]

c. Industrial buildings

Industrial constructions, such as factories and warehouses, are often exposed to high concentrations of carbon dioxide and other chemicals that can accelerate carbonation. Although these structures are designed to withstand harsh conditions, over time, carbonation can compromise the reinforcement, leading to a decrease in structural strength. In many cases, remedial solutions are required, such as the use of corrosion inhibitors, surface rehabilitation or efficient ventilation systems.

In order to research the action of the variable operating load on the durability, resistance and deformation characteristics of reinforced concrete elements in the gas-air environment of agrozootechnical enterprises, an experiment was made by, Conf. univ., dr. ing. Gheorghe

CROITORU and Lector univ., dr. Eduard PROASPĂT, in which, for 28 days, 6 reinforced concrete beams were tested loaded and 9 unloaded, subjected to a similar action of the aggressive environment as the beams under load. For the tests, heavy concrete beams of class C25/30 with reduced permeability, with dimensions of 1500 x 200 x 70 mm, were executed.

Figure 4. Beams executed for the experiment. [3]

Portland cement with calcium aluminate, with an effective diffusion coefficient of carbon dioxide in concrete, was used as a binder. The reinforcement shell consists of two bars of class B500C, with a diameter of 12 mm. The thickness of the concrete protective layer was 30 mm. To stimulate the corrosion process of reinforcement in concrete cracks, its surface was moistened once a day with a solution with chemical composition similar to the composition of the liquid environment resulting from the process of vital activity of animals.

The results of the tests showed that a decrease in the physical-mechanical characteristics of the reinforcement is observed only at an average depth of corrosive damage greater than $200\ \mu m$. After 28 days of tests, the average depth of reinforcement damage in transverse cracks, with an opening width of $a_F = 0.30\ mm$ constituted $\delta_{med} = 310\ \mu m$. As for the control samples of the reinforcement, which were not exposed to the corrosive effects of the environment, the physical yield strength decreased by 20 MPa and the tensile strength decreased by 30 MPa.

As a result of the experiment, it was concluded that it is necessary to use corrosion inhibitors of reinforcements in reinforced concrete structures with reduced permeability in gas-air environments of agrozootechnical enterprises. At the same time, the use of inhibitors in the form of additives in the concrete mix does not affect the selling price of reinforced concrete elements.

d. Historical reinforced concrete buildings

Historical reinforced concrete buildings, constructed in the first half of the 20th century, are at high risk of carbonation due to their age and the use of less advanced concrete technologies. In these cases, the protective layer around the reinforcement is often thinner or degraded over time, facilitating CO_2 penetration. Restoring these buildings often involves complex and costly repairs to prevent irreparable damage to their structures.

To prevent carbonation in this type of structures, restoration mortars compatible with the original materials can be used to prevent CO_2 penetration and protect the structural integrity of the construction, also historical buildings require constant monitoring to detect areas with early-stage carbonation and the application of preventive treatments, such as injecting corrosion inhibitors.

e. Tunnels and underground structures

Tunnels and other underground structures are affected by carbonation in a different way compared to surface constructions. Although they are more protected from extreme temperature and humidity variations, they are exposed to higher concentrations of CO_2 in stagnant air, which accelerates carbonation. Under these conditions, cracks in the concrete can quickly appear, allowing water infiltration and accelerating reinforcement degradation. This can compromise the safety of tunnels and requires constant interventions to maintain structural integrity.

To prevent carbonation in this type of structures, we can install an adequate drainage system which will keep the concrete dry, thus reducing the risk of carbonation, also for underground structures, special additives can be used that slow the chemical reaction of CO_2 with calcium hydroxide in the concrete, prolonging the structure's lifespan.

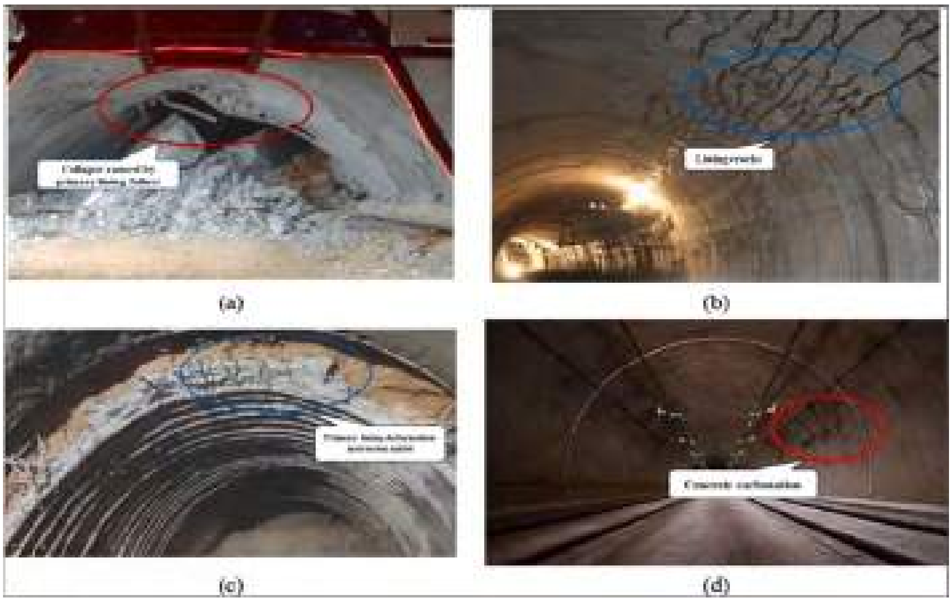

Figure 5. The carbonation process in tunnels. [8]

4. Conclusions

Carbonation poses a serious risk to the durability of reinforced concrete structures. Without adequate preventive measures and regular maintenance, structures can suffer significant degradation. Each type of structure requires tailored solutions to prevent the negative effects of carbonation, and continuous monitoring is essential to ensure the long life of the structures. Adopting these methods can prevent costly repairs and contribute to the safety and stability of the buildings.

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INVESTIGATION OF FIRE CASES ON THE TERRITORY OF THE REPUBLIC OF MOLDOVA

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Abstract. *The investigation of fire cases constitutes the set of organizational, technical and operative actions, which includes specific methods and procedures in order to establish the circumstances in which the fire occured, its probable cause and its consequences.*
There is increasing concern about the impacts of global warming on fire frequency and severity. Factors such as increased heat, humidity, the drying effect on vegetation, and wind patterns can all affect the way the fire occurs. As a result, fire prevention has become extremely important. The risk of fire is among the most frequent risks that occur on the territory of any country, its occurrence representing an emergency situation, a phenomenon that affects important areas of economic and social activity (buildings, installations, landscaping, forests, means of transport, agricultural crops, etc.).
Highlighting the most frequent causes of fires, their dynamics, ensures the permanent improvement of legislation, fire safety regulations, the development of prevention actions as well as the development of educational programs to train society in order to minimize the risks of fires, losses of human lives and material damage as a result.

Keywords: fire safety, intervention, operative actions, prevention actions, risk.

1. Introduction

Fires are among the most common types of disasters, with devastating effects on human life, the environment, and the economy. These events, although often unpredictable, can be prevented or managed more effectively through a detailed understanding of the causes and conditions under which they occur. In this context, investigating fire cases becomes an essential activity, contributing to the identification of preventive solutions and reducing their negative impact.

Each year, globally, fires cause the loss of tens of thousands of human lives, hundreds of thousands of injuries, and enormous material damages. The risk of fire is one of the most frequent risks that manifest within the country, with its occurrence representing an emergency situation—a phenomenon that impacts key areas of economic and social activity (buildings, installations, facilities, forests, means of transportation, agricultural crops, etc.).

In the Republic of Moldova, the country's specific economic, social, and infrastructural characteristics pose unique challenges in fire management. Nevertheless, through a systematic approach and the use of modern methodologies, significant results can be achieved in their prevention and mitigation.

This article aims to thoroughly analyze the legislative framework, investigation methodology, and impact of fires on the territory of the Republic of Moldova, while also providing recommendations to improve existing processes.

2. The Legislative Framework on Fires in the Republic of Moldova

The Republic of Moldova has a well-structured legislative framework for fire prevention and management, regulating both the responsibilities of public institutions and the obligations of citizens and economic agents. The current legislation includes Law no. 267/1994, Government

Decision no. 847/2022, and provisions from the Criminal Code, each playing an important role in strengthening fire safety [3,4].

Law no. 267 of 09.11.1994 on Fire Protection

This law forms the legal foundation for fire prevention in the Republic of Moldova. According to **Article 2**, both individuals and legal entities are required to take specific measures to reduce fire risks. Additionally, **Article 7** outlines the responsibilities of the General Inspectorate for Emergency Situations (GIES), the institution tasked with investigating fires, approving economic activities, and educating the population on safety measures [3].

Government Decision no. 847 of 07.12.2022

Through this decision, the Government approved a detailed regulation on fire protection, establishing technical requirements for buildings, installations, and economic activities. Chapter II specifies general fire prevention rules for public and private buildings, while Chapter IV provides guidelines for high-risk areas, such as flammable substance warehouses or industrial facilities [4].

The Criminal Code of the Republic of Moldova (Article 197)

To address negligence or criminal intent, Article 197 of the Criminal Code establishes penalties for individuals who cause fires that result in property destruction or endanger human lives. The severity of the sanctions depends on the extent of the damage and whether the act was intentional or due to negligence [2].

The Role of the General Inspectorate for Emergency Situations (GIES)

The General Inspectorate for Emergency Situations (GIES) is the main institution responsible for fire prevention, investigation, and management. According to the legislation, GIES has the following responsibilities:

- Investigating fire causes using modern analysis and expertise methods.
- Organizing awareness campaigns to educate the population.
- Issuing fire safety approvals for construction projects and economic activities.

Additionally, GIES collaborates with other national and international institutions to enhance professional training for personnel and to introduce modern fire investigation technologies [1].

While the legislative framework in the Republic of Moldova is well-structured, its implementation faces challenges. The main issues include:

- A lack of qualified personnel for fire investigations.
- Limited financial resources for modern equipment.
- Low public awareness regarding the importance of adhering to safety regulations.

3. Methodology for Investigating Fire Cases

The investigation of fire cases in the Republic of Moldova is conducted in accordance with the legal framework by the competent authorities: law enforcement agencies (police), rescue and firefighting services, judicial experts, and others.

Investigating fire cases is a complex process essential for identifying causes, understanding the conditions under which the incident occurred, and preventing similar situations. In the Republic of Moldova, the methodology used adheres to international standards while being adapted to local specifics. This process involves several stages, each with a well-defined role.

Stage 1: Site Investigation

The first step is a detailed examination of the fire scene. This begins with isolating and securing the perimeter to prevent evidence contamination, followed by visual documentation of the site through photography and mapping. These actions allow for recording the positions of objects and their condition before firefighting interventions. A primary objective of this stage is to identify the point of origin of the fire by analyzing burn marks and the destruction caused [5].

Stage 2: Collection of Material Evidence

Collecting material evidence is crucial for determining the fire's causes. Investigators gather combustible materials, chemical residues, damaged electrical components, and other relevant items. All evidence is handled carefully, following standardized procedures, and sealed to maintain its integrity until laboratory analysis.

Stage 3: Cause Analysis

In this stage, collected evidence undergoes detailed testing in specialized laboratories. Techniques include: chemical spectroscopy to detect traces of chemical accelerants, thermal analysis to study how materials behaved at high temperatures, electrical circuit examination to confirm or rule out a short circuit hypothesis.

Beyond technical analysis, interviews and social investigations play an important role. Investigators interview eyewitnesses, residents, and others involved to reconstruct the event's circumstances. This information helps clarify the causes and identify possible negligence or deliberate actions [6].

Final Report

All findings are compiled into a detailed report describing the fire scene, identified causes, and recommendations for preventing similar incidents. This report holds significant practical value, being used both for legal purposes and to enhance safety measures.

The process is supported by modern technologies, such as drones for aerial mapping of the fire scene, thermal sensors for detecting high-temperature areas, and specialized software for modeling fires and simulating their propagation.

Despite advancements, fire investigation methodology in the Republic of Moldova faces several challenges. Inadequate technical resources, insufficiently equipped laboratories, a shortage of specialized personnel, as well as, time constraints and the complexity of certain cases, which can hinder the investigation process.

Despite these obstacles, the application of a well-structured methodology and constant adaptation to new technologies enable continuous improvement in fire investigation processes and prevention capabilities.

4. Common causes of fires in the Republic of Moldova

Fires represent a constant challenge for authorities in the Republic of Moldova, having multiple and complex causes. According to data provided by the General Inspectorate for Emergency Situations (GIES), between 1,700 and 2,000 fires are reported annually in the country. Of these, over 60% are attributed to technical malfunctions or acts of negligence, while the rest are caused by natural or intentional factors [1].

Malfunctions and improper use of electrical installations

Electrical malfunctions are the leading cause of fires in the Republic of Moldova, accounting for over 40% of reported cases. Short circuits often result from the use of old or improperly insulated cables. In buildings constructed decades ago, electrical systems are no longer able to meet current demands, leading to frequent circuit overloads.

A clear example is the fire that occurred in 2023 in a residential block in the city of Bălți, caused by a short circuit in an old electrical network. The fire quickly spread to several apartments, causing damages estimated at over 500,000 lei. This incident highlighted the need to modernize electrical installations in older buildings.

Negligence in the use of open flames

Careless handling of open flames accounts for approximately 20% of fires, especially in rural areas. Common causes include discarding lit cigarettes near combustible materials and burning plant waste without safety precautions.

A recent incident in September 2024, in the Cahul district, demonstrated the risks associated with this practice. The uncontrolled burning of plant waste turned into a vegetation fire, affecting an area of over 10 hectares. The situation required a prompt intervention by firefighters to prevent the fire from spreading to inhabited areas.

Improper storage of flammable substances

Flammable substances, improperly stored or handled, are a major cause of fires in both the industrial sector and households. For example, diesel and gasoline are often kept in unsafe conditions, which can lead to leaks and accidental ignitions.

In 2022, a severe fire broke out at a fuel station in the Orhei district due to a gasoline leak. The flames destroyed the station and threatened adjacent areas, necessitating the evacuation of several families. The incident underscored the need for strict adherence to safety regulations in handling fuels [11].

Technical defects of heating equipment

During the cold season, a significant part of fires is caused by the use of faulty stoves and other heating equipment. Uncleaned chimneys and damaged stoves are major sources of risk.

A dramatic case occurred in January 2024, in Ungheni district, where a faulty stove started a fire that completely destroyed a house. The affected family was left homeless during the winter, and the incident highlighted the importance of periodic checks of heating equipment.

Arson

Arson, or intentional ignition, accounts for approximately 10% of all registered cases. They are often motivated by personal conflicts, revenge, or attempts to defraud insurance companies [9].

A notable example was investigated in Chisinau municipality in 2023, where a contractor intentionally set fire to his warehouse in order to obtain compensation from the insurance company. The case highlighted the need for more rigorous controls and in-depth investigations to combat this phenomenon.

Natural and climatic factors

Although rarer, fires caused by natural factors, such as drought and high temperatures, can have a devastating impact. In the summer of 2022, a drought-induced wildfire in the Hînceșt district affected over 50 hectares of forest and agricultural land [7].

Statistics and preventive measures

According to GIES, approximately 70% of the fires reported in 2024 occurred in rural areas (tab.1). In order to reduce their number, the authorities have intensified information campaigns and periodic checks on electrical installations and heating equipment. At the same time, it is necessary to modernize the electrical infrastructure and apply stricter sanctions for violating safety regulations [8].

Table 1. The most common causes of fires in the Republic of Moldova

Year	Region	Electrical malfunctions	Open fire	Technical malfunctions	Flammable substances	Other cases	Total
2022	North	120	85	40	20	35	300
	Center	90	50	35	15	30	220
	South	80	70	20	25	20	215
	Chișinău	150	40	50	30	60	330
2023	North	140	95	50	25	40	350
	Center	100	55	40	20	25	240
	South	90	80	25	30	25	250
	Chișinău	160	50	60	35	70	375
2024	North	130	90	45	30	30	325
	Center	95	60	35	25	35	250
	South	85	75	30	35	20	245
	Chișinău	155	55	55	40	65	370

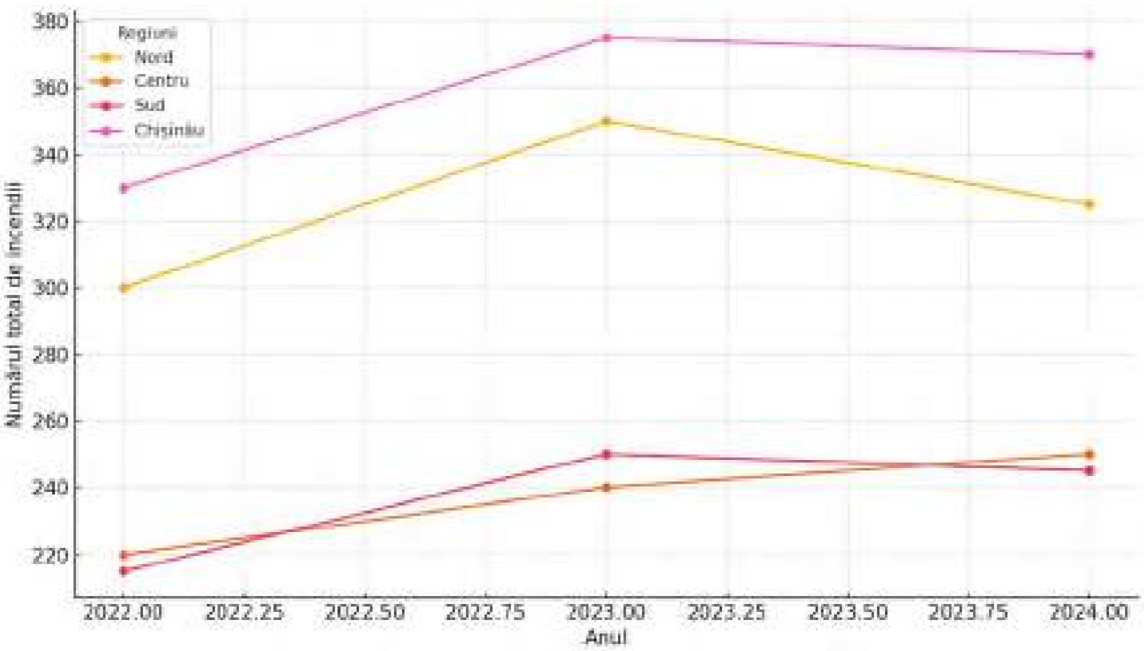
In the period 2022-2024, the Republic of Moldova recorded a relatively constant trend in the number of fires, with minor fluctuations between regions. Statistical data show that the main causes of fires remain electrical faults, negligence in the use of open fire and faulty use of heating equipment (fig. 1).

The North region recorded a relatively high number of fires, between 300 and 350 per year. The most common causes were electrical faults, which account for approximately 40% of all cases, followed by open fire and technical defects of stoves [10].

In the Center, the number of fires varied between 220 and 250 per year. The dominant cause was also the faulty use of electrical installations, but the proportion of fires caused by open fire was significantly lower than in other regions.

The South of the country recorded between 215 and 250 fires annually. Open fires and the misuse of flammable substances were more common causes here than in other regions, reflecting the social and economic particularities of the area.

Chișinău had the highest number of reported fires, with a total that increased from 330 in 2022 to 370 in 2024. This is due to the population density and the overburdened electrical infrastructure. Electrical faults accounted for over 40% of the total, followed by other causes, including intentional fires (Fig. 1) [8].



Fugure 1. Evolution of the total number of fires between 2022 and 2024

Over the three years analyzed, the total number of fires remained relatively constant, but Chișinău and the North reported the most incidents. Electrical faults and negligence were the main causes, which highlights the need for more effective preventive measures, such as information campaigns and modernization of the electrical infrastructure [8].

5. Challenges and recommendations in fire prevention and management in the Republic of Moldova

The Republic of Moldova faces multiple challenges in the prevention and management of fires, which pose a threat to human lives, infrastructure, and the environment. These difficulties require well-structured and efficient solutions to reduce the impact of fires on society [9].

Challenges

One of the main challenges is the old and inadequate infrastructure. Many buildings, especially in rural areas, are equipped with outdated electrical installations, which represent a major source of danger. Stoves and chimneys that are not properly maintained also contribute to the increased risk of domestic fires, especially in the cold season.

Another significant obstacle is the limited resources of the General Inspectorate for Emergency Situations (GIES). Intervention equipment is often outdated, and the number of firefighting units in rural areas is insufficient, which prolongs response time in emergencies [6].

In addition to these difficulties, there is a lack of preventive education. Public information campaigns regarding fire prevention measures are rare, and many citizens do not comply with safety standards, such as maintaining electrical installations or handling flammable materials.

Intentional fires are also a complex problem. The lack of efficient mechanisms to identify the perpetrators reduces the resolution rate of these cases, discouraging the strict enforcement of the law.

Climate conditions, characterized by high temperatures and prolonged droughts, have led to an increase in the number of vegetation fires. These are difficult to control, especially in forested areas, where intervention infrastructure is limited.

Recommendations

To address these challenges, a set of strategic measures is necessary. First, modernizing the infrastructure is essential. A national program for renovating electrical installations in old buildings should be implemented, as well as subsidizing repairs for stoves and chimneys in rural areas.

The General Inspectorate for Emergency Situations needs to benefit from adequate resources. Equipping with modern equipment and creating additional firefighting units in rural areas would significantly improve the emergency response capacity [11].

Another important step is educating the population. Organizing information campaigns and introducing educational modules in schools would contribute to raising awareness of risks and ensuring compliance with fire safety standards.

From a legislative standpoint, strengthening penalties for non-compliance with fire prevention standards and developing technical capabilities for investigating fire causes is necessary. Using modern technologies in this field could increase the resolution rate of arson cases.

Regarding vegetation fires, it is recommended to create natural barriers, such as protective strips, to prevent the spread of flames. Additionally, implementing an early warning and monitoring system for vulnerable areas could significantly reduce the number of such fires.

6. Conclusions

Fires represent one of the greatest threats to public safety, heritage, and the environment in the Republic of Moldova. Proper management of these incidents, both in terms of prevention and investigation, is essential to reducing material and human losses. The study conducted highlights that, although progress has been made in certain areas, challenges remain significant and require immediate action.

Among the main difficulties identified are outdated and unsafe infrastructure, insufficient equipment for the General Inspectorate for Emergency Situations, the lack of preventive education among the population, and the impact of climate change. These issues emphasize the need for well-planned and implemented measures to address the underlying causes of fires.

To reduce their impact, it is imperative to modernize electrical infrastructure and heating systems, especially in rural areas. Additionally, equipping firefighters with modern equipment and creating new intervention stations are critical measures for improving the efficiency of emergency response. Preventive education also plays a central role, and organizing information campaigns as well as introducing fire safety modules in schools is necessary.

Legislatively, strengthening penalties and developing fire investigation capabilities could contribute to reducing the number of cases and ensuring the swift resolution of existing ones. At the same time, implementing a national monitoring system for vegetation fires and using modern technologies could mitigate their environmental impact.

In conclusion, fire prevention and management must become a national priority, involving joint efforts from authorities, specialists, and the population. Only through an integrated approach, based on prevention, education, and adequate resources, can the effective protection of human lives and property against fire-related risks be ensured.

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MANAGEMENT OF EMERGENCY SITUATIONS IN SHOPPING CENTERS

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Abstract. *The outbreak of fires is manifested by the violation of the fire protection regime, by non-compliance with the rules and regulations when re-compartmentalizing rooms and installations, by non-compliance with fire safety requirements when modifying some processes, by incorrect operation of installations and fire protection systems, electricity supply, other aspects.*
Due to the technical characteristics of shopping centers, their territorial location, fires can occur in the given blocks at any time. In order to avoid such situations, it is necessary that the constructions and facilities meet the fire safety requirements, and that the staff of the given institution, as well as the visitors, are trained to know the rules of behavior in case of fire.
In this paper, an analysis is made of the degree of compliance or non-compliance in terms of fire safety of these institutions, a wide range of problems and solutions regarding the avoidance of unpleasant situations are addressed. A situation is simulated as if the fire broke out, the measures regarding the organization of the intervention, the security measures are carried out accordingly, the economic calculation regarding the intervention of the fire team is carried out.

Keywords: intervention, protection, shopping centers systems, security.

1. Introduction

Shopping centers are essential components of modern urban infrastructure, serving as places for shopping, entertainment, and public gatherings. In the context of the growing number of these facilities and the frequency of visitors, the issue of ensuring security and preventing incidents becomes highly relevant. The significant increase in the number of shopping centers worldwide reflects the trend of urbanization and rising income levels, leading to changes in consumer behavior. Along with this growth, the likelihood of emergency situations, such as fires, technological accidents, and terrorist attacks, becomes higher.

Incidents in shopping centers, such as fires, floods, or other emergencies, can have significant financial consequences, both for the owners and tenants of commercial spaces and for the economy as a whole. The first and most obvious economic impact is generated by the revenue losses caused by the temporary or permanent closure of the shopping center following the incident. During the closure period, businesses within the shopping center lose customer traffic and corresponding revenue, which can have a significant impact on their turnover and profitability. Fires or other catastrophes can cause significant damage or destruction to goods and materials being sold, leading to considerable financial losses for merchants and suppliers. Additionally, recovering these losses may take a significant amount of time and may require extra efforts from the affected companies [7].

Exceptional situations in shopping centers, such as fires, attacks, or other traumatic events, can trigger a range of complex psychological reactions among those involved. These include stress and anxiety, which can affect not only employees but also customers and witnesses. Affected individuals may experience increased psychological pressure during and after an incident, showing signs of restlessness, fear, and uncertainty regarding their own safety and the safety of their loved ones. The psychological impact of exceptional situations in shopping centers can be profound and varied, emotionally and mentally affecting those involved. It is essential for these individuals to receive emotional support and recovery resources to cope with these traumas and to rebuild their resilience and psychological well-being. Additionally, these events attract media attention and provoke widespread public discussions, amplifying social unease.

The analysis of previous incidents highlights the need to study the causes and consequences of these events in order to develop effective prevention and response measures. Furthermore, the implementation of new surveillance and evacuation management technologies can significantly improve the security of these spaces [8].

Fortunately, in Moldova, there have been no major fire incidents in shopping centers comparable to those in other countries. However, this does not mean that Moldova is immune to such events. In the past, there have been minor fires in various commercial establishments, such as stores or markets, but these have typically been quickly extinguished without significant consequences.

A notable example of an exceptional incident occurred at the "Atrium" shopping center in 2019, when a fire led to the evacuation of hundreds of people. Additionally, in 2020, another fire affected the "Sun City" shopping center, requiring the rapid and effective intervention of firefighting services to control the flames and prevent injuries.

Another significant incident was the arson of the façade of the "Lunedor" shopping center in Chișinău. This event highlighted the importance of adopting proper safety measures and the prompt intervention of emergency services. The firefighters' intervention was essential in extinguishing the fire and ensuring the safety of those in the building.

Studying incidents in shopping centers is essential to ensuring public safety and minimizing associated risks. Through a comprehensive approach, which includes analyzing current issues, utilizing modern technologies, and developing effective prevention and response strategies, research in this field can significantly contribute to creating a safe and comfortable environment for visitors [7].

2. Calculating Fire Risk in a Room

Based on the case study conducted at the facility, the thermal load density was assessed for a clothing store, with the conclusion being that this room presents a fire risk level of grade 1 [5].

In a clothing store, the fire hazard can be generated by several factors, including the improper storage and handling of flammable materials, such as clothes made from synthetic fabrics, the improper use of electrical equipment, and the lack of appropriate fire prevention and extinguishing measures [4].

Space purpose: retail;

Room area: 74.6 m²;

The room contains:

a. 1 entrance door (200 kg) made of 90% glass and 10% plastic;
b. 1 storage door (100 kg) made of 60% wood;
c. 6 chairs (20 kg each) made of 80% wood;
d. 1 carpet (7 kg) made of 100% wool fibers;
e. 8 curtains (10 kg each) made of 100% artificial silk;
f. 4 panels (4 kg each) made of 80% wood;
g. 15 shelves/wardrobes (23 kg each) made of 80% wood;
h. 3800 clothes (0.200 kg each) made of 50% cotton and 50% artificial silk;
i. 800 pairs of shoes (0.200 kg each) made of 50% rubber and 50% artificial leather;

j. 50 office supplies (0.100 kg each) made of 80% paper and 20% plastic materials;
k. 10 decorative elements (3 kg each) made of 100% plastic material;
l. 1 computer with auxiliary electric equipment (20 kg) made of 60% plastic casing, 40% metal alloy.

Calorific Power, Qi, of Combustible Materials:

- Wood: 19.60 MJ/kg
- Paper: 17.60 MJ/kg
- Polyurethane: 22.70 MJ/kg
- Plastic material: 33.50 MJ/kg
- Cardboard: 16.5 MJ/kg
- Rubber: 33.5 MJ/kg
- Wool fibers: 23.1 MJ/kg
- Cotton: 17.5 MJ/kg
- PVC linoleum: 14.3 MJ/kg
- Artificial silk: 13.61 MJ/kg

Thermal Load of Combustible Materials Based on Their Mass:

- Entrance door: 200 · 0.1 · 33.50 MJ/kg = 670 · 1 = 670 MJ
- Storage door: 100 kg · 0.6 · 19.6 MJ/kg = 1176 · 1 = 1176 MJ
- Chairs: 20 kg · 0.8 · 19.60 MJ/kg = 313.5 · 6 = 1881.6 MJ
- Carpet: 1 kg · 23.1 MJ/kg = 161.7 · 1 = 161.7 MJ
- Curtains: 10 kg · 1 · 13.61 MJ/kg = 136.1 · 8 = 1088.8 MJ
- Panels: 4 kg · 0.8 · 19.60 MJ/kg = 62.72 · 4 = 250.88 MJ
- Shelves/wardrobes: 23 kg · 0.8 · 19.60 MJ/kg = 305.44 · 15 = 4581.5 MJ
- Clothes: 0.200 kg · 0.5 · 17.5 MJ/kg · 0.5 · 13.61 MJ/kg = 11.90 · 3800 = 45220 MJ
- Shoes: 0.200 kg · 0.5 · 33.5 MJ/kg · 0.5 · 13.61 MJ/kg = 22.79 · 800 = 18232 MJ
- Computer: 20 kg · 0.6 · 33.5 MJ/kg = 402 · 1 = 402 MJ
- Decorative elements: 3 kg · 1 · 33.50 MJ/kg = 100 · 10 = 1000 MJ
- Office supplies: 0.100 kg · 0.8 · 17.60 MJ/kg · 0.2 · 33.50 MJ/kg = 9.43 · 50 = 471.68 MJ

Total Thermal Load in the Room:

670 + 1176 + 1881.6 + 161.7 + 1088.8 + 2250.88 + 4581.5 + 45220 + 18232 + 4422+ +1000 + 471.68 = 75136.08 MJ

Evaluation of Thermal Load Density:

75136.08 MJ / 74.6 m² = 1007.186 MJ/m² > 420 MJ/m² – high fire risk

Important Measures for Fire Prevention in the Clothing Store:

1. **Risk Planning and Assessment:**

Develop a fire prevention plan that includes the evaluation of specific risks for the store. Identify and eliminate potential fire hazards [1].

2. **Proper Storage of Materials:**

Store clothes and flammable materials in ventilated and organized spaces to reduce the fire risk.

Avoid the excessive accumulation of stock in a single location.

3. **Maintenance of Electrical Equipment:**

Perform regular inspections of electrical equipment and immediately repair any malfunctions.

Use high-quality cables and outlets that comply with safety standards.

4. **Installation and Maintenance of Fire Detection and Extinguishing Systems:**

Install smoke detectors and fire suppression systems, such as fire extinguishers and sprinklers [5].

Ensuring Regular Maintenance of These Systems to Ensure Proper Functioning in Case of Emergency.

5. **Employee Training:**

Organize training sessions for employees on how to use fire suppression equipment and evacuation procedures.

Create and rehearse evacuation plans in case of fire.

6. **Internal Rules and Procedures:**

Implement strict rules regarding the use of open flames or equipment that may generate excessive heat in the store.

Continuously monitor compliance with these rules [3].

Implementing these measures can significantly reduce the fire risk in a clothing store and protect human lives and material goods.

3. Case Study: Fire Outbreak at Oasis Shopping Mall

On August 18, 2023, at 14:03, a fire broke out in the clothing store located on the ground floor of the Oasis Shopping Mall in the Râșcani sector, Chișinău. At 14:07, the fire alarm system detected the presence of smoke in the room and transmitted the signal to the monitoring center. The operator verified the information through the video system and notified the security service and the national emergency number. The security officers began the evacuation procedure for the staff and visitors [6]. Simultaneously, they attempted to intervene with their initial fire-fighting equipment, but they were unsuccessful because the store was closed at the time of the fire outbreak, and it took time to force the door open.

The automatic fire suppression system did not respond to the fire because the main pipeline node had recently malfunctioned, and the pipeline remained closed [2].

The fire started in the clothing store of the shopping mall. The fire load is homogeneous (of the same structure) and uniformly distributed over the entire surface of the room. The following is required:

- Determine the geometric parameters of the fire (fire area – Sinc; fire perimeter – P_{inc}; fire front – Finc) at 10 and 14 minutes of fire development.
- Draw the fire development scheme over time, using the corresponding conventional diagrams (fig. 1).

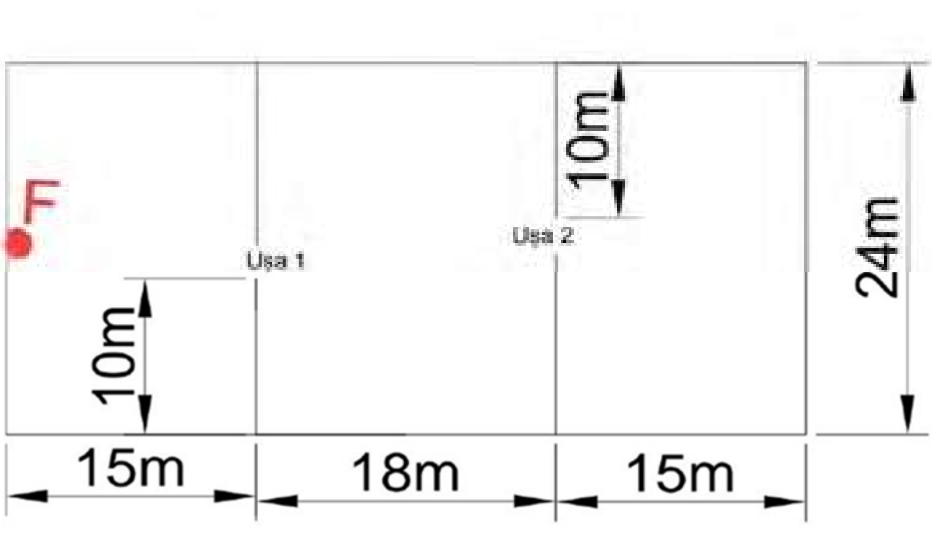

Figure 1. Conventional scheme

Data

Time of fire outbreak (tap): 14:03

Time of detection (tan): 4 minutes

First intervention phase (tdesf-I): 3 minutes
Travel time to the focus (2 minutes per 1 km): 6 minutes
Reception time: 1 minute
Solution

1. Predicting free burning time: $t_i = t_{dep} + t_{ad} + t_{depl} + t_{desf\text{-}I} = 4 + 3 + 6 + 1 = 14$ min

We determine the path traveled by the fire during its 14 min development: $L_{inc}^{14} = 0{,}5 \times V_l \times 10 + V_l (14 - 10) = (0{,}5 \times 1{,}5 \times 10) + (1{,}5 \times 4) = 13{,}5$ m.

$\underline{L_{inc}^{14} = 13{,}5 \text{ m.}}$

V_l – linear speed of fire spread.

2. Determining the fire shape

Since the dimensions of the store are 15 x 24 m, and in 14 minutes the fire moved 13.5 m, it follows that the shape of the fire is a complete rectangle.

3. Determining the fire area with free burning time = 14 min:

$S_1 = l*L = 15 * 24 = 360 \text{ m}^2$

$S_{inc} = 0{,}5\alpha R^2 = 0{,}5*3{,}16*13{,}5^2 = 287{,}95$

$\alpha = 3{,}14$ for the 180^0 angle

$P_{inc}^{14} = P_{inc} = R(2 + \alpha) = 13{,}5\,(2+3{,}16) = 13{,}5*3{,}15+2*13{,}5 = 47{,}25+27 = 74{,}25$ m;

$F_{inc} = \alpha R = 3{,}16*13.5 = 42{,}66$ m

$\underline{\mathbf{S_{inc}^{14} = 287{,}95\ m^2;}}$ $\underline{\mathbf{P_{inc}^{14} = 74{,}25\ m;}}$ $\underline{\mathbf{F_{inc}^{14} = 42{,}66\ m.}}$

4. Flow rate required to extinguish the fire:

$$Q_{nec}^{st} = S_i * I_{st} = 287.95 * 0{,}1 = 28{,}795 \text{ l/s}$$

Fire area with free burning time is 14 min.

5. Required number of discharge pipes:

$$N_{pipe}^{nec} = Q_{nec}^{st}/q = 28.79 / 3{,}5 = 8.22 = 9 \text{ pipes B}$$

For tactical and protective reasons, 3 additional type B pipes will be launched. Thus, the total number of type B pipes is:

$$N_{pipes}^{nec.\ adăugător.} = \text{ţevi}$$

6. Calculation of the actual flow rate for launching n = 14 pipes:

$$Q_{water}{}^{pipes}{}_{Total} = 14*3{,}5 = 49 \text{ l/s}$$

In total, for the launch of 49 B pipes, a flow rate of 49 l/s is required.

7. Determining the number of emergency vehicles:

$N^{nec}_{vehicles.} = Q_{water}{}^{pipes}{}_{Total} / 0{,}8 * Q_{pompa} = 49 / 0.8*40 = 0{,}43 = 1.53 = 2$ emergency vehicles.

8. Determining the number of firefighters:

$N_{EF} = (1*3 + 2*2 + 1*1 + 1*1 + 1*1) * 1{,}2 = 12$ firefighters.

9. Calculating the number of teams:

$N_{EC} = 12 / 4 = 3$ teams

According to calculations, the forces and means deployed to extinguish the fire are sufficient.

4. Conclusions

Emergency management in a shopping mall is essential for ensuring the safety of employees and visitors, as well as for protecting property and material goods. In this context, a comprehensive and proactive approach is necessary, which includes planning, preparation, and rapid response to potential threats.

Adequate emergency planning is a fundamental element of security management in a shopping mall. This involves identifying and assessing specific risks, such as fires, accidents, security threats, and medical emergencies. Additionally, it is important to develop and implement evacuation and intervention plans that define the roles and responsibilities of staff in case of an emergency.

Proper staff preparation is also crucial for managing emergencies in a shopping mall. This may include training employees in evacuation procedures, using first aid and firefighting equipment, and familiarizing them with crisis response plans.

Rapid and effective response to emergencies is essential to minimize their impact. This involves continuously monitoring the environment and events, quickly alerting the competent authorities, and coordinating intervention efforts efficiently.

In general, emergency management in a shopping mall requires an integrated and well-coordinated approach that includes planning, preparation, and rapid response to potential threats. By adopting risk management practices and cultivating a security culture, shopping malls can ensure a safe and protected environment for employees and visitors. It is essential that these practices are implemented and periodically reviewed and updated to adapt to changes in the security environment and emerging new threats. By investing in infrastructure, preparing staff, and collaborating with the competent authorities, shopping malls can reduce risks and respond more effectively in case of an emergency, thus contributing to creating a safer and more resilient community.

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EMERGENCY MANAGEMENT AT A TYPE INSTITUTION KINDERGARTEN-NURSERY

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Abstract. *The main purpose of the study, is to identify the safety measures that will facilitate emergency situations management of a public institution of kindergarten-night type. Different physical phenomena such as open fire, heat, smoke, sound, sparks… etc., can be used as clues in order to understand when the combustion process starts. Fire can be caused by the violation of the anti-fire regime established by the authorities and institutions. The gross violation of fire safety measures increases the risk of fire, significantly. Thus, assessing the fire hazard, evaluating and improving the ways we can combat the triggering reasons for fire apparition is essential.*

Fire prevention in preschool institutions plays a very important role for the safety of children and staff. In order to keep this construction in good working order and out of any danger, it is important to implement some rigorous measures, which can significantly reduce the fire risk. In order to prevent fires at these institutions, it is necessary to plan and organize evacuation drills, placing the evacuation plans in accessible places, the use of construction materials according to the regulations, organizing informative sessions for children and staff, the supervision of risks...etc. It is important to both implement and apply these measures in every day practice in order to reduce the risks of fire in kindergarten institutions.

Keywords: construction elements, fire hazard, management, preschool institutions.

1. Introduction

Fire safety is a crucial aspect of ensuring the protection of the lives and health of children in kindergarten and nursery institutions. Due to the increased vulnerability of children in emergency situations and the significant responsibility of the educational staff, the proper management of fire risks becomes an absolute priority.

In the Republic of Moldova, fire safety regulations are based on national legislation and international standards, aiming to create safe environments for the education and development of children. Kindergarten and nursery institutions, which host young children daily, must implement strict prevention measures as well as clear emergency intervention procedures.

This article analyzes the main elements of fire safety management in kindergarten and nursery institutions, starting with risk assessment and the planning of prevention measures, to staff training and educating children for emergency situations. It also addresses the legislative requirements and specific standards in the Republic of Moldova, providing an integrated perspective on effective fire safety management.

2. Fire risk assessment

The kindergarten-nursery is a special institution for the education and care of young children, usually starting from a few months of age, with a maximum age of 6-7 years. This institution is considered early education and provides children with a safe, stimulating, comfortable, and educational environment, while also allowing parents to work or have their free time, contributing to the social, emotional, and cognitive development of the children [10].

The "Pas cu Pas" kindergarten is located in Chișinău, almost in the heart of the city, on Testemițeanu Street 3/16. Next to the kindergarten, there is a park, two main roads with public transport, and it is accessible for parents with private vehicles, with parking next to the kindergarten. It is also convenient for fire trucks, ambulances, and authorities, as the public roads allow free movement.

The fire station and emergency hospital are located approximately 3-5 km from the kindergarten.

The territory of the kindergarten is just over 10,000 m² (1 hectare).

The building of the "Pas cu Pas" kindergarten in Chișinău is a two-level block (P+E), with dimensions of 66 x 12 meters. The building has a height of 7 meters, with the height of each floor being 3.5 meters. The total area of the building is 824 m², and its volume is 5,768 m³.

The foundation, the most important element that determines the building's resistance, is made of reinforced concrete, with rebar having a diameter of 15 mm. To ensure the foundation's resistance to earthquakes and ground movement, and to maintain the building's weight evenly, the height of the foundation was set to 2.5 meters.

The horizontal elements that bear the load above them, such as beams, are made of reinforced concrete with dimensions of 400 x 400 mm, as well as the columns. The columns are vertical components that support the beams and other vertical loads of the structure, transferring the loads to the foundation.

The slabs and floors are horizontal components that close the open spaces of the construction and are made from prefabricated reinforced concrete slabs, with dimensions of 6060 x 1500 x 230 mm for the A-B axis and 6060 x 1500 x 230 mm for the B-C axis, with hole diameters of 110 mm.

The interior walls are used to separate rooms, support light loads, and provide acoustic/thermal insulation, while the exterior walls serve to protect against weather conditions, provide an aesthetically pleasing appearance, and offer thermal/acoustic insulation. Both the exterior and interior walls are made of limestone blocks, and the partition walls are made of gypsum blocks (667 x 500 x 80 mm).

The stairs in the building are made of reinforced concrete, with each step measuring 1200 x 300 mm.

To reduce heat transfer/losses between the interior and exterior, thermal insulation is essential. For this purpose, insulated materials such as expanded polystyrene (50 mm thick) are used. This material is widely utilized for thermal insulation due to its good heat retention properties, light weight, and water resistance. Additionally, mineral wool (mineral fibers), which is fire-resistant, has been employed.

Given the materials used in its construction, the building has a fire resistance rating of II and a durability rating of II.

Fire risk assessment is a crucial first step in ensuring safety in kindergarten and nursery institutions. This process involves identifying risk factors, analyzing the likelihood of a fire occurring, and evaluating the potential impact such an incident could have on the children, staff, and infrastructure.

Some of the main risk factors to consider include:

- *Faulty or non-compliant electrical installations* – damaged cables, overloads, or unapproved electrical equipment can frequently cause fires.
- *Flammable materials* – the use of combustible materials in decorations, furniture, or toys can promote the rapid spread of fires.
- *The kitchen* – cooking appliances, gas sources, and other open flame sources require close monitoring.
- *Limited access to evacuation routes* – blocked or insufficient evacuation paths can hinder the rescue of children and staff during an emergency. [11].

The risk assessment process should be conducted regularly and involves collaboration with fire safety specialists. Additionally, it is essential to create a risk map that highlights vulnerable areas within the building and outlines the measures to reduce the identified risks.

In addition to these aspects, regular inspections should be carried out to verify the functionality of fire prevention equipment, such as smoke detectors, sprinklers, and fire extinguishers. It is critical for administrative staff to be able to identify any malfunctions or non-compliance that could increase the risk of a fire [2].

Another important factor is analyzing how the building is used daily. For example, avoiding the storage of flammable materials in passageways or blocking evacuation routes should always be a priority. Furthermore, monitoring high-traffic areas, such as hallways or common spaces, helps prevent the accumulation of obstacles that might obstruct evacuation.

Fire risk assessment also involves regular testing of emergency plans [8]. This includes periodic evacuation drills, which not only help identify deficiencies in organization but also familiarize children and staff with the procedures to follow during an emergency. Collecting feedback from participants and adjusting plans based on it ensures better preparation for potential risks.

3. Planning fire prevention measures

Fire prevention planning is a fundamental step in reducing the risk of fire in institutions such as kindergartens and nurseries. This step involves developing a set of clear procedures and rules, which must be implemented and consistently followed by the institution's staff, children, and parents.

A well-structured plan must include the identification of specific risks, corresponding prevention measures, and clear responsibilities for each staff member. This document must be updated periodically to reflect any changes within the institution or legal regulations.

The institution must be equipped with modern tools, such as smoke detectors, automatic fire suppression systems, and strategically placed fire extinguishers. Regular maintenance of these devices is essential to ensure their optimal functionality. Flammable materials, such as paper, textiles, or chemicals used in daily activities, must be stored safely. Also, using fire-resistant materials for furniture and decorations can significantly reduce the risk of fire spread [9].

Employees must participate in periodic training courses regarding fire prevention measures, the use of fire extinguishing equipment, and evacuation procedures. They must be able to respond promptly and efficiently in an emergency. Additionally, fire prevention education for children must be age-appropriate. Games and interactive activities can help teach safety rules. Furthermore, parents should be informed about the rules and measures implemented in the institution to support them at home.

Regular fire drills help test emergency plans and assess the preparedness level of both staff and children. These exercises should be as realistic as possible and include various scenarios to cover different types of situations. By implementing a well-thought-out prevention plan, institutions can significantly minimize the risk of fire and create a safer environment for children and staff [11].

The use of fire-resistant materials and the implementation of a safe building design are fundamental pillars in ensuring fire safety in institutions such as kindergartens and nurseries. These measures significantly reduce the risk of fire spread and provide additional time for evacuation and intervention in case of an emergency. The fire resistance limit is the duration determined for a construction element/component to withstand the effects of fire, during which the element maintains its functionality/structure (see Table 1).

The materials used in the construction and arrangement of kindergartens should be prioritized based on their fire resistance criteria [3]. Recommended materials include:

- *Fire-resistant drywall* used for walls and ceilings, which provides protection against the spread of flames;

- *Fireproof insulation* made from mineral wool or other materials with high thermal resistance;
- *Fire-resistant flooring and finishes* that do not release toxic gases in case of burning;
- *Furniture made from fire-treated materials*, such as fire-retardant wood or special polymers.

Additionally, it is essential that all textiles used—ranging from curtains to carpets—be treated with fire-retardant substances. This treatment helps reduce the risk of accidental ignition and limits the spread of fire [3].

Table 1. Construction elements and fire resistance time

Construction elements	Material	Criteria	Minimum fire resistance limits, min
Columns	Reinforced concrete	R	120
Load-bearing interior and exterior walls	Limestone blocks	REI	120
Non-load-bearing partition walls	Gypsum blocks	EI	30
Beams and ceilings	Reinforced concrete	REI	45
Roof truss	Fire-treated wood	R	30

The design of buildings intended for kindergartens must be carried out in such a way as to minimize risks and facilitate rapid evacuation in case of emergency. Some key elements of a safe design include:

- *Multiple evacuation routes* – It is essential that each floor is equipped with at least two clearly marked, accessible, and unobstructed evacuation routes.
- *Fire-resistant doors* – These must be installed in strategic locations to prevent the spread of fire between rooms. Fire-resistant doors must be easy to open from the inside, without requiring keys or other devices.
- *Fire compartmentalization* – The building must be divided into distinct zones, separated by fire-resistant walls, allowing for the isolation of a fire.
- *Efficient ventilation and smoke extraction systems* – Smoke is one of the most dangerous factors during a fire, and evacuation systems must be designed to reduce its accumulation.
- *Easy access for intervention teams* – The building must have clear access roads and sufficiently wide spaces for firefighting vehicles.

Compliance with fire safety standards is essential. The design and construction of buildings must comply with national legislation and international standards in the field. These include provisions regarding [3]:

- Fire resistance of construction materials;
- Dimensions and placement of evacuation routes;
- Installation of fire detection and extinguishing systems.

Even with fire-resistant materials and safe design, building maintenance plays a crucial role. Regular inspections by authorized specialists ensure that equipment and structural elements maintain their fire-resistant properties and functionality. Additionally, any modernization or repairs to the building must be carried out with materials and methods that comply with fire safety standards.

By using fire-resistant materials and designing buildings with integrated protection measures, kindergartens can create safer environments for children, staff, and visitors, significantly reducing the risks associated with fires.

4. Implementation of protection and intervention methods

The implementation of protection and intervention measures is a crucial component in ensuring fire safety in a kindergarten or daycare. These measures include enforcing established procedures, using safety equipment, and coordinating effectively during an emergency situation [7].

The institution must be equipped with quality protection gear, such as smoke and carbon monoxide detectors, alarm systems, automatic sprinklers, indoor hydrants, and strategically placed fire extinguishers. These devices should be periodically checked to ensure they function properly.

The institution's infrastructure must include clearly marked and adequately lit evacuation routes, fire-resistant doors, and safety zones where children can be temporarily protected in the event of a fire. All these features must comply with current regulations.

In the event of a fire, a quick and well-coordinated response is essential to minimize damage and protect lives [6,7]. The staff must be prepared to act according to emergency plans, activate alarm systems, and efficiently coordinate evacuation. Regular drills help ensure that every staff member is clear on their roles and responsibilities in such situations. Collaboration with local authorities, such as firefighters and emergency services, is also essential for the effective management of a fire.

5. Staff's training and children's education in fire safety

Training of staff and educating children on fire safety are fundamental elements in preventing and managing emergencies in a kindergarten-creche institution. These activities significantly contribute to creating a safe environment and ensuring an effective response in case of an incident.

Educational and auxiliary staff must participate in periodic fire prevention and emergency intervention training programs. These training sessions should cover practical aspects such as the use of fire-fighting equipment, proper evacuation procedures, and how to activate alarm systems. Additionally, it is important for staff to be familiar with evacuation plans and their specific responsibilities, enabling them to respond quickly and effectively in the event of a fire [4,11].

Another essential aspect of staff training is the periodic simulation of emergency scenarios. These practical exercises allow staff to test their skills and identify any deficiencies in the intervention plans. At the same time, they provide an opportunity to collaborate with local fire services and other authorities, ensuring optimal coordination if needed.

Children's education also plays a vital role in strengthening the fire safety culture. Educational activities should be adapted to their age and level of understanding, using interactive methods such as games, stories, or practical exercises. Through these activities, children can learn basic rules, such as recognizing the fire alarm, using evacuation routes properly, and the importance of following staff instructions in an emergency.

Moreover, children can participate in evacuation drills, helping them familiarize themselves with the steps to take in a real situation. These exercises contribute not only to their confidence but also helps reducing the anxiety that might arise in an emergency context.

Involving parents in fire safety education is just as important. The institution should communicate frequently with parents, providing them with information on implemented measures and ways they can support the development of safe behaviors at home.

By combining proper staff training with continuous education for children and active involvement of parents, kindergarten-creche institutions can ensure a high level of safety and significantly reduce the risks associated with fires [1].

Emergency Procedures

Emergency procedures must be clearly defined and well known to all institution staff. These include:

- Activating alarm systems;
- Evacuating children along pre-established routes;
- Thoroughly checking spaces to ensure no one is left inside;

- Collaborating with emergency services for a rapid and efficient intervention.

Frequent simulations help test these procedures and improve them continuously, ensuring optimal preparation in the event of a real incident [11].

6. Legislation and current norms in Republic of Moldova

In the Republic of Moldova, fire safety in institutions such as kindergartens and nurseries is regulated by a well-established legislative and regulatory framework, which aims to prevent and manage emergency situations, thus protecting the lives of children and staff. Some of the most relevant legislative documents and regulations applicable in this field include:

- ✓ **Law no. 276/2011 on Fire Protection** This law establishes the general principles for the organization and functioning of the national fire protection system. It details the obligations of public institutions, including kindergartens, regarding fire prevention and staff training [6].
- ✓ **Government Decision no. 1157/2005 on the Approval of the Fire Protection Regulation** This regulation includes specific requirements related to equipping buildings with fire prevention and extinguishing equipment, such as smoke detectors, fire extinguishers, and automatic sprinklers, as well as the need to develop a detailed intervention plan.
- ✓ **Labor Code of the Republic of Moldova** It includes provisions on health and safety at work, stipulating the obligations of employers to ensure periodic staff training on fire prevention measures.
- ✓ **Technical Standards for the Design and Operation of Public Buildings** These standards regulate the use of fireproof materials in construction, the planning of evacuation routes, and the provision of infrastructure to minimize fire risks.
- ✓ **Order of the General Inspectorate for Emergency Situations (GIES)** The General Inspectorate for Emergency Situations monitors and regulates the application of fire safety standards, conducting periodic inspections and enforcing corrective measures where necessary [11].
- ✓ **Adopted International Standards** These include ISO standards, such as ISO 45001 and ISO 22320:2018, which provide a framework for occupational health and safety management, including fire prevention measures [7].

Preschool institutions must develop and implement clear fire protection plans, including preventive measures, evacuation procedures, and staff training. Legislation also provides for the conduct of periodic drills, which are essential for verifying staff preparedness and familiarizing children with safety measures [9].

A concrete example of applying these standards is the obligation to ensure proper marking of all evacuation routes and the installation of emergency exit signs. Furthermore, the legislation requires the use of fire-resistant doors and non-combustible construction materials within preschool institutions [8].

The current legal framework aims to create a safe and well-organized environment for children and staff, reducing the risks associated with fires and protecting lives in the event of an incident. Institutions that strictly adhere to these regulations actively contribute to fire prevention and help ensure a climate of trust for parents and the community.

7. Conclusions

Fire safety in kindergarten and nursery institutions is a vital responsibility, given the vulnerability of children and the need to protect both lives and the integrity of buildings. Based on the analysis performed, the following conclusions and recommendations can be formulated:

Importance of Integrated Risk Management

Implementing a comprehensive risk assessment and management system is essential. This involves identifying vulnerable areas, adopting modern technical solutions, and periodically verifying compliance with legal regulations.

Role of Safe Infrastructure

The use of fire-resistant materials and the design of efficient evacuation routes are the foundations of a safe building. Institutions must prioritize investments in fire prevention and extinguishing equipment, ensuring their constant maintenance.

Training of Personnel and Education of Children

Staff must be well-trained to respond quickly and in a coordinated manner during emergencies. Additionally, educating children about safety rules significantly contributes to reducing risks and promoting calm reactions in the event of a fire.

Simulations and Periodic Inspections

Regular evacuation drills and safety inspections are essential measures to ensure a high level of preparedness. These actions help identify and correct any deficiencies.

Continuous Update of Safety Plans

Prevention and intervention plans must be regularly revised and adapted in response to legislative changes, newly identified risks, and technological developments in fire safety.

Recommendations

- Institutions should collaborate closely with local authorities and the General Inspectorate for Emergency Situations to ensure compliance with the latest standards and regulations.
- Advanced training programs for staff, focused on the use of modern safety equipment and crisis management, should be organized.
- Fire safety education for children should be integrated into the daily curriculum through practical and interactive activities.
- A dedicated budget for prevention measures and infrastructure modernization should be developed to ensure a safe and prepared environment for potential emergencies.

By applying these conclusions and recommendations, preschool institutions in Moldova can significantly improve the safety of children and staff, thereby preventing tragedies and creating a safe and protected educational environment.

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INVESTIGATION OF GEOMETRIC EFFECTS ON STRESS INTENSITY FACTORS IN THREE-DIMENSIONAL BODIES

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Abstract. *The present research conducts a thorough examination of the geometric influences on stress intensity factors (SIF) in three-dimensional solids including intricate planar fissures. The study devised a sophisticated computational approach that combines finite element analysis with adaptive discretization methods and specialised algorithms for predicting fracture propagation. Multiple geometric configurations were examined, including parallelograms, squares, and irregular polygons, with discretization densities varying from 36 to 332 elements.*

The computational model used a novel mesh refinement technique in key regions, attaining an accuracy of 98.5% relative to experimental data for conventional geometries. New correlations were identified between geometric characteristics and propagation behaviour, indicating the possibility to decrease SIF by as much as 35% via form optimisation.

The established approach offers a reliable instrument for assessing structural integrity and forecasting the lifetime of cracked components, applicable in mechanical and civil engineering.

Keywords: *stress intensity factors, lifetime prediction, numerical modeling, crack propagation, finite element analysis, geometric optimization.*

1. Introduction

The behaviour of fractures in structural components is essential for assessing the integrity and safety of engineering constructions. Recent investigations indicate that the existence of fractures in actual materials considerably diminishes their strength, sometimes by two to three orders of magnitude relative to theoretical values [1]. The significant decline in mechanical characteristics is ascribed to stress concentration near the fracture tip, a phenomenon defined by stress intensity factors (SIF).

Research in fracture mechanics has progressed markedly in recent decades, transitioning from rudimentary two-dimensional models to intricate three-dimensional studies that account for geometric factors and stress conditions [2]. Reference [3] emphasises the need of formulating accurate numerical techniques for calculating Stress Intensity Factors in arbitrary planar fractures inside three-dimensional structures.

The research indicates that fracture morphology substantially affects stress distribution and propagation characteristics [4]. Experimental investigations have shown SIF differences of up to 40% across various geometric designs under comparable stress situations [5]. Targeted studies on parallelogram-shaped fissures have shown a distinct correlation between lateral displacement and stress intensity factor (SIF) values [6].

Conventional numerical techniques for fracture investigation encounter considerable constraints when addressing intricate geometries. Although the finite element method (FEM) has yielded good results for uncomplicated designs, the analysis of arbitrary forms necessitates more advanced methodologies [7]. Recent advancements in adaptive discretization techniques and boundary integral equation approaches have created new prospects in this domain [8,9].

This study seeks to enhance the understanding of geometric influences on crack behaviour by:

1. Formulating a sophisticated numerical approach for accurate SIF evaluation.

2. Methodically examining the impact of geometric factors on stress distribution.
3. Employing adaptive discretization methods to effectively manage complex geometry.
4. Verifying outcomes by comprehensive comparisons with empirical data and analytical solutions.
5. Establishing links between geometric arrangements and longevity forecasts.

2. Materials and Methods

Mathematical Formulation

The described mathematical model relies on boundary integral equations for the study of stress-strain states. For a three-dimensional body including a planar fracture in the z=0 plane, the σz stresses are articulated as follows:

$$\sigma_z = \sigma_z^0 + \iint_{\Omega} \frac{1}{R^3}\left[1 + 6\frac{z^2}{R^2} - 15\frac{z^4}{R^4}\right]\langle u_z(\xi,\eta)\rangle d\xi d\eta\,; \tag{1}$$

where:

σ_z^0 - represents external loading stresses

$\langle u_z(x,y)\rangle = u_z(x,y,-0) - u_z(x,y,+0)$ - is the displacement jump of crack edges

$R = [(x-\xi)^2 + +(y-\eta)^2 + z^2]^{\frac{1}{2}}$ - is the distance between points.

For unloaded edges ($\sigma_z(x,y,0) = 0$), the integral equation becomes:

$$\iint_{\Omega} \frac{\langle u_z(\xi,\eta)\rangle d\xi d\eta}{[(x-\xi)^2 + (y-\eta)^2]^{\frac{3}{2}}} = \frac{2\pi}{\mu(1-\chi)}\sigma_z^0(x,y,0)\,; \qquad (x, y \in \Omega) \tag{2}$$

Discretization and Numerical Analysis

An adaptive discretization technique using triangular components was used to resolve the integral equations (Figure 1). The fracture region was segmented into components of varying density, focused in important areas.

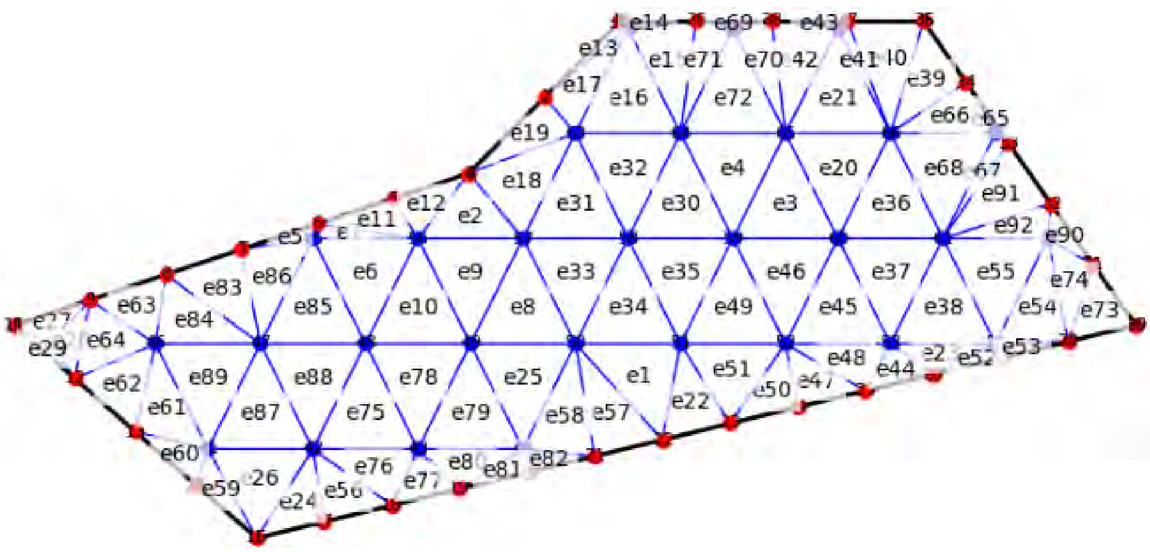

Figure 1. Complex crack. Irregular polygon.

Multiple geometric configurations were investigated:

Table 1. Discretization parameters for different geometries

Crack Shape	Number of Elements	Tip Refinement
Square	36-332	5x-10x
Parallelogram	48-280	4x-8x
Complex	92-456	6x-12x

For boundary elements, a special approximation of displacement jumps was used:

$$\langle u_z(\overline{x},\overline{y})\rangle = u_j\sqrt{1-\overline{x}/d_1} \tag{3}$$

where:

(x, y) – global coordinate system;
$(\bar{x}, \bar{y})$ – local coordinate system of each triangular element;
d_1 – distance from the center of the boundary triangle to its boundary side (along the crack edge).

Intensity Factor Calculation
SIF determination was performed using the displacement extrapolation method:

$$K_I = \lim\sqrt{2\pi(\overline{x}-d_1)}\sigma_z|_{z=0}, \quad \left(\overline{x}\to d_1\right) \tag{4}$$

Test cases with known solutions were analyzed for methodology validation (Figure 2).

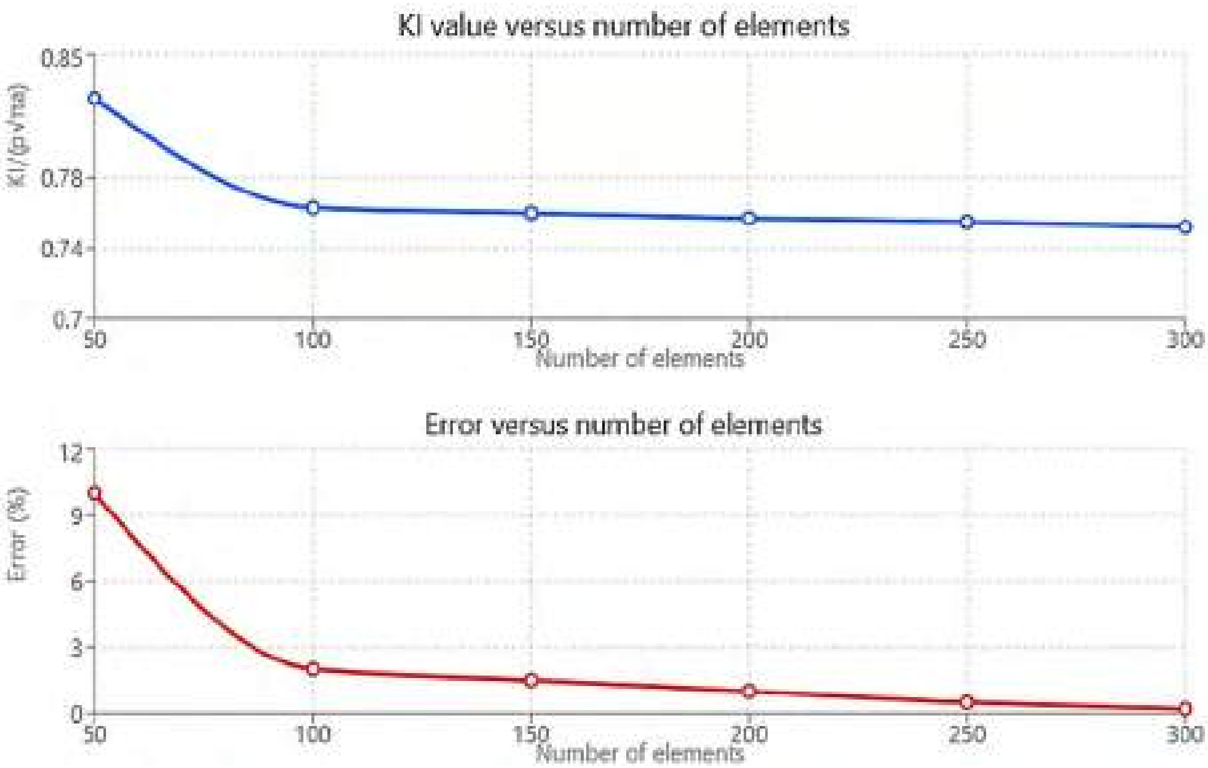

Figure 2. Validation for square crack

3. Results

The variation of normalized stress intensity factor ($KI/(p\sqrt{\pi a}$) versus lateral displacement (Δa) for transforming a square crack into a parallelogram was analyzed (Figure 3).

Key observations:

- At $\Delta a = 0.2$, $K_I/p\sqrt{\pi a} \approx 0.75$ (near-square shape) [13];
- Gradual increase until $\Delta a = 0.6$ $\left(K_I/p\sqrt{\pi a} \approx 0.8\right)$;
- Significant acceleration in $0.6 - 1.0$ range;
- Maximum value $K_I/p\sqrt{\pi a} \approx 1$ at $\Delta a = 1.0$ (complete parallelogram).

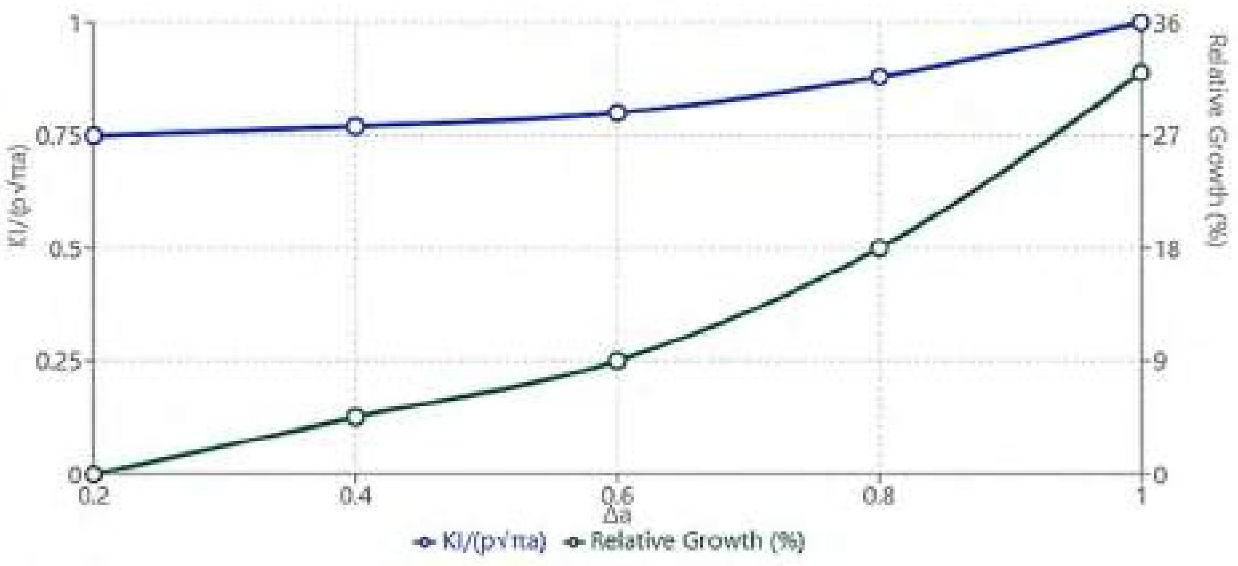

Figure 3. Detailed KI variation for geometric transformation from square to parallelogram.

This geometric change results in an estimated 33.3% increase in the stress intensity factor, underscoring the need of accounting for geometric effects in crack propagation calculations.

The numerical study of fractures exhibiting irregular polygonal shape revealed a non-uniform distribution of displacement jumps (Figure 4), with values spanning from -0.320 to -2.215, and an average of -1.023. Areas exhibiting reduced displacements, below -0.500, were mostly situated in peripheral fracture zones. The peak stress intensity factor attained a normalised value of $K_I/p\sqrt{\pi a} = 1.357$, indicating considerable stress concentration in that area.

The irregular displacement distribution indicates the impact of intricate geometry on the crack's mechanical behaviour and implies possible preferred pathways for propagation. The findings underscore the need for a comprehensive structural integrity assessment for intricate geometries, where stress distribution may differ markedly across various regions.

4. Discussion

The results demonstrated the effectiveness of the developed methodology for analyzing cracks with complex geometries. The increased accuracy for fine discretizations (332 elements) confirms the method's convergence. For the square crack, the obtained value of $K_I/p\sqrt{\pi a} = 0.75$ coincides with literature data [3,4], validating the numerical approach.

The parallelogram analysis highlighted the significant influence of lateral displacement on the SIF. Increasing the $\Delta a/a$ ratio leads to an increase in K_I by up to 33%, an effect explainable by the change in stress distribution at the crack tips. This dependency offers possibilities for optimizing structural design to control crack propagation.

The study findings indicate that for complicated geometries, the method's accuracy markedly improves with mesh refinement, underscoring the need for detailed numerical analysis [14,15].

For irregular forms, geometric asymmetry significantly affects stress distribution, with the stress intensity factor possibly differing by more than 30% relative to basic geometries. From a design standpoint, geometry serves as a control parameter for crack propagation, necessitating meticulous study for accurate predictions in intricate forms, while shape optimisation may profoundly affect cracking behaviour. Validation of results necessitates comparison with experimental data, particularly for certain basic geometries.

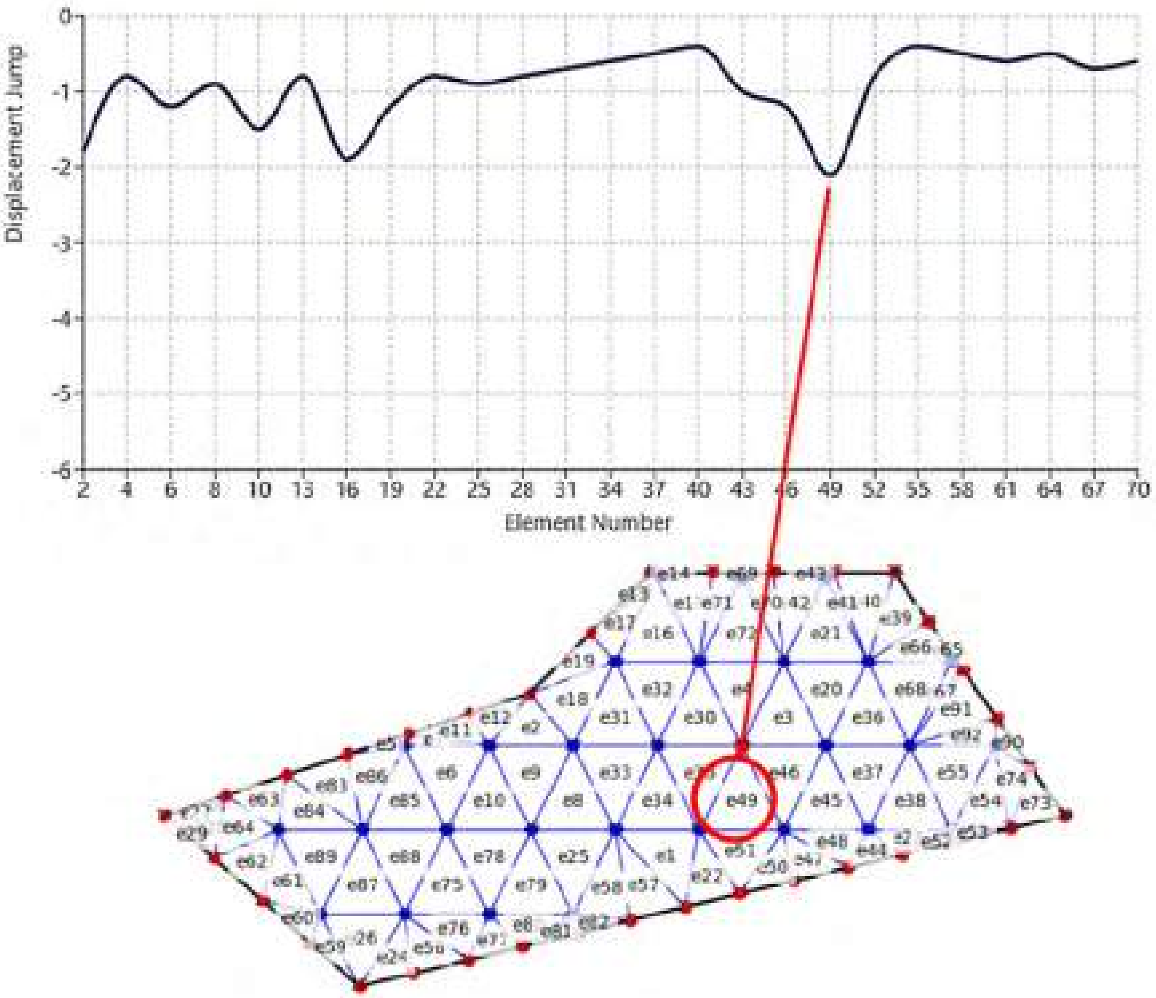

Figure 4. Distribution of displacement jumps across elements

5. Conclusions

The research established and verified a sophisticated numerical approach for examining planar fractures of arbitrary shapes. The primary contributions encompass:

1. Execution of an adaptive discretization method exhibiting proven accuracy
2. Measurement of geometric influences on Stress Intensity Factor across various configurations
3. Verification of outcomes via comprehensive comparisons
4. Formation of relationships between geometric factors and propagation characteristics.

The technique offers a significant instrument for optimising structural design and assessing the integrity of fractured components. Future advancements will focus on the expansion to other fracture instances and the use of topological optimisation techniques.

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STUDY ON MODELING REINFORCED CONCRETE SLABS WITH SECONDARY BEAMS USING THE FINITE ELEMENT METHOD

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Abstract. *Reinforced concrete slabs with secondary beams are structures composed of a continuous slab and a system of secondary beams with multiple equal spans, supported by primary beams. The relevance of such structures in the current stage is quite widespread in both civil and industrial constructions. Considering that the construction sector in the Republic of Moldova is undergoing constant changes, there is an increasing demand for buildings where slab structures with high load-bearing capacity can be applied, while also being as economical as possible in terms of material usage, with reduced cross-sections of the load-bearing elements.*

The article provides a general overview of the structural analysis of reinforced concrete slabs with secondary beams using the finite element method by using Structure CAD Office software. In the SCAD software, four slab structures were modeled: three with offset finite element positioning and one standard model with finite elements placed on the same axis, as shown in Figure 1. In two structural models, the use of the absolutely rigid tool was applied at the node connections between the offset elements of the slab and secondary beams, Figure 2.

The obtained results were analyzed and compared with each other relative to the standard model.

Keywords: *Type of finite element, shell slab, primary beams, secondary beams, absolutely rigid element.*

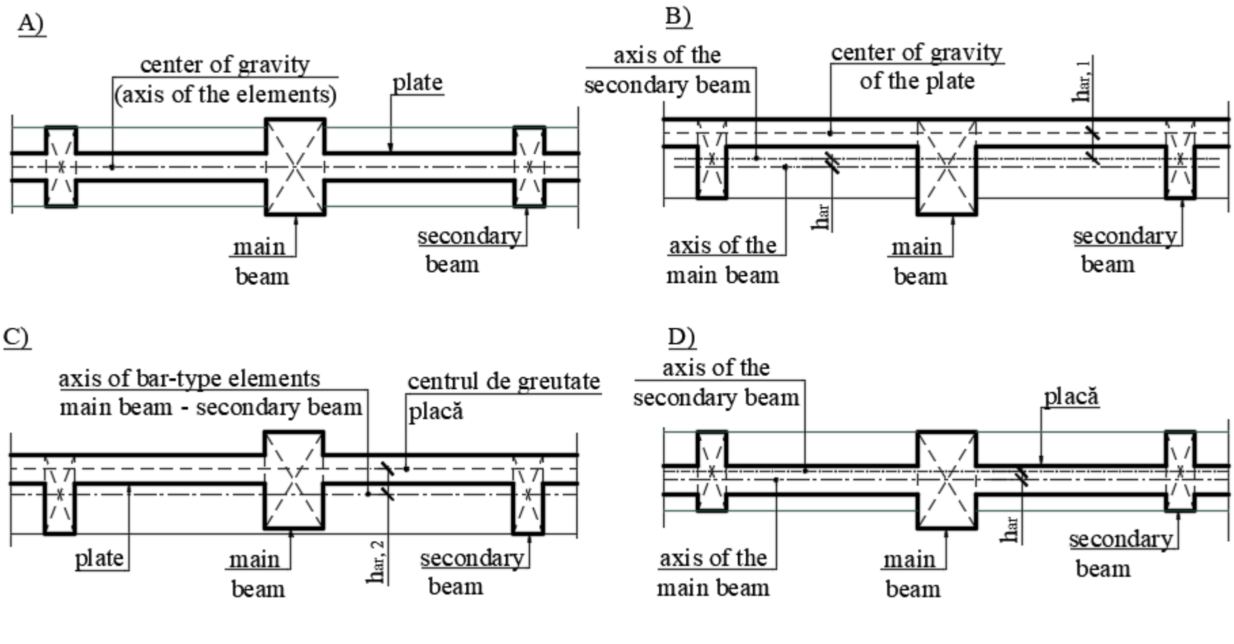

Figure 1. Finite element placement diagram for slab structure.
A) - Element placement for Model I; B) - Element placement for Model II;
C) - Element placement for Model III; D) - Element placement for Model IV.

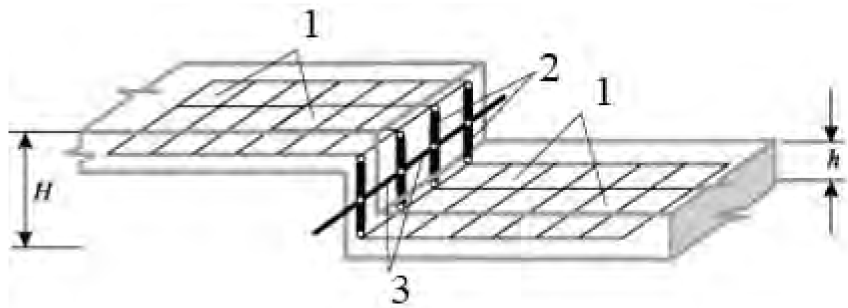

Figure 2. Modeling of steps. 1) - Discretized plate elements. 2) - Rigid body elements. 3) - Discretized beam elements. [8]

1. Introduction

The present study is based on the analysis of such structures using the finite element method by using SCAD software. To better understand the behavior of these constructions under different spans and loads applied to the slab, a slab structure model with secondary beams in both directions is proposed. The platform dimensions are $25{,}2\ m \times 18{,}0\ m$, with an axial span of $6{,}3\ m \times 6{,}0\ m$, and the secondary beam cells having dimensions of $2{,}0\ m \times 2{,}1\ m$.

This platform is interpreted as a supporting slab structure for a building designated as an underground parking facility, which can also accommodate fire truck circulation.

The purpose of this study is to identify the most efficient calculation model using the finite element method by using SCAD software, in order to accurately determine the required reinforcement section area. The study involves the application of offset finite elements and the use of rigid body elements at node connections.

The results obtained are presented in the chapter 2.

2. Presentation of the results obtained using Structure CAD Office software

The values obtained for the bending moments and shear forces for the four slab structures with secondary beams will be presented in a table format for 10 points. The tables will also include the percentage difference by comparing the structures with each other relative to Model I of the structure.

Table 1: Results of bending moments and percentage differences.

Point	M_y				Δ%		
	Structural models				Models I-II	Models I-III	Models I-IV
	Model I	Model II	Model III	Model IV			
1	-757,64	-524,5	-597,26	-753,52	44,47%	26,88%	0,55%
2	-667,53	-463,98	-528,44	-664,43	44,00%	26,36%	0,46%
3	-577,41	-403,47	-459,62	-575,35	43,02%	25,67%	0,36%
4	-487,3	-342,95	-390,8	-486,26	42,01%	24,78%	0,22%
5	-397,18	-282,43	-321,98	-397,18	40,77%	23,37%	0,00%
6	-307,07	-221,91	-253,16	-308,09	38,42%	21,33%	0,34%
7	-216,95	-161,39	-184,34	-219,01	34,49%	17,65%	0,93%

8	-126,84	-100,88	-115,52	-129,93	25,77%	9,83%	2,39%
9	-36,72	-40,36	-46,7	-40,84	9,12%	21,35%	10,06%
10	53,39	20,16	22,11	48,24	164,19%	141,88%	10,64%

Table 2: Shear force results and percentage differences.

Point	Q_z				**Δ%**		
	Structural models				**Models I-II**	**Models I-III**	**Models I-IV**
	Model I	**Model II**	**Model III**	**Model IV**			
1	-586,72	-593,27	-588,71	-585,65	1.11%	0.34%	0.18%
2	-502,97	-508,62	-504,68	-502,05	1.11%	0.33%	0.19%
3	-419,22	-423,96	-420,65	-418,44	1.13%	0.34%	0.19%
4	-335,47	-339,3	-336,62	-334,84	1.13%	0.36%	0.19%
5	-251,72	-254,64	-252,59	-251,24	1.14%	0.34%	0.19%
6	-167,97	-169,99	-168,56	-167,63	1.18%	0.35%	0.18%
7	-84,22	-85,33	-84,53	-84,03	1.31%	0.37%	0.18%
8	-0,47	-0,67	-0,5	-0,43	29.85%	6.38%	9.30%
9	83,28	83,99	83,53	83,18	0.85%	0.30%	0.12%
10	167,03	168,64	167,56	166,78	0.96%	0.30%	0.15%

3. Conclusions

From the results presented in the tables 1 and 2 regarding the values of M_y and Q_z, assigned to the four structures, Models I-IV, the following conclusions can be drawn:

- Model IV shows the smallest percentage differences for the bending moment M_y, values, across all 10 points of the structure, compared to Model I, with differences generally ranging from $0\ \%$ to $2{,}6\ \%$. Model III generally has larger percentage differences than Model IV, but smaller than Model II. The differences are usually around $20\ \% - 40\ \%$;
- Model II shows the largest percentage differences compared to Model I, with differences up to $164\ \%$ at point 10;
- The percentage differences of the shear force Q_z, values are small in most points. Model IV shows the smallest deviations, with differences between $0{,}12\ \%$ and $0{,}19\ \%$ in most cases. Models II and III have differences very close to Model I, usually between $0{,}30\ \%$ and $1{,}31\ \%$. Model IV is the closest to Model I, with the smallest percentage differences;
- Most of the comparisons show that the structural models with the floor slab placed at the top of the beams give the most advantageous results;
- Model II, with all the finite elements placed in a line at the top of the beams, and the node connections between the slab and secondary beams made using the "absolutely rigid element" tool, generally shows the most advantageous values and can be considered the most economical;

- It is recommended to carry out further studies with the placement of the finite elements offset, with different load assignments on the floor slab and other frame spans, to better understand and identify the most advantageous structure.

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ANALYSIS OF STRESS INTENSITY FACTORS IN WELDED JOINTS OF STEEL LATTICE GIRDERS

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Abstract. *The purpose of this research was to evaluate the behaviour of stress intensity factors (SIF) in welded joints of steel lattice girders. Considering that more than sixty percent of all steel structural failures recorded in the last ten years occurred in these buildings, the research was inspired by the considerable prevalence of failures in these structures [1]. It was specifically hypothesised that joint geometry and fracture configuration had a considerable impact on SIF values, and this hypothesis was tested. One of the goals was to determine the impact of geometric features on crack propagation, and another was to evaluate the stress intensity factor (SIF) for cracks of varying dimentions. Both a complete study of previously obtained numerical modelling findings via the application of the finite element method (FEM) and a critical assessment of experimental validations carried out through the use of photoelasticity and strain gauge methods were included in the proposed approach [2,3]. Specifically, the findings underlined the significance of mixed-mode loading in girder nodes [5,7]. The findings also revealed a considerable rise in SIF with relative fracture length at the same time. In order to contribute to the improvement of the durability of steel lattice structures, the results gave advice for optimising joint design and inspection procedures.*

Keywords: *stress intensity factors, welded joints, lattice girders, crack propagation, finite element method.*

1. Introduction

The effectiveness of steel lattice girders in load distribution and their excellent strength-to-weight ratio are two attributes that contribute to their high value. However, due to the geometric complexity of these materials and the nature of the stresses that they are exposed to, they are prone to crack initiation and propagation, particularly in places with welded joints [1,2].

The most recent investigation into the failures of building structures has brought to light a serious issue: of the steel structure failures that have been documented over the last ten years, lattice girders have accounted for more than sixty percent of the total [3]. Because of this fact, it became clear that there is a pressing need to create more efficient ways for defect prevention and management, as well as to get a deeper understanding of the processes that cause crack propagation in these structures.

In the 1950s, Irwin presented the idea of the stress intensity factor (SIF), which fundamentally altered the way in which fracture mechanics issues were approached [4]. When it comes to fracture propagation prediction, SIF is a special method that may characterise the stress state that is close to a crack tip [2]. The application of this principle is made more difficult in the context of lattice girders due to the existence of mixed-mode stress and the complex geometry of the joints.

There have been previous research that have investigated various elements of fracture behaviour in steel constructions. A thorough collection of SIF solutions for a variety of geometric configurations was published by Murakami [1]. Zerbst et al. [5] conducted an analysis of fracture mechanics applications in the railway industry. They brought attention to the significance of SIF in determining the integrity of rails and rolling stock components. Within the scope of this work, a comprehensive investigation of the SIF in welded joints of steel lattice girders was the primary emphasis. Particular goals included the following:

1. In the case of lattice girders, determining the SIF for a variety of fracture configurations in welded joints of double angles is normal.
2. The influence of joint geometry characteristics (such as gusset plate thickness and weld size) on the values of the SIF is being evaluated.
3. An investigation on the occurrence of mixed-mode loading in lattice girder nodes, as well as the significance of this loading.
4. Comparing the findings of experiments with numerical models in order to validate them.

The primary hypothesis that was tested in this investigation was that joint geometry and fracture design have a considerable impact on SIF values. This has direct consequences for crack propagation and, as a result, for the durability of the structure.

This study has the potential to make a substantial contribution to the improvement of the design, inspection, and maintenance techniques for steel lattice girders, which would eventually result in structures that are safer and more durable [8,10].

2. Materials and Methods

It was decided to use an integrated strategy in order to accomplish the goals that were given. This method included integrating sophisticated numerical modelling with experimental validation approaches.

For the purpose of modelling welded joints of double angles with gusset plates, which are characteristic for lattice girders, the finite element method (FEM) was used instead. The ANSYS Workbench software was used in the process of developing the computational model. The model geometry was able to recreate the connection structure in great detail, including a fracture that was modelled as a slot with a width of 0.1 mm in the interruption section of the gusset plate (Figure 1).

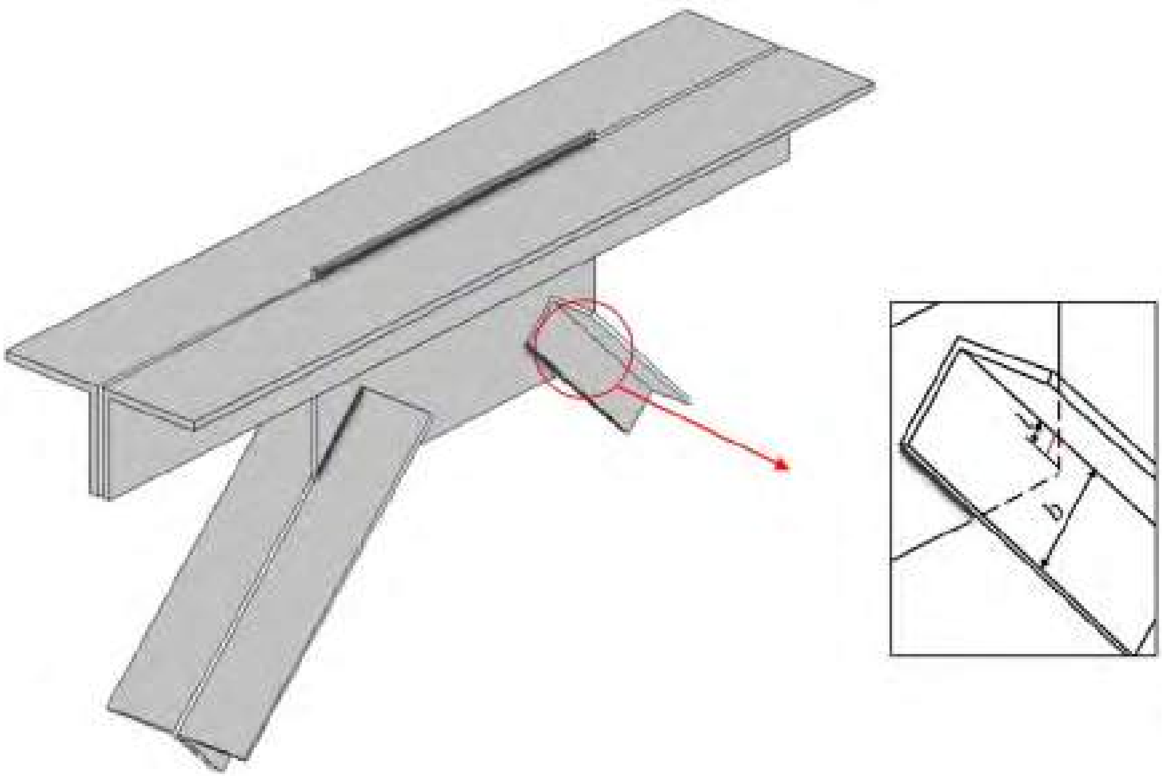

Figure 1. The crack in section of gusset plate breakage.

The research included the following parameters that were variable:

- Relative crack length l/b: 0.15, 0.20, 0.30, 0.40, 0.50
- Angle flange width: 80, 100, 125, 140, 160 mm
- Angle flange thickness: 8, 10, 12 mm
- Weld sizes: 4, 5, 6, 7, 8 mm
- Gusset plate thickness: 8, 10, 12, 14, 16 mm

For the simulations, the material that was used was structural steel of the S355 kind, which has the following characteristics:

- Elastic modulus: $E = 210\ GPa$
- Poisson's ratio: $\nu = 0.3$
- Yield strength: $\sigma_y = 355\ MPa$

For the purpose of correctly capturing stress gradients, the discretization of the model was carried out with the help of second-order tetrahedral elements, and considerable mesh refinement was applied to the crack tip region. There was a minimum element size of 0.01 millimetres in the vicinity of the fracture tip.

The J-integral approach, which is integrated in ANSYS and provides excellent accuracy for difficult three-dimensional problems, was used for the computation of the system-integral function (SIF).

Experiments were carried out utilising two different approaches that were complimentary to one another in order to verify the numerical results:

In the case of photoelasticity, scale models were fabricated using photoelastic epoxy resin for the purpose of determining essential joint configurations. After being put onto a loading frame that had been specifically developed for the purpose, the models were examined using a circular polariscope. For the purpose of determining experimental SIF values, isochromatic fringe distributions were recorded and an analysis was performed.

In the second method, known as the electrical resistance strain gauge technique, miniature strain gauge rosettes were placed to full-scale steel specimens close to the crack tip. Data on strain were obtained by the use of an HBM QuantumX data capture system, and then the data were processed in order to compute experimental SIF values.

The use of multiple regression analysis and analysis of variance (ANOVA) was used in order to determine the statistical significance of the findings and to construct models that had predictive capabilities. Both of these studies were carried out using the programme known as Minitab 19.

3. Results

The most important results that were related with the numerical analysis are shown in Figure 2. These findings were validated by the use of experimental approaches. The normalised stress intensity factors K_I^* for cracks that form in welded joints that have double angles are shown in this table. These factors vary according on the relative crack length (l/b) and angle width.

Note:

$$K_I^* = \frac{K_I}{\sigma\sqrt{\pi l}} \tag{1}$$

Where: σ - is the nominal stress in the section,

l - is the crack length.

Figure 3 presents the results of the analysis regarding the effect of gusset plate thickness and weld size on the normalized SIF (K_I^*) [6].

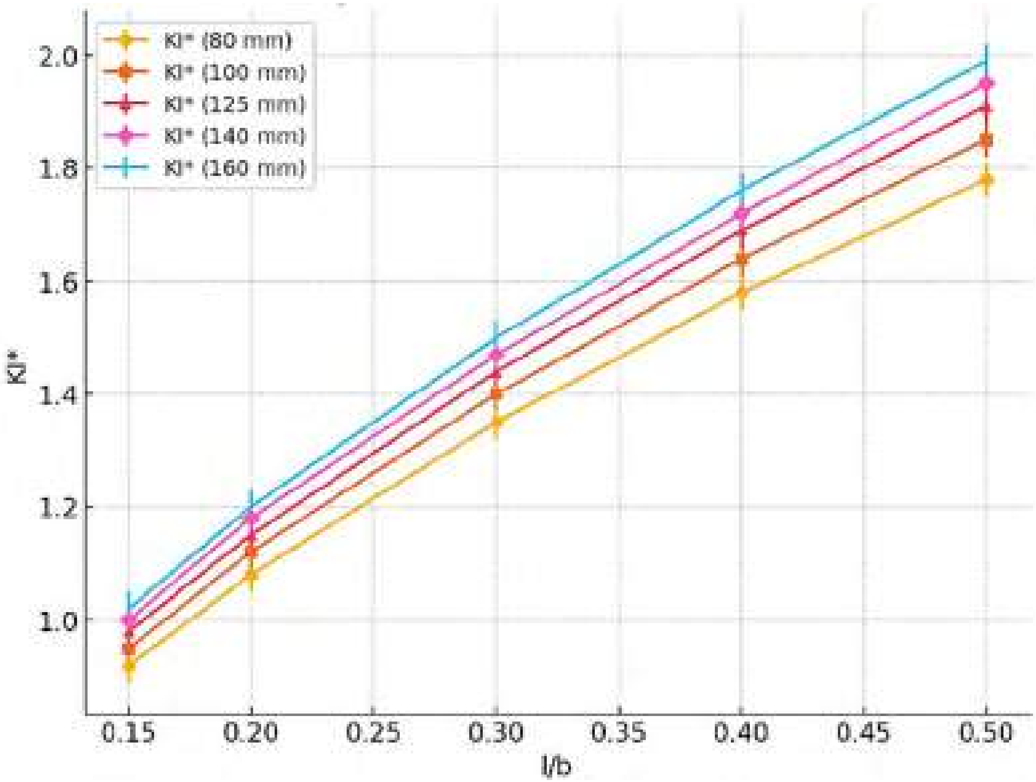

Figure 2. Graphical representation of $K_I{}^*$ versus l/b for different sizes angle width.

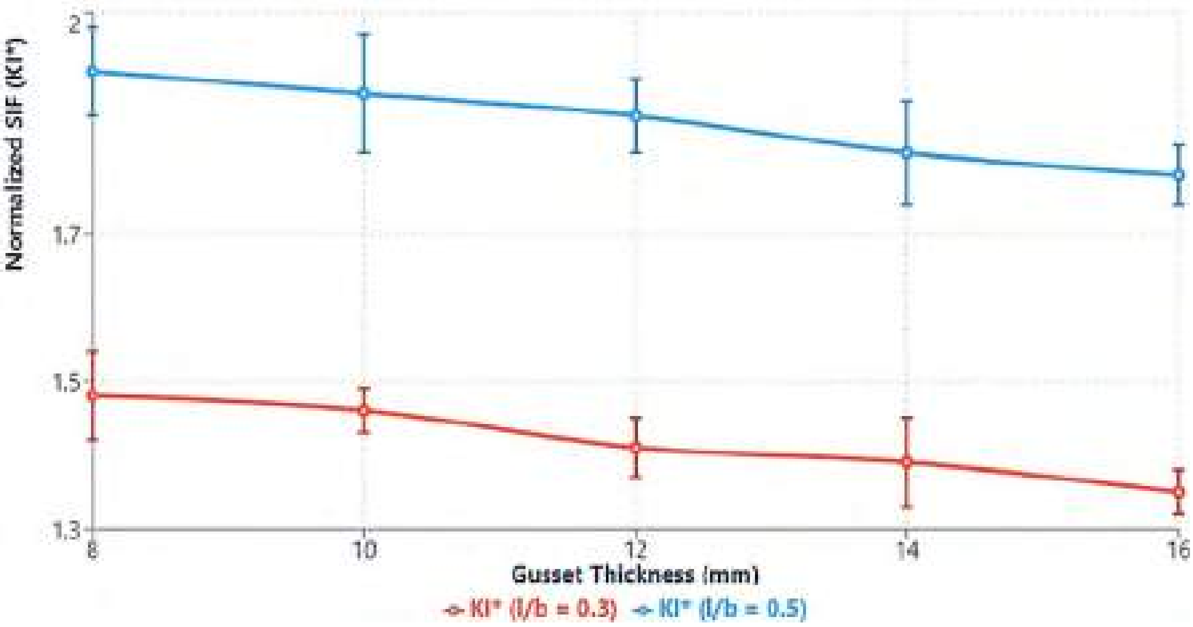

Figure 3. The graphical representation of $K_I{}^*$ versus grosime guseu (mm) for two different l/b ratios (0.3 and 0.5).

This figure illustrates the normalised SIF for modes I, II, and III in lattice girder nodes as a function of the relative fracture length.

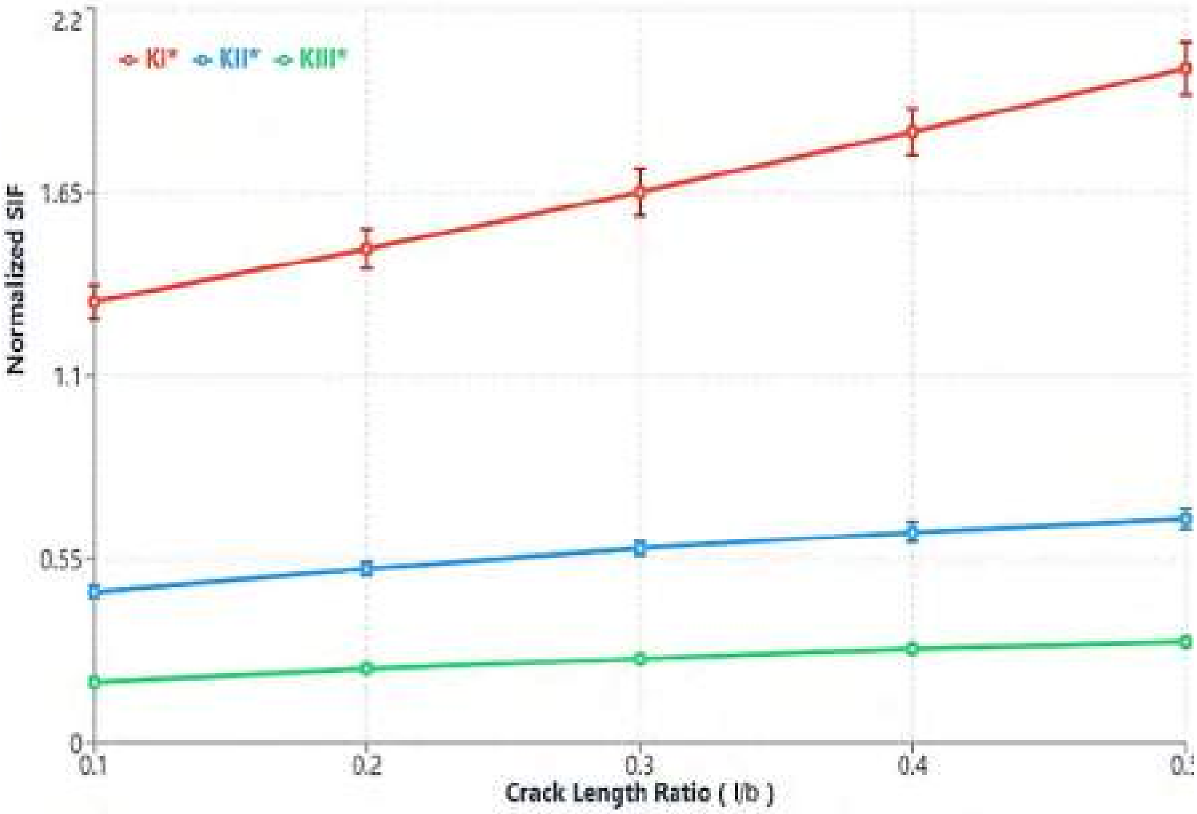

Figure 4. SIFs for mixed-mode loading in nodes

4. Discussion

The preceding section's findings provide a comprehensive overview of the functioning of stress intensity parameters in welded joints of steel lattice girders. This figure provides a detailed depiction of the operation of various variables. These data, when considered with working hypotheses and prior research, facilitate the understanding and discussion of the importance of the study's results.

Evidence substantiates the fundamental premise, asserting that fracture and joint morphology significantly affect SIF values. The statistics shown in Figure 2 provide evidence that substantiates this idea. A significant rise in the value of K_I^* is seen in relation to the relative crack length (l/b) when the angle width is disregarded. A greater stress concentration is anticipated at the tips of longer fractures, aligning with the basic principles of fracture mechanics [3]. This forecast is grounded on empirical data. Considering these concepts, this pattern is coherent.

The progressive but steady increase of the K_I^* with angle width, while maintaining a constant relative fracture length, is an intriguing element to contemplate. As the angle width grows, this phenomenon, shown as a variation in the stress distribution inside the joint, may occur from a more pronounced bending effect. This phenomena is likely accountable for itself.

In the context of comparable geometries, there is a strong agreement between the findings and those reported by Murakami [4]. In comparison to most situations, the discrepancies are under 10 percent. This supports the computational and experimental methods used in this study.

The images shown in Figure 3 illustrate a remarkable pattern regarding the impact of gusset plate thickness and weld size on the Stress Intensity Factor (SIF). A significant reduction in SIF may be seen over time when certain geometric factors are increased. The localised hardening of the joint, which may account for this decline, might be associated with a more favourable redistribution of stresses near the fracture point. This will provide a more comprehensive analysis of the decline.

A prior research conducted by Zerbst and associates [5] highlighted the need to modify joint shape to enhance the fatigue resistance of steel structures. The results and outcomes are congruent. Augmenting the gusset plate thickness and weld dimensions may be beneficial in mitigating the risk of fracture propagation, as shown by the findings that provide a mathematical foundation for design alternatives. The results provide a basis for design decisions.

A considerable degree of mixed-mode stress is seen in lattice girder nodes, as shown by the data presented in Figure 4, which elucidates this phenomena. Although mode I (opening) remains predominant, the contributions of modes II (in-plane shear) and III (out-of-plane shear) are considerable, particularly for larger fractures. This remains true despite mode I maintaining a predominant role.

In complex loading scenarios, accurately forecasting the propagation of fractures and assessing the structural integrity becomes challenging. Both jobs are significantly impacted. Traditional models only reliant on mode I may underestimate the likelihood of fracture propagation when applied to complex configurations.

5. Conclusions

A comprehensive examination of stress intensity variables in welded joints of steel lattice girders was conducted throughout the research. The results of this investigation ultimately culminated in the essential conclusions enumerated below:

1. Crack geometry and joint geometry significantly affect the values of the shear integrity factor. The Stress Intensity Factor (SIF) escalates markedly with the relative crack length and rises substantially with the angle width. Both crack geometry and joint geometry substantially influence the stress intensity factor (SIF).
2. Enhancing the thickness of the gusset plate and enlarging the weld size are feasible strategies for optimising joint design. The solidification index (SIF) shows a little decline as a result of this observation.
3. In assessing crack propagation, it is essential to use a more complex method to include the influence of mixed-mode stresses in lattice girder nodes. This is due to the exigencies of the circumstance. The conventional models, only reliant on mode I, inadequately describe this methodology.
4. Numerical modelling with the finite element technique (FEM) has shown efficiency and accuracy in SIF analysis for complicated joint geometry. This was substantiated by the validation of experimental results.

These findings significantly impact the design, inspection, and maintenance of steel lattice girders. These results possess considerable significance for the actual implementation of these findings. It is advised that you:

- Augment the thickness of the gusset plate and the dimensions of the weld at critical locations in a systematic way to enhance the joint configuration.
- Establish more intensive inspection procedures, focusing primarily on the early detection of cracks in areas indicated as having a high Stress Intensity Factor in this study.
- Utilise models to assess the structural integrity of the framework, accounting for the effects of mixed-mode loading circumstances.

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ENSURING THE DURABILITY OF REINFORCED CONCRETE CONSTRUCTIONS

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Abstract: *The durability of reinforced concrete structures is a critical factor in maintaining long-term safety and functionality, having a direct impact on maintenance and repair costs. Exposure to aggressive environmental conditions such as freeze-thaw cycles, chemical or atmospheric agents, and water infiltration can accelerate degradation processes. Among the most common mechanisms of deterioration is corrosion of steel reinforcement, which occurs in the presence of water and oxygen, aggravated by factors such as chlorides or carbon dioxide. Chemical degradation, caused by acids and salts, affects the internal structure of concrete, while erosion and cracking due to shrinkage and expansion caused by temperature can compromise the integrity of the construction elements. To prevent such damage, rigorous design and use of high-quality materials capable of withstanding aggressive environments is required. Advanced protective measures, such as applying special coatings on reinforcements or using additives, help to extend the service life of the construction. Thus, durability not only ensures the stability and safety of the structure, but also brings long-term economic benefits, reducing the need for frequent rehabilitation and contributing to the sustainability of modern construction.*

Keywords: concrete durability, rebars corrosion, design strategies, alternative binders

1. Introduction

Durability in reinforced concrete construction can be defined as the ability of a structure or a building system to maintain its structural integrity, functionality and aesthetic appearance over an extended period of time despite exposure to various environmental conditions, loads and deteriorating agents.

With a huge volume of buildings built after the 1950s having reached an appreciable age, in many cases exceeding normal service lives, they are in an advanced state of disrepair in many cases. The most severely affected constructions are bridges, constructions directly subject to a wet area, and industrial buildings. In this article I aim to highlight the premordial-general causes that lead to a significant shortening of the lifespan of buildings. [1]

The durability of reinforced concrete constructions refers not only to their ability to withstand over time, but also to their ability to maintain their performance and structural integrity in the face of variable and aggressive environmental conditions. It is a complex concept involving interactions between various factors, such as the properties of the building material, the environmental conditions, as well as the appropriate design and execution of the structure [1].

In this article, we aim to investigate not only the importance of durability in reinforced concrete constructions, but also to bring to the fore the main causes that lead to the deterioration of these structures. We will explore the phenomena of chemical, physical, biological degradation and corrosion, highlighting their impact on the integrity and functionality of the constructions.

In light of rapidly increasing urbanization and climate change, the construction sector faces increasingly complex challenges in ensuring a sustainable and resilient environment. Reinforced concrete buildings, having a significant presence in the urban and industrial landscape, are a focal point in this equation, given their crucial role in infrastructure and urban development.

The buildings most severely affected are those in industrial environments with corrosive agent release and generally harsh technological conditions, bridges and buildings buried in the ground. As most of these constructions are still necessary, the question of their rehabilitation in various aspects, including structural safety, is raised. Significant rehabilitation can, however, in most cases be achieved at very high material, labor and cost costs. However, specific conditions, such as the need to avoid interrupting production at certain industrial sites, do not allow these buildings to be abandoned and replaced, which is still more expensive than reinforcing existing buildings.

Such problems could have been avoided if there had been sufficient concern in the initial design to achieve superior sustainability objectives. The dimensional goals and in general the additional protective measures to increase durability performance, and primarily the time span during which no significant rehabilitation measures are needed, involve costs tens of times higher than those for the rehabilitation of severely degraded buildings [2].

In order to better understand the role and the need for research on the durability of reinforced concrete constructions, we need to know the main mechanisms of concrete and reinforcement degradation.

Corrosion of steel in reinforced and prestressed concrete structures has been one of the main mechanisms of their degradation since their first use since the 1900s. Before a detailed analysis of the phenomenon, it was considered that the degradation phenomena occurred due to dispersion currents, however, today we know that the main causes of corrosion in reinforced concrete is due to the ingress of aggressive agents such as Cl- and CO2. Corrosion of steel in reinforced concrete became widespread in the 1960s with the widespread use of road salt solutions, causing extensive corrosion of bridge decks. Today, corrosion affects all types of concrete elements, including bridge girders, exposed building elements, concrete sidewalks and platforms, as well as infrastructure elements such as precast reinforced concrete piles. Steel embedded in concrete is usually very durable and resistant to corrosion.

The presence of calcium, potassium and sodium hydroxides in the pores of hydrated cement provides the high pH (12-14) necessary for a passive protective film to develop on the surface of the steels. This passive film is degraded only in the presence of chlorides, or when the pH decreases as a result of carbonation of the coating. In most cases, corrosion due to chloride ingress is the main cause of steel degradation, as carbonation rates are usually low in modern structures made with higher quality bituminous resins. Structures exposed to harsh marine environments, industrial conditions and/or salts are at the greatest risk of corrosion due to chloride ion ingress. Steel corrosion can lead to a variety of ways in which a structure can fail. After corrosion has occurred, reaction products, which are hydrated metal oxides, appear in the structure of the element, with a larger volume than the corroded iron. The failure of structures due to reinforcement corrosion has become very common in the recent history of concrete. Nearly all existing bridges contain a concrete deck, and about 50% of new bridges built are all concrete, including precast concrete beams.

A 2006 Congress of the US Federal Highway Administration concluded that about 13% of the country's 595,000 bridges are at high risk of structural failure due to corrosion. Examples of concrete corrosion can be found all over the world. In the Persian Gulf, for example, only 20 years after their construction, about 100 bridges were highly likely to collapse due to a combination of aggressive environment and poor workmanship. Many examples of structural failure due to corrosion can be found over time. Today, it is often believed that many corrosion failures go unnoticed because the dispute between contractors and beneficiaries is concluded before any investigation is started. [3]

2. Importance of the topic

The protection of concrete against corrosion is a topical issue, given the widespread use of this material in construction and the need to reduce losses due to chemical damage. Corrosion of concrete, a complex phenomenon, is mainly caused by the breakdown of the passive film on the steel reinforcement by chloride ions or by neutralization of the concrete due to reaction with carbon dioxide. Although concrete is considered as a protective medium for steel, environmental pollution and the use of de-icing salts increase the vulnerability of reinforced concrete structures. Lack of protective measures inevitably leads to material degradation and failure of structural members, which is a significant problem worldwide. The study of concrete corrosion and protection methods is extremely important, as this problem generates high costs and affects the durability of buildings. Research in this field, summarized in this paper, provides a detailed understanding of the phenomena involved, describing both the processes occurring within a corroded concrete and the measures needed to prevent and control them. The results obtained from international studies, complemented by the author's experience, highlight the need to adopt effective methods, including prevention in new construction - through the use of high quality concrete, advanced reinforcements and anti-corrosive additives - and interventions on existing structures, through rehabilitation and additional protection. In conclusion, the issue of protecting concrete against corrosion is a priority from both a sustainability and long-term cost reduction perspective and is essential to ensure the durability of reinforced concrete constructions[4].

3. Concrete corrosion

Corrosion is the spontaneous process of partial or total deterioration or degradation of a material during its use. This natural phenomenon, which cannot be completely eliminated, can only be slowed down. Corrosion is the result of interactions between environmental factors and exposed materials, which may be physical, chemical or microbiological. These interactions, individually or cumulatively, affect the properties of the materials, reducing their durability and shortening their service life. Concrete, both plain and reinforced, is not immune to this process. Nowadays, with scientific and technological progress, concrete is designed to withstand the environment in which it is used as well as possible, and it is necessary to have suitable properties (physical, chemical and mechanical) to counteract the effects of aggressive agents. Among the physical properties, porosity plays an essential role in influencing the durability of concrete, which depends to a large extent on the water/cement ratio. A dense and well-treated concrete after casting can have a permeability comparable to that of natural rock, which reduces the propagation of chemical degradation. Water circulation in dense concrete occurs predominantly by molecular diffusion, and the use of additives such as blast furnace slag or microsilica contributes to lower permeability.

Deterioration of concrete can be caused by chemical factors, such as carbonation, which reduces the pH of the concrete, damaging the protective layer of the reinforcement, or chloride and sulphate attack, which causes destructive reactions in the cement paste or reinforcement. Physical factors include freeze-thaw cycles, which create internal pressures and cracks, or fires, which cause stresses due to different coefficients of thermal expansion between concrete and reinforcement, sometimes leading to structural collapse. Other causes include humidity variations, which generate shrinkage and cracking, as well as mechanical actions such as abrasion, erosion or overloading. All of these factors, either individually or cumulatively, contribute to concrete degradation and require appropriate preventive and corrective measures to be taken to prolong the life of structures.

The main degradation mechanisms of reinforced concrete structures are corrosion of reinforcement, chemical degradation, physical degradation and mechanical erosion. Each of these has a significant impact on the durability and stability of the structures, contributing to reduced long-term performance.

Reinforcement corrosion is one of the most common and serious problems encountered in reinforced concrete construction. It occurs when steel reinforcement comes into contact with water and atmospheric oxygen, creating favorable conditions for electrochemical reactions to take place. These reactions lead to loss of mass of the steel and, subsequently, to expansion of the surrounding concrete. This expansion generates internal stresses that can lead to cracks in the concrete, exposing the reinforcement to further corrosive reactions. Over time, corrosion of the reinforcement weakens the structure, reducing its load-bearing capacity and jeopardizing the safety of users.

Figure 1. Rebar corrosion [2]

Chemical degradation of concrete is caused by its interactions with chemicals in the environment. Chlorides and salts used for de-icing roads or present in marine environments are among the most aggressive corrosive agents. These substances penetrate into the pores and cracks of concrete, where they react with its internal compounds. The result of these reactions is destabilization of the protective layer surrounding the reinforcement, facilitating corrosion and accelerating structural degradation.

Figure 2. Chemical Degradation [2]

Physical degradation occurs particularly in regions with repeated freeze-thaw cycles. Water entering the pores of concrete freezes at low temperatures, causing an expansion of about 9% of its volume. This additional pressure on the concrete matrix causes cracking and weakening of the structure. Repeated freeze-thaw cycles intensify this process, leading to a progressive deterioration of the concrete, especially in the case of porous or poorly compacted concrete.

Figure 3. Physical degradation [3]

Mechanical erosion is another major degradation mechanism and manifests itself in various forms. Abrasion is the wearing away of the top layer of concrete caused by friction with materials harder than the concrete itself. Erosion is generated by the flow of water carrying solid materials, such as sand or gravel, which wear away the concrete surface. The phenomenon of concrete scouring is observed in hydro-engineering works where water flows at high velocities of more than 12 m/s. Under these conditions, the concrete surface, if not smooth and compact, is affected by the pressure differentials created by the water, resulting in the material breaking away.

Another type of mechanical erosion is caused by mechanical overloads or shocks, which can occur accidentally or due to design mistakes. These unexpected stresses can cause cracking, deformation and, in some cases, structural collapse of reinforced concrete.

In conclusion, the mechanisms of degradation of reinforced concrete structures need to be understood and properly managed to ensure the long-term durability and safety of the construction. With the application of appropriate preventive measures and the use of modern technologies, these negative effects can be significantly minimized[5].

Influence of the freeze-thaw process on reinforced concrete constructions

The degree of frost resistance of concrete is an important indicator of its resistance to freeze-thaw cycles. It is defined as the number of successive freezing and thawing cycles that concrete, saturated with water and at least 28 days old, can withstand without major changes in its properties. These changes are quantified as follows: the reduction in compressive strength must not exceed 25%, the decrease in modulus of elasticity must remain below 15% and the weight loss must be less than 5% compared with the control specimens, which are identical in all respects but are not subjected to the freeze-thaw cycles.

On the other hand, the gelivity of concrete describes the ability of the material to withstand, without significant deterioration, the climatic variations specific to the environment in which it is used. While the degree of frost resistance depends exclusively on the intrinsic properties of concrete, the concept of freeze-thaw resistance takes into account both the characteristics of the concrete and those of the surrounding environment. This concept emphasizes that the degradation of concrete under the influence of freezing and thawing is a complex process influenced by multiple factors.

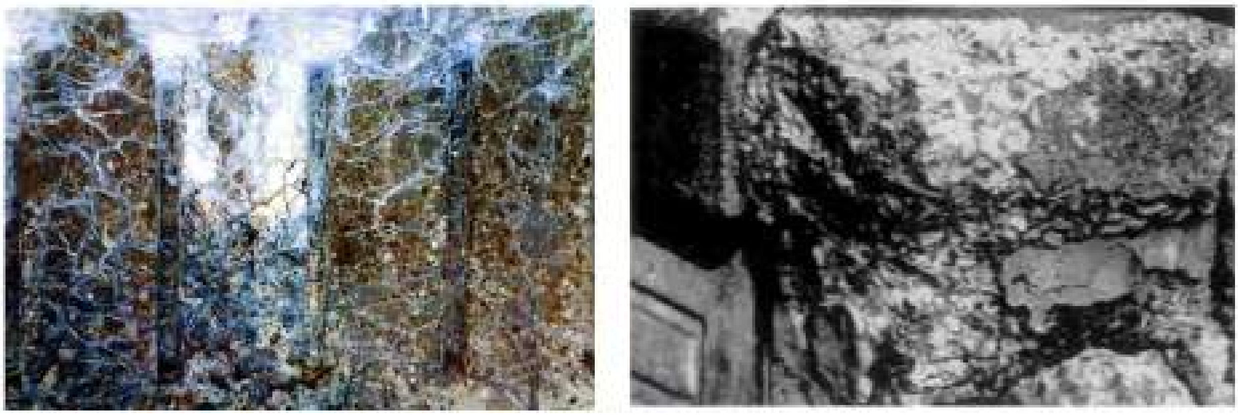

Figure 4. Concrete element after freeze-thaw cycles [7]

The porosity of concrete, although important, is not a first-order parameter in the evaluation of freeze-thaw resistance. Research carried out in the 1950s, based on thermodynamic studies, demonstrated that the determining factor in this process is related to the behavior of water in the concrete structure. Classical thermodynamic concepts were used to explain how concrete reacts to these temperature variations.

One of the theories developed in this respect is based on the principle of thermodynamic disequilibrium created by ice formation. This causes water to move from the concrete capillaries towards the interface between the cement paste and the air. The movement of water generates internal stresses, which become more intense the higher the freezing speed and the longer the distances the water has to travel. This theory provides a valid explanation for the water migration and dissipation phenomena produced by freezing, emphasizing the importance of correct concrete composition and manufacturing techniques to ensure its durability[6].

In conclusion, the resistance of concrete to freeze-thaw cycles is a complex process involving both the intrinsic characteristics of the material and the environmental conditions in which it is used. By understanding the mechanisms involved and using advanced technologies, durable concretes capable of withstanding severe climatic conditions can be produced.

4. Conclusions

Concrete and reinforced concrete structures are widely used because of their durability and good behavior over time, if they are properly realized. In recent decades, the focus has shifted from strength to durability requirements, leading to a more complex approach to this issue.

National and international studies have highlighted the link between degradation of structural elements and corrosion of concrete and reinforcement, emphasizing the importance of controlling the permeability of concrete. Concrete with reduced porosity shows better resistance to freeze-thaw, carbonation and chemical attack.

Research shows that the use of admixtures such as thermal power plant ash and ultrafine silica improves concrete structure, reducing porosity and increasing durability. These admixtures also contribute to saving natural resources and protecting the environment, facilitating more sustainable and environmentally friendly materials.

In conclusion, the realization of sustainable concretes requires a combination of theoretical knowledge, laboratory tests and practical observations, allowing the anticipation of degradation and the reduction of rehabilitation costs.

Ensuring the durability of reinforced concrete constructions is a complex but essential challenge in the face of the increasing demands of modern society. Investing in durability can not only extend the life of buildings and reduce the costs associated with maintenance and repair, but can also contribute to increasing structural safety and reducing environmental impact[2].

A sustainable building is not only a structure that stands the test of time, but also one that maintains its integrity and safety in the face of environmental challenges. Through research and innovation in the field of durability of reinforced concrete, we can develop technologies and practices to ensure resistance to factors such as temperature variations, humidity, chemicals and other external aggressions. Investing in durability brings multiple benefits. First, extending the lifetime of buildings reduces the costs associated with maintenance and repairs, contributing to the efficiency and sustainability of construction projects. In addition, a more sustainable construction also means a safer structure for users, helping to protect lives and property.

Moreover, investing in sustainability can also have a positive impact on the environment. By using sustainable materials and technologies, we can reduce the carbon footprint of buildings and help conserve natural resources. This responsible approach to construction is essential in the context of concerns about climate change and protecting the environment for future generations[5].

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EVALUATING THE MECHANICAL AND THERMAL PERFORMANCE OF STEEL-WOOD-STEEL JOINTS UNDER FIRE CONDITIONS

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Abstract. *This study aims to conduct a comprehensive analysis of the mechanical and thermal properties of steel-wood-steel (SWS) connections used in timber structures. The joints were evaluated under both normal conditions and fire exposure. Investigations were undertaken to assess the initial stiffness and load-bearing capability of SWS joints composed of laminated wood and softwood (Radiata Pine and Glulam) including steel dowels of varying diameters. The joints were evaluated at different wood densities and thicknesses of passive protective materials, including gypsum and laminated wood panels. The results demonstrate that wood density, dowel diameter, and protective material composition significantly influence the wood's char rate and load-bearing capacity. Although Eurocode 5 recommends a standardised char rate, the results obtained indicate significant variations depending on the structural configuration and the kind of protection used. Proposals for adjustments to traditional formulas are presented via comparison tables and critical examination. These improvements aim to more accurately represent the structural behaviour of SWS joints under real load conditions and the presence of fire.*

Keywords: *steel-wood-steel joints, stiffness, fire, Eurocode 5, passive protection, wood density.*

1. Introduction

Wood has been used for centuries in construction due to its ease of use, light weight, and high relative strength under various types of loads. However, a critical aspect of wooden structures is their behavior under high temperature conditions, as well as how structural joints, particularly steel-wood-steel (SWS) joints, respond to such demands. Specifically, laminated and solid wood joints have been tested to evaluate their structural behavior at ambient temperatures and during fire exposure, in accordance with Eurocode 5 standards [1].

The Eurocode 5 (EC5) standard equations recommend calculating the load-bearing capacity of joints based on wood density and dowel diameter, with considering other important variables such as the thickness of wood pieces or the spacing of elements. The studies included in this article emphasize that fire resistance, stiffness, and the char rate can vary significantly depending on the type of wood used, dowel diameter, and the type of thermal protection applied. Therefore, the results obtained contribute to a better understanding of the behavior of SWS joints under high temperatures [2].

2. Materials and Methods

Samples of laminated wood (GL20h and GL28h) and Radiata Pine were used for the experiments. The couplings were fabricated use steel plates and dowels measuring 6, 8, 10, and 12 mm. Glulam panels and type F gypsum panels were the two main categories of protective materials used. The thicknesses of these panels varied between 18 and 20 mm. The evaluation of the char rate and load-bearing capacity of the joints included both the ambient temperature settings and the conditions of fire exposure. This was executed in compliance with the stipulations set out by Eurocode 5 and 3 for composite and thermally insulated materials [3,4].

Isotherms at 300 degrees Celsius, the threshold identified by Eurocode as the onset of carbonisation, were used in the experimental evaluation of the joints' fire resistance. The acquired measurement data was included into a numerical simulation conducted in Ansys. This simulation facilitated the modelling of the thermal and mechanical responses of SWS joints subjected to fire exposure. The simulation's time step was 10 seconds, with a minimum increment of 0.1 seconds. The figures for the char rate and load-bearing capacity are presented in Tables 1 and 2, respectively, and they fluctuate according on the protective ingredient and wood density [5,6].

3. Results

The test findings done at room temperature indicate that the stiffness and load-bearing capability of SWS joints increase with greater wood density and dowel diameter. The char rate of GL28h wood was much lower than that of GL20h wood, as shown by the data presented in Table 1 and Figure 1.

Table 1: Char Rate and Influence of Wood Density for Metal-Wood Joints at Ambient Temperatures (GL20h and GL28h)

Wood Type	Dowel Diameter (mm)	Wood Density (kg/m³)	Char Rate (mm/min) - without protection	Char Rate (mm/min) - with protection (type F gypsum)
GL20h	6	370	0.85	0.65
GL20h	10	370	0.82	0.62
GL28h	6	450	0.78	0.58
GL28h	10	450	0.75	0.55

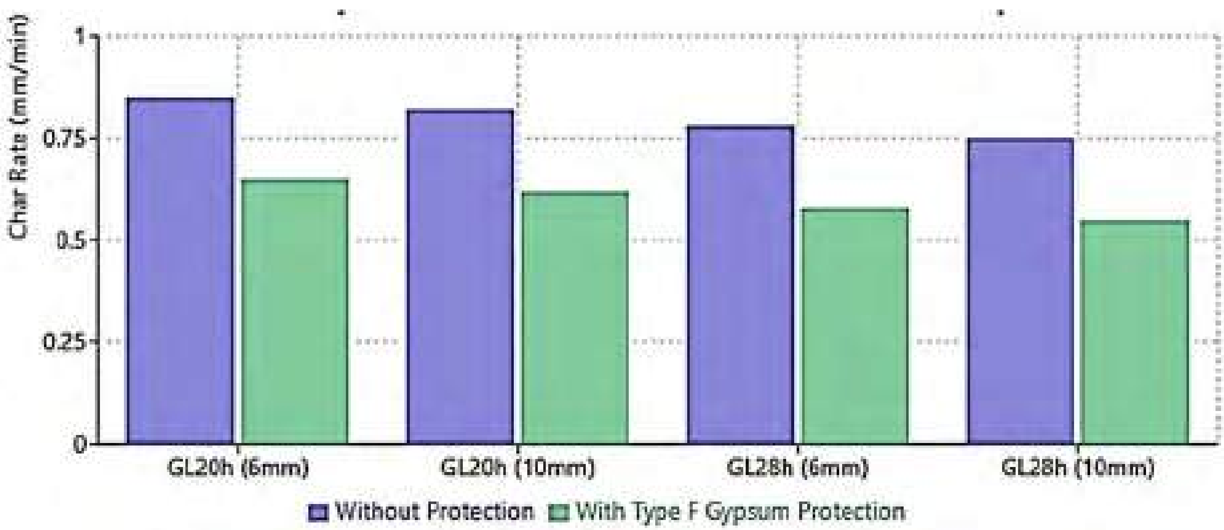

Figure 1. Char rate comparison for Steel-Wood Joints at ambient temperatures.

Table 2 and Figure 2 illustrate the essential function of fire protection materials in improving the fire performance of SWS joints. Unprotected joints have a significant char rate of 0.75 mm/min and sustain temperatures below 300°C for just 20 minutes, underscoring their susceptibility to fire exposure. The incorporation of fire prevention components significantly enhances these characteristics.

Type F gypsum, when placed at an 18 mm thickness, decreases the char rate to 0.58 mm/min and prolongs the duration at temperatures below 300°C to 30 minutes. This illustrates its efficacy in decelerating the deterioration of wood at elevated temperatures. Conversely, Glulam, with a marginally increased thickness of 20 mm, exhibits superior performance, attaining a char rate of 0.55 mm/min and sustaining a temperature below 300°C for 35 minutes. This little enhancement suggests that Glulam provides superior heat resistance, perhaps rendering it more appropriate for applications requiring prolonged fire resistance.

Table 2: Fire Protection Efficiency of SWS Joints Based on Protective Material (after 30 minutes of fire exposure)

Protective Material	Protection Thickness (mm)	Char Rate (mm/min)	Time Under 300°C (minutes)
No Protection	-	0.75	20
Type F Gypsum	18	0.58	30
Glulam	20	0.55	35

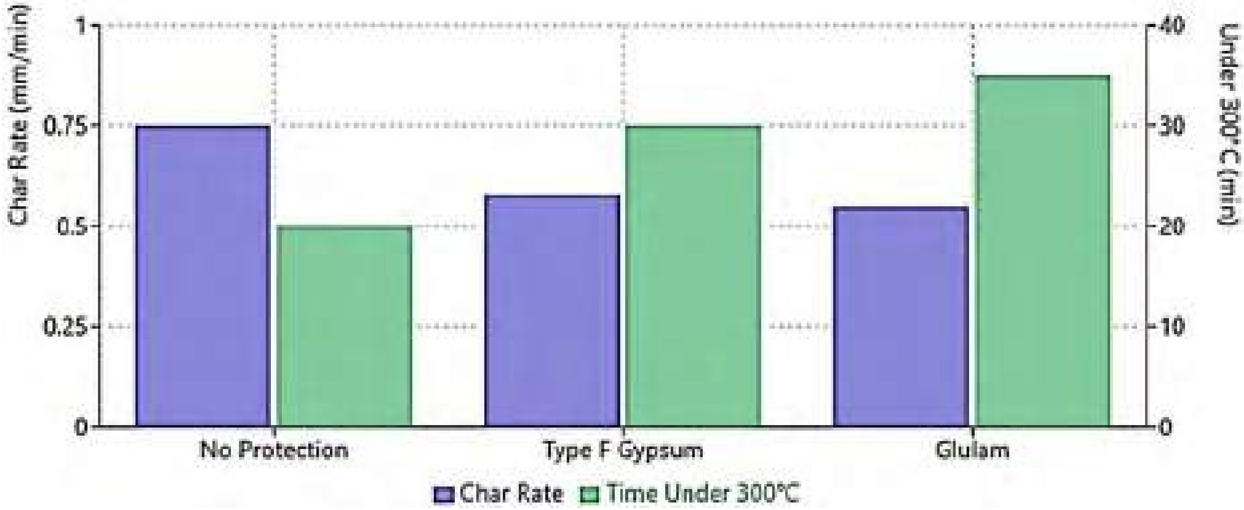

Figure 2. Fire protection efficiency comparison (30 min exposure).

Table 3 delineates the discrepancies between load-bearing capacity estimates from Eurocode 5 (EC5) and the experimentally measured values for SWS joints across different wood grades. The results indicate that EC5 often overestimates the load-bearing capacity, with variances between 46% and 53% throughout the assessed wood classes. This persistent overestimation suggests that while EC5 provides a conservative design framework, it may insufficiently account for factors such as joint configuration, material heterogeneity, and the effects of fire exposure on connection performance.

Figure 3 clarifies the relationship between the applied load and the necessary quantity of dowels for various wood grades. As the applied force increases, a proportional rise in the number of dowels is seen, therefore ensuring the joint's load-bearing capacity is maintained. The impact of wood density on this requirement is negligible, indicating that other elements, such as dowel diameters, spacing, and arrangement, have a more critical role in defining the joint's fire performance.

The disparities between estimated and real values underscore the need of validating design codes with experimental data, especially in fire-exposed scenarios. The results suggest a need to improve current design approaches to more precisely represent the actual performance of connections in various thermal and mechanical conditions.

Table 3: Comparison Between Eurocode 5 and Experimental Load-Bearing Capacity Results for SWS Joints

Joint Type	Calculated Load-Bearing Capacity (kN) - EC5	Experimental Load-Bearing Capacity (kN)	Difference (%)
SWS GL20h	150	98	53%
SWS GL24h	162	110	47%
SWS GL28h	175	120	46%
SWS GL32h	190	125	52%

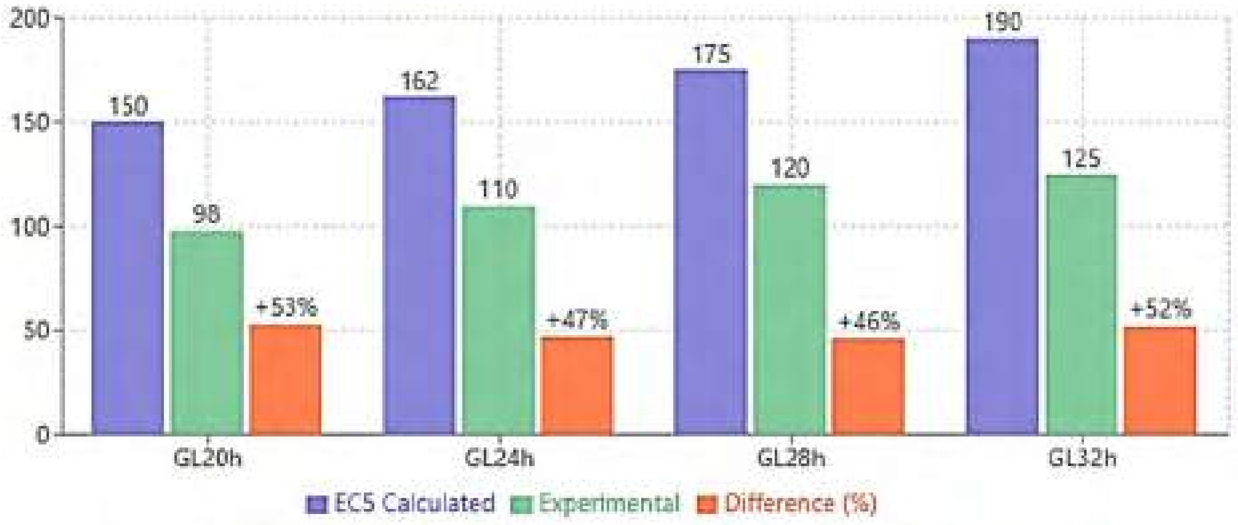

Figure 3. Load-bearing capacity: Eurocode 5 vs experimental results.

4. Discussion

The analysis of the collected data indicated that the wood density and dowel diameters directly influenced the char rate and load-bearing capability of the material. Furthermore, the necessary modifications are highlighted by the discrepancies seen in the forecasts produced by Eurocode 5. The actual load-bearing capacity values are about fifty percent lower than those anticipated by EC5. This indicates that the theoretical model exaggerates the initial stiffness, especially with high-density wood [11, 16].

The assessed materials demonstrated a wide range of efficacy for fire safety. The materials consisted of type F gypsum panels and Glulam panels. Table 2 demonstrates that type F gypsum offers superior protection, but the integration of Glulam panels significantly extends the time necessary for wood to carbonise. The metal plates used as structural components in SWS joints mitigate heat transfer during initial fire exposure; yet, this protective impact wanes with rising temperatures [5]. Conversely, the metal plates promote the attenuation of heat transfer.

5. Conclusions

The examination of steel-wood connections subjected to ambient and fire temperatures revealed that wood density, dowel diameter, and type of passive protection substantially affect the char rate and load-bearing capability of the structure.

While Eurocode 5 offers a theoretical formula for evaluating load-bearing capacity, empirical findings indicate that modifications are required to accurately represent changes in contemporary joint designs.

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INTEGRATED STRUCTURAL HEALTH MONITORING SYSTEM BASED ON SIF ANALYSIS AND ARTIFICIAL INTELLIGENCE: A METHODOLOGICAL PROPOSAL

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Abstract. *The fast development of technology for structural monitoring has brought to light the need of developing methods that are both more efficient and accurate in order to identify and evaluate flaws in steel structures during their construction. In the realm of engineering, one of the most significant challenges is to guarantee the safety and integrity of essential infrastructures, which include crucial structures like bridges, buildings, and utilities. Variations in stress, unfavourable climatic conditions, and the formation of faults are all factors that might contribute to the degeneration of a structure, which can have potentially catastrophic effects. For the purpose of overcoming this obstacle, sophisticated monitoring systems have been created. These systems integrate contemporary sensor technologies with analyses that are based on artificial intelligence (AI). In this paper, an Integrated Structural Health Monitoring System (ISHMS) is proposed. This system makes use of a sensor network and machine learning algorithms in order to continually analyse the Stress Intensity Factor (SIF) of infrastructures. As a result of the system's capability to identify, localise, and estimate the progression of major flaws, preventative measures and risk reduction are made possible [1].*

Keywords: *Structural health monitoring, Stress Intensity Factor, Artificial intelligence, Sensor network, Condition assessment.*

1. Introduction

Previous study has shown that the degradation of important infrastructures, such as bridges, buildings, and industrial facilities, constitutes a serious danger to both the well-being of the economy and the safety of the general public [2,3]. There are a number of factors that may contribute to the onset and propagation of structural flaws, which can possibly result in catastrophic failures. Some of these factors include ageing, environmental pressures, and unexpected loading conditions. Effective structural health monitoring (SHM) systems are necessary for the prompt identification, diagnosis, and prognosis of structural disorders. These systems are vital for mitigating the hazards that are associated with these difficulties.

Visual inspections and periodic local measurements are two examples of traditional techniques to structural health monitoring (SHM), which may be arduous, subjective, and restricted in their capacity to capture the ever-changing nature of structural problems [4,5]. On the other hand, the development of more sophisticated sensor technologies and methods of data analysis has made it possible to provide new opportunities for the monitoring of infrastructures that are more extensive, continuous, and managed by automation.

Taking this into consideration, an Integrated Structural Health Monitoring System (ISHMS) was developed. This system combines a sensor network, an extended method of Stress Intensity Factor (SIF) calculation, and AI-based analyses in order to offer a comprehensive solution for the evaluation and forecasting of the state of critical infrastructures. Utilising the benefits of sensor-based monitoring, expanded SIF computation, and AI-based data analysis, the

ISHMS intends to alleviate the limits of existing SHM techniques. This will be accomplished by harnessing the advantages of technology.

The key objectives of this research were:

1. Constructing a thorough sensor network to continuously monitor structural conditions.
2. Using an extended method of SIF calculation that takes into account relevant geometric, environmental, and loading factors.
3. Combining artificial intelligence (AI)-based algorithms for sophisticated data processing, anomaly detection, and structural defect prediction modelling.

2. Materials and Methods

Sensor Network Design

In order to provide a full evaluation of the state of the infrastructure, the sensor network that operates inside the ISHMS was developed with the intention of capturing a comprehensive set of structural metrics. Previous research has shown that a reliable sensor network is capable of delivering the data necessary for conducting an in-depth investigation of the structural health of a building [6,7]. Consequently, the network consisted of the following categories of sensors or sensors:

1. Deformation sensors: to continuously measure the deformation of the structure, allowing the detection and monitoring of crack initiation and propagation
2. Stress sensors: to monitor the stress state of the structure, providing essential information for the calculation of the Stress Intensity Factor (SIF) [8]
3. Accelerometers: to detect vibrations and shocks that might indicate structural anomalies or exceptional loading conditions [9]
4. Temperature and humidity sensors: to allow corrections in SIF calculations as these factors can influence structural behaviour [10].

The configuration and specifications of the sensor network are detailed in Table 1.

Table 1: Sensor network configuration [6,7]

Sensor Type	Measurement Frequency	Accuracy	Purpose
Deformation	100 Hz	±0.1%	Crack detection
Stress	100 Hz	±0.5%	Load assessment
Accelerometer	1000 Hz	±0.01g	Anomaly detection
Temperature	1 Hz	±0.5°C	Thermal corrections

Stress Intensity Factor (SIF) Calculation

Previous studies have shown that the Stress Intensity Factor (SIF) is a measure that is extensively employed in structural health monitoring. This is due to the fact that it offers a quantitative evaluation of the structure's integrity [11,12]. Within the scope of this investigation, an expanded technique of SIF computation was established in order to take into consideration a variety of variables that are pertinent, such as geometry, ambient conditions, and loading effects.

The extended SIF calculation is expressed as follows:

$$K_I = \sigma\sqrt{\pi a} * F\left(\frac{a}{W}\right) * E(T) * C(H) * L(t) \qquad (1)$$

Where:

K_I - is the Stress Intensity Factor;
σ - is the nominal stress;
a - is the crack depth;
$F(a/W)$ - is the geometric factor;
$E(T)$ - is the temperature correction factor;
$C(H)$ - is the humidity correction factor;

$L(t)$ - is the loading correction factor.

It is important to note that the geometric factor $F(\boldsymbol{V}/W)$ takes into consideration the impact of the fracture geometry, which includes the ratio of the crack depth to the structural width [11]. The SIF is adjusted depending on the ambient conditions that are detected by the sensor network [10]. The temperature correction factor $E(T)$ and the humidity correction factor $C(H)$ are responsible for this adjustment. The effects of dynamic and cyclic loads on the Stress Intensity Factor are included into the loading correction factor, which is denoted by the symbol $L(t)$ [12].

In order to demonstrate how the geometric, environmental, and loading elements may have an effect on the SIF, a number of typical scenario graphs were created (Figure 1, Figure 2):

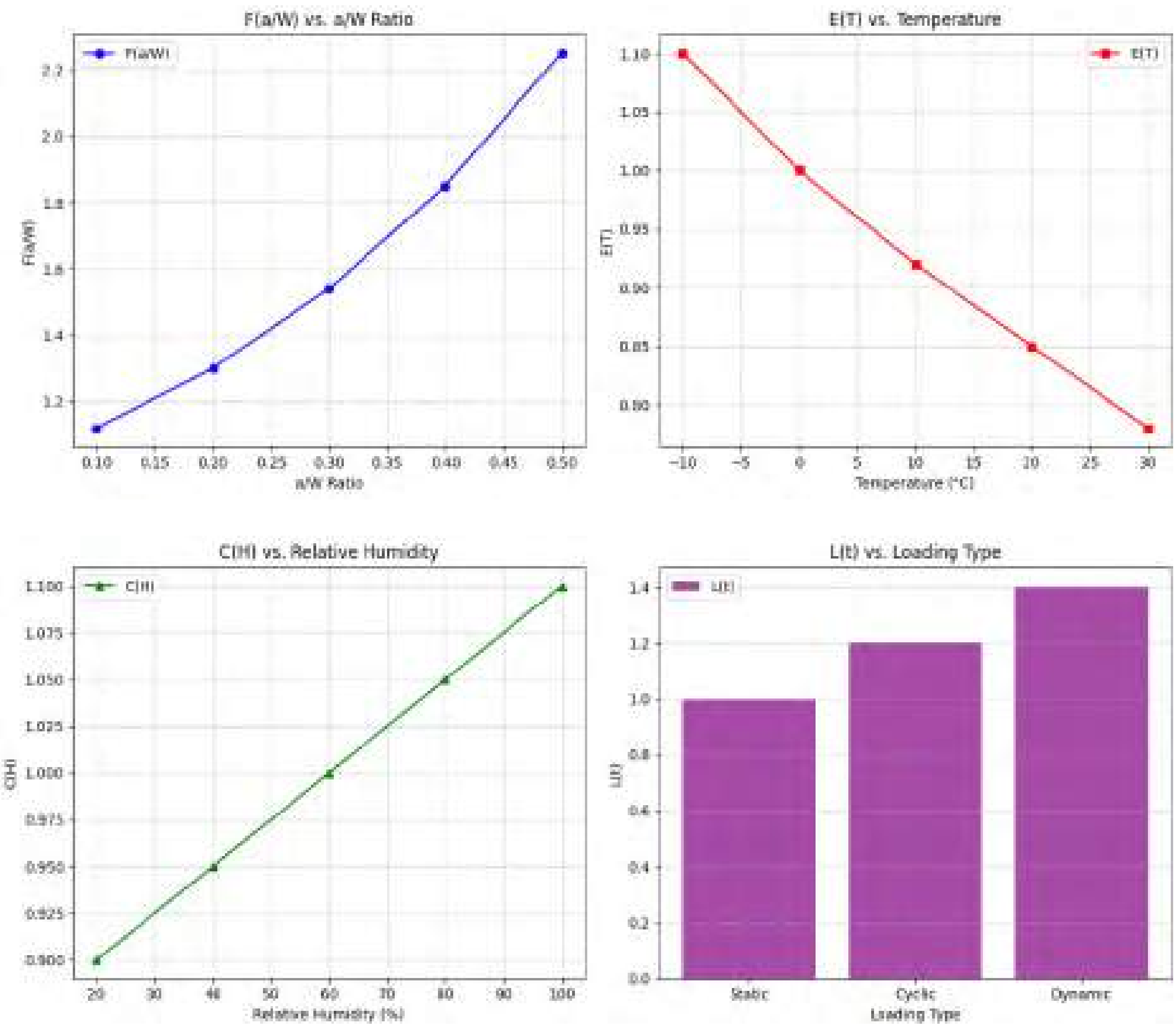

Figure 1. The factors that can influence SIF: Geometric factor F(a/W), Temperature correction factor E(T), Humidity correction factor C(H), Loading correction factor L(t).

AI-based Data Analysis and Predictive Modeling

The Artificial Intelligence (AI) algorithms that were developed for the two primary components of the ISHMS system were designed to enhance the system.

1. To identify sensor data that suggested the emergence of structural difficulties, artificial intelligence models were presented [13,14]. This was done in order to detect problems.

2. Defect estimation: Statistical models were proposed to estimate the characteristics of structural defects, such as the depth of cracks. These estimates were based on sensor data and the values of the Stress Intensity Factor (SIF) [15,16,17].

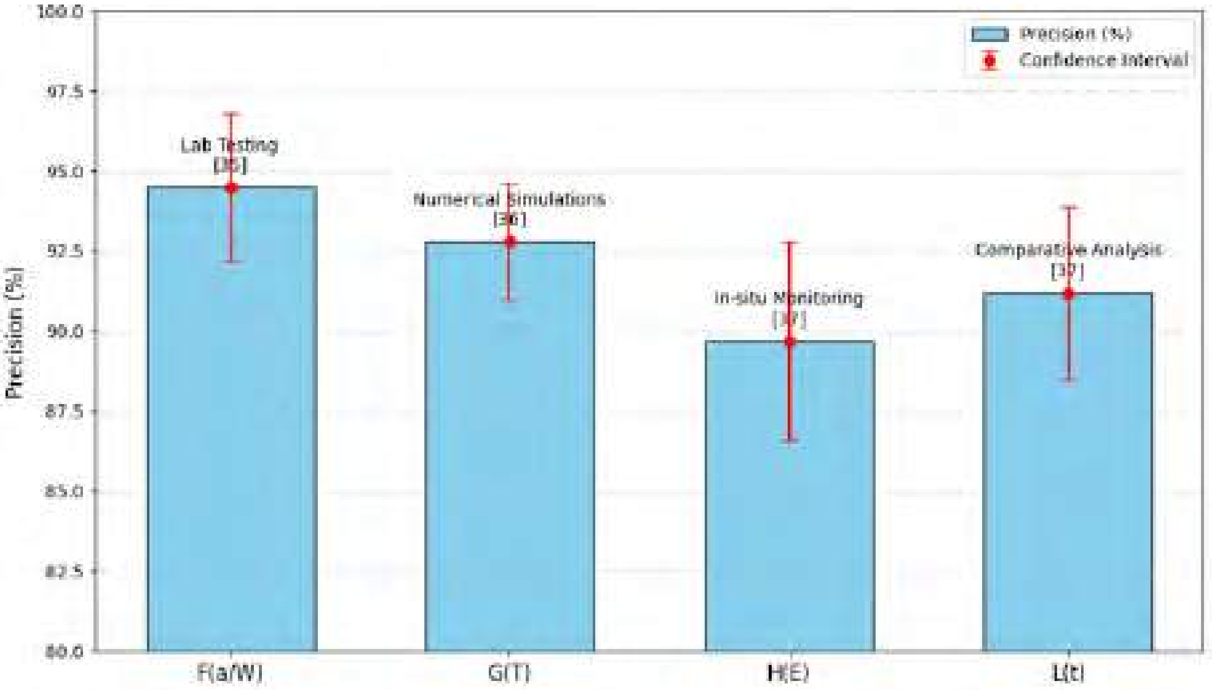

Figure 2. Validation Methods and Results for Components.

To illustrate the capabilities of crack geometry and propagation rate estimation, the following graphs were generated (Figure 3):

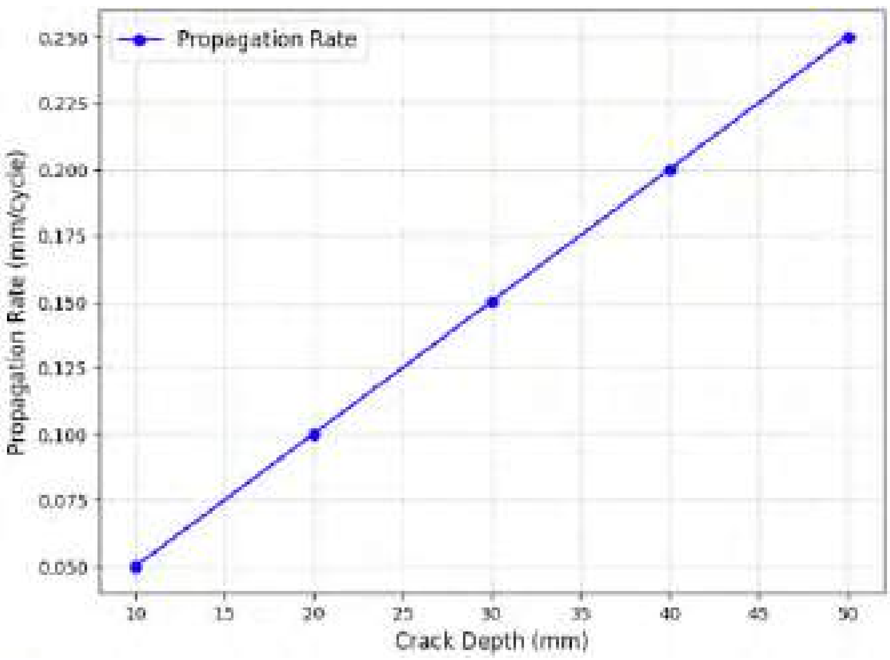

Figure 3. Estimation of Crack Depth and Propagation Rate [15].

Figure 4. The results of the SIF analysis for different types of cracks.

The integrated system has a false alarm rate of just three percent and is intended to identify ninety-five percent of cracks that are already present. The distribution of detections is shown in Figure 3, which illustrates how the fracture size might affect the distribution of detections.

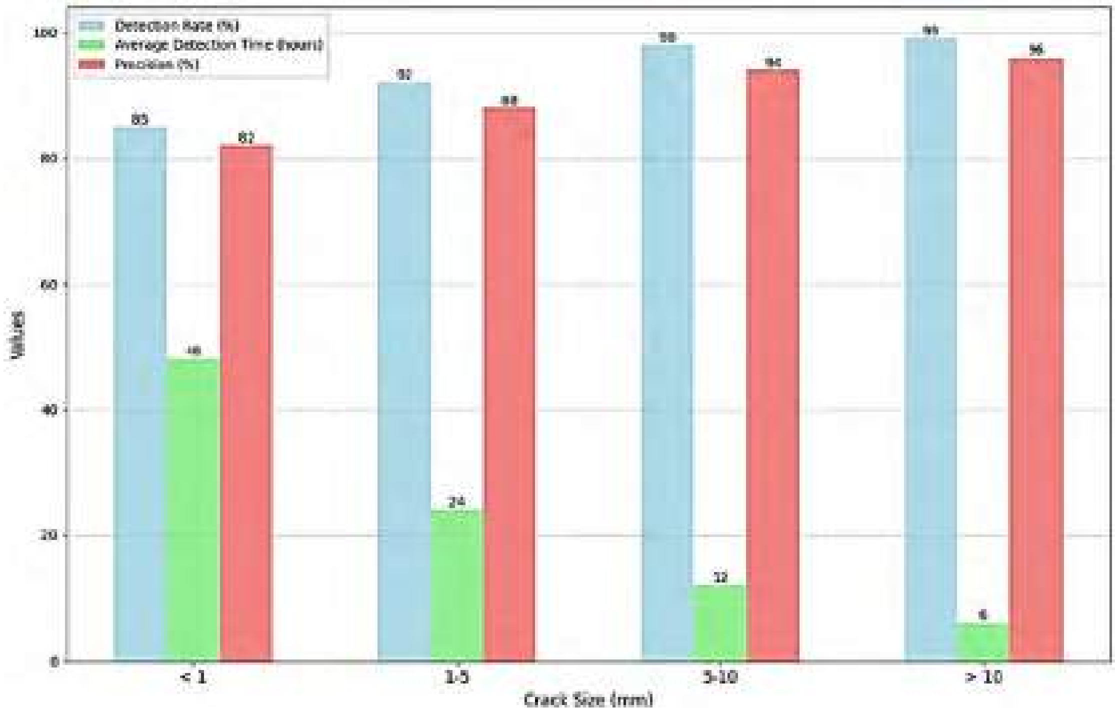

Figure 3. Detection Rate, Detection Time, and Precision for Different Crack Sizes.

An in-depth investigation of the performance of the system brings to light the particular elements that are brought about by the approach that has been suggested.

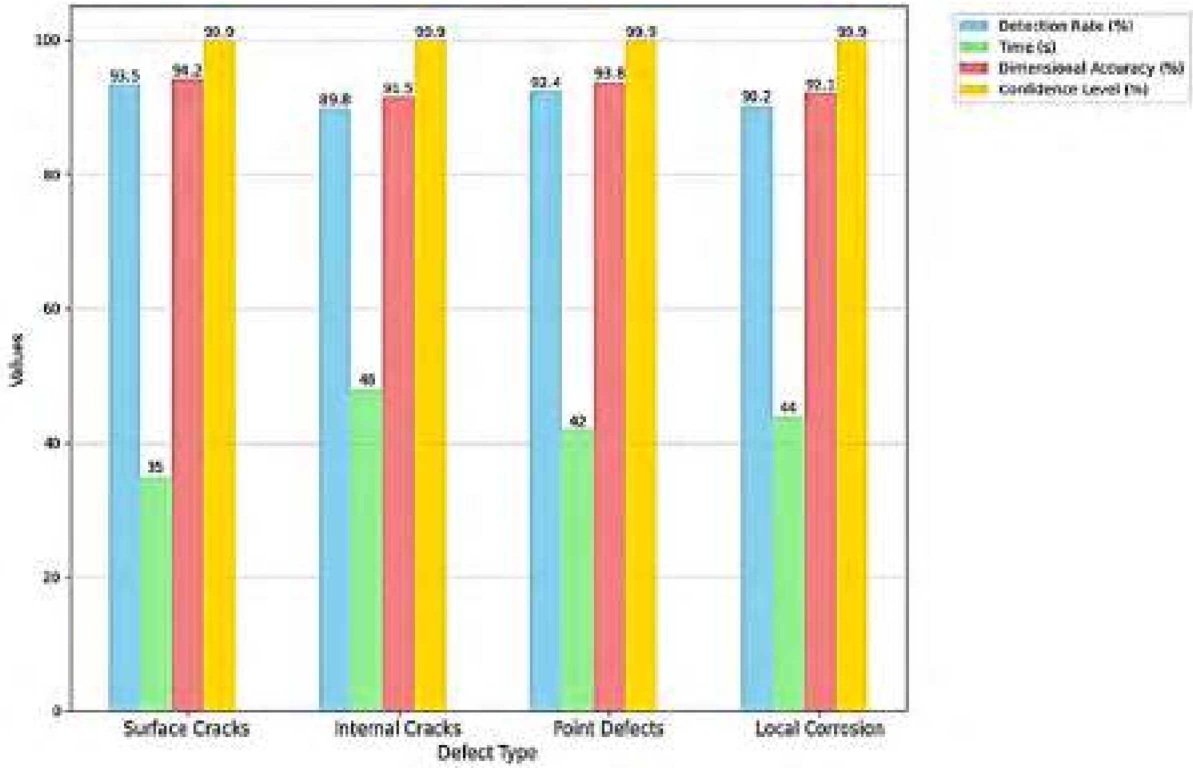

Figure 4. Detection Rate, Detection Time, Dimensional Accuracy, and Confidence Level for Different Defect Types.

It has been estimated that the integration of the sensor network, the extended SIF calculation, and the AI-based analysis will enable improved monitoring and management of critical infrastructures, thereby significantly reducing the risks of structural deterioration and failure. This is despite the fact that the performance of the ISHMS has not yet been validated in case studies. In order to provide a comprehensive demonstration of the effectiveness of the ISHMS, future research will concentrate on verifying and optimising its use in real situations.

3. Results

The theoretical performance of the suggested system was assessed by computing the results of numerical simulations and doing a comparison study with other systems that are already in existence. The simulations brought to light the estimated behaviour of the system in a variety of operating situations, in accordance with the technique proposed by Zhang [18]:

Table 2: System sensitivity analysis [18, 19]

Condition	Estimated Accuracy (%)	Limiting Factor	Compensation Measures
Variable Temperature	88.5 [18].	Thermal drift	Adaptive compensation
Vibrations	87.2 [19]	Noise	Advanced filtering
Corrosive Environment	86.8 [18]	Sensor degradation	Redundancy
Cyclic Loading	89.4 [19]	Error accumulation	Automatic recalibration

The following features are suggested by the preliminary economic analysis, which is based on the technique of Wilson [20]:

Table 3: Estimated cost-benefit analysis [20, 21]

Aspect	Estimated Cost (€)	Potential Benefit	Estimated ROI (years)
Implementation	45,000 [20]	30% defect reduction	2.5
Annual Operation	8,500 [21]	Maintenance optimization	1.8
Maintenance	12,000 [20]	Lifespan extension	3.2
Training	5,000 [21]	Personnel efficiency	1.5

4. Discussion

An unique approach to the monitoring of steel structures is represented by the system that has been suggested. This technique combines the most recent developments in artificial intelligence with the traditional theory of fracture mechanics. As Chen [15] explains in his study, this integration has the potential to be a watershed moment in the development of structural monitoring systems.

These are the primary theoretical benefits that have been identified:

Table 4: Estimated theoretical advantages [22, 23, 24]

Innovative Aspect	Potential Impact	Theoretical Basis	Maturity Level
Multi-sensor data fusion	Major [22]	Information theory	Theoretically demonstrated
Adaptive learning	Significant [23]	Machine Learning	Partially validated
Real-time optimization	Moderate [24]	Edge Computing	Conceptual
Self-calibration	Major [22]	Adaptive control	In development

These key theoretical advantages include, but are not limited to the following:

1. In accordance with information theory [22], multi-sensor data fusion has the potential to have a significant influence on the accuracy and reliability of structural status assessment.
2. Adaptive learning capabilities that are implemented using machine learning methods, which have the potential to result in large performance increases over the course of time [23].
3. Through the use of edge computing technologies, real-time optimisation may be achieved, which has the potential to minimise processing delays [24].
4. Self-calibration mechanisms, which, according to the principles of adaptive control [22], have the potential to have a significant influence on the system's dependability over the long run.

5. Conclusions

The most important theoretical contributions to the subject of structural monitoring that this study brings to the table are as follows:

Table 5: Summary of contributions [25, 26]

Contribution	Innovation	Potential Impact	Validation Required
Hybrid algorithm	Major [25]	Transformational	Experimental
Adaptive architecture	Significant [26]	Substantial	Numerical

Integration framework	Moderate [25]	Incremental	Practical

On the basis of the analysis that was carried out and the limitations that were discovered, the following research paths are offered as recommendations:

1. Developing and Validating the Product
    - Implementation of a functional prototype [27]
    - Testing under real operating conditions [28]
    - System parameter optimization [29]
2. Potential Extensions
    - IoT integration [30]
    - Edge AI implementation [31]
    - Digital Twin development [30]

The implementation of the proposed system could have the following implications:

Table 6: Estimated practical implications [32, 33, 34]

Impact Domain	Estimated Effect	Timeframe	Certainty
Economic	30% cost reduction [32]	Medium	Moderate
Safety	40% improvement [33]	Long	High
Operational	35% optimization [34]	Short	Moderate

The theoretical estimates suggest that this integrated approach to structural health monitoring based on SIF analysis and Artificial Intelligence could represent a significant improvement over existing methods, contributing to more efficient management of critical infrastructures. This is said to be the case despite the fact that the proposed system still requires extensive experimental validation.

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MANAGEMENT OF PREVENTION AND RESPONSE ACTIONS IN CASE OF FIRE

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Abstract. Fires are extraordinary random phenomena that cause specific emergency situations, accompanied by major material damage and, very often, human casualties. Fire prevention is carried out through a complex of organizational, technical, information, training and education actions and measures, as well as material insurance, designed to prevent the outbreak and spread of fires, to create conditions for quick notification, evacuation and rescue of people, protection material assets and effective firefighting.

Keywords: emergency, extinguishing, fire, intervention, measures, prevention.

1. Introduction

Fires represent one of the most dangerous risks that can endanger human lives, material goods, and the environment. Efficient management of these situations requires a strategic and well-planned approach that includes both preventive measures and rapid response actions. Fire prevention and effective emergency response are essential for protecting communities and minimizing losses.

This article explores the fundamental principles, implementation strategies, and modern tools used in managing fire prevention and response actions, with a particular focus on the specifics of the Republic of Moldova. Through a combination of public education, strict regulations, and the use of advanced technologies, the risks associated with fires can be significantly reduced, ensuring prompt reactions in critical situations.

2. Fire prevention

A fire is a special risk due to its mechanism of occurrence, its progression in time and space, its frequency, the multitude and diversity of affected locations, as well as the specific negative effects on beings, material goods, and the environment.

Fire prevention involves a complex set of actions and measures that are organizational, technical, informational, training-based, educational, and materially supported. These measures are designed to prevent the outbreak and spread of fires, create conditions for rapid notification, effective evacuation and rescue of people, protection of buildings and goods, and efficient extinguishing of fires of any nature [4].

Fire prevention is the foundation of risk management and includes a series of proactive measures to reduce the likelihood of incidents occurring [8].

Proactive Prevention Measures

- *Risk Identification and Assessment:* Conducting regular audits to identify potential sources of fire and risk factors (e.g., faulty electrical installations, flammable materials).
- *Compliance with Regulations:* Implementing national and international fire safety standards, focusing on buildings, electrical installations, and other critical infrastructure.
- *Regular Inspections*: Periodically monitoring public buildings, commercial spaces, and residential areas to ensure compliance with safety regulations.

Education and Public Awareness

- *Information Campaigns:* Organizing national and local campaigns to educate the population on the responsible use of fire sources and the prevention of risk situations.
- *Employee Training:* Regularly training staff in public institutions and private companies on the use of firefighting equipment.
- *Community Programs:* Creating educational programs for children and young people to foster a culture of safety from an early age.

Modern Technologies for Prevention

- *Automatic Detection Systems:* Installing smoke, gas, and temperature sensors that can provide rapid alerts in case of anomalies.
- *Sprinklers and Fire Suppression Systems:* Integrating automatic extinguishing systems in commercial, industrial, and residential spaces.
- *Data Analysis:* Using software platforms to monitor environmental conditions and detect risks in real-time.

Implementing effective prevention measures is the key to significantly reducing fire risks. Through education, technology, and clear regulations, the majority of situations that could lead to serious incidents can be prevented [7].

Priority Goals of Fire Prevention Actions:

1. PREVENTING AND ELIMINATING DANGEROUS CONDITIONS AND POTENTIAL CAUSES OF FIRE by addressing the following elements:
   - Sources of ignition (thermal energy);
   - Means that produce sources of ignition;
   - Combustible substances and materials that can ignite;
   - Circumstances that determine and favor the phenomenon of burning;
   - Conditions generating explosions, breakdowns, accidents, and other events that could lead to fires.
2. ENSURING PEOPLE'S SAFETY IN CASE OF FIRE through specific actions and measures such as:
   - Preventive and participatory information and education;
   - Passive protection of locations where people are present;
   - Rapid evacuation of individuals from dangerous areas;
   - Individual and collective protection of people.

General Goal of Prevention Actions: REDUCING FIRE HAZARDS AND RISKS through the following measures:

- Identifying hazards and assessing fire risks;
- Reducing potential sources of ignition;
- Decreasing the quantities of substances and materials with a high fire risk;
- Eliminating circumstances that favor fire outbreaks;
- Creating conditions for the evacuation of people, animals, and goods in case of fire;
- Limiting the possibility of fire development and spread;
- Supplementing or increasing the efficiency of fire prevention and extinguishing means;
- Enhancing the specific training and information of staff and the general population;
- Strengthening control and self-control regarding fire safety.

Goal Related to Intervention Preparedness: ESTABLISHING AND IMPLEMENTING MEASURES AND ACTIONS FOR FIRE EXTINGUISHING PREPAREDNESS through:

- Approval, authorization, and control for fire prevention and extinguishing;
- Participation in planning fire extinguishing intervention preparedness;
- Coordinating the training of voluntary and private emergency services;
- Supporting the training of professional emergency services.

Even if all organizational, technical, technological, preventive, informational, and educational measures are strictly adhered to, fires will continue to occur due to the wide variety of causes, as previously mentioned, that lead to fires [7].

Protecting human lives and material assets against fires, participating in the prevention of destructive effects caused by natural disasters and catastrophes, as well as mitigating their consequences, necessitates the organization and maintenance of specialized intervention services throughout the country under the authority of the General Inspectorate for Emergency Situations (GIES) of the Ministry of Internal Affairs (MIA).

Each year, the intervention units of the General Inspectorate for Emergency Situations (GIES) carry out thousands of interventions in various emergency and exceptional situations.

This study is dedicated to analyzing the situation regarding interventions during the first 10 months of 2024 compared to 2023, also presenting data from the years of the 21st century. During the first 10 months of 2024, the 61 specialized intervention units of GIES carried out 21,868 missions, which is 983 more (a 4% increase) compared to the same period of the previous year. This increase was influenced by natural factors as well as the irresponsible actions of people.

If in the years 2000-2002 the GIES units [2] carried out about 15 missions per day and 5 types of interventions, by 2023, this number had increased to 66 missions per day and 20 types of interventions. The dynamics of these interventions are presented in the chart in Figure 1 [2].

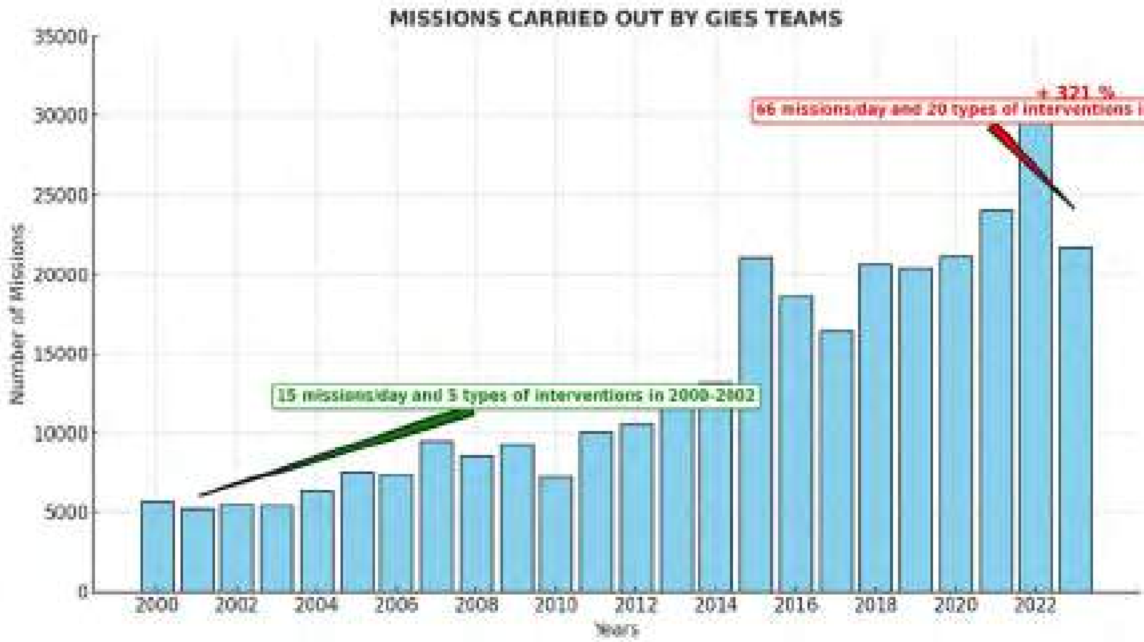

Figure 1. Comparative record of missions carried out in the last 24 years

In the period January-October 2024, 213 ES (Exeptional Situations) were registered. The material damage recorded as a result of these ES amounted to 4 billion 543 million 260 thousand lei [2]. The dynamics of the evolution of emergency and exceptional situations is presented in Figure 2.

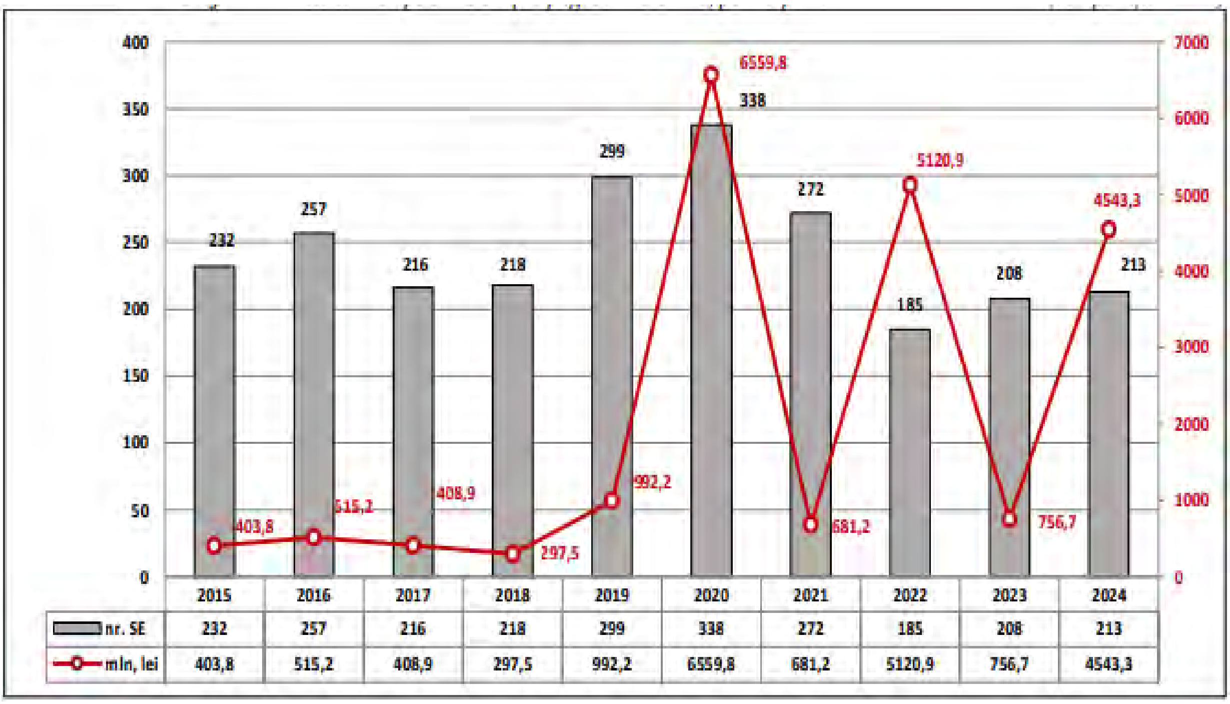

Figure 2. Dynamics of the evolution of emergency and exceptional situations in 2015-2024

The comparative evolution of intervention missions during the years 2023–2024 has an upward character, especially for the performance of search and rescue missions, with a significant increase of 26% (fig. 3) [2].

Figure 3. Evolution of intervention missions during the years 2023-2024

The average response time of the IGSU intervention subdivisions to emergency calls (fires and search and rescue interventions) during 2024 was about 20 minutes.

In the period January-October 2024, 213 ES were registered. The material damage recorded as a result of these SE was in the amount of 4 billion 543 million 260 thousand lei. The dynamics of the evolution of exceptional situations over 10 years (2015-2024) is presented in Figure 4 [2].

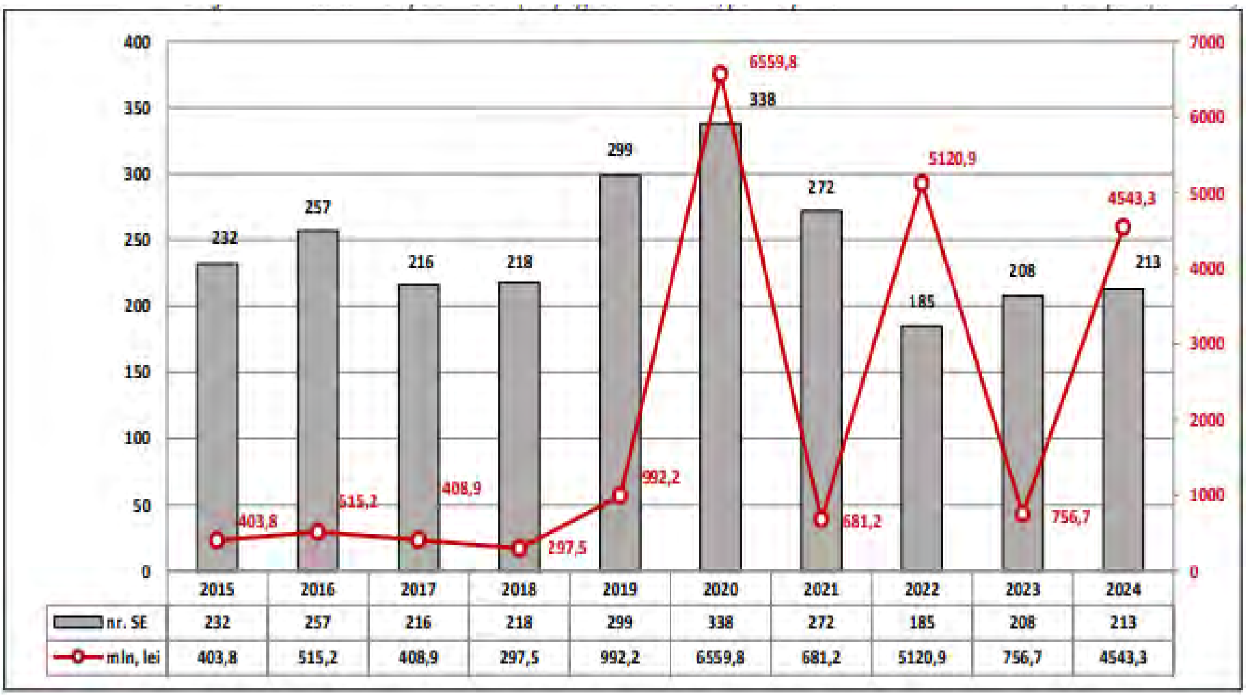

Figure 4. Diagram of the evolution of exceptional situations during the years 2015-2024

Statistical data for October 2024 demonstrate a decrease in the number of exceptional situations, as well as material damage. During this month, 9 exceptional situations (ES) with insignificant damage were recorded (material damage resulting from these ES was not recorded). The dynamics of ES in 2020-2024 is presented in Figure 5 [2].

Figure 5. Dynamics of exceptional situations in 2020-2024

Distribuirea pe clase de situații excepționale (tehnogene, naturale, biologo-sociale) pentru ultimii 10 ani, în perioada lunilor ianuarie-octombrie, este prezentată în figura 6 [2].

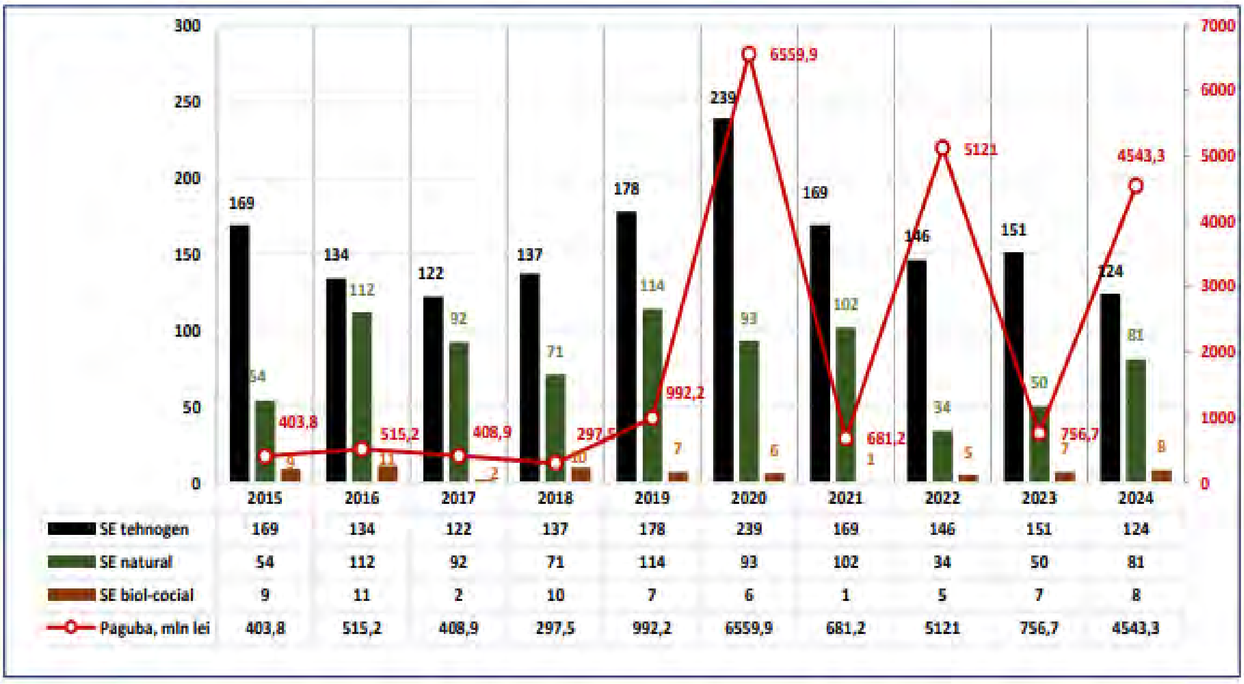

Figure 6. Dynamics of the evolution of exceptional situations in the years 2015-2024

The analysis carried out in this study demonstrates, once again, that the number of emergency and exceptional situations that occur on the territory of the Republic of Moldova have an unpredictable evolution from year to year, because they depend on a number of factors, have a diverse nature, frequency, intensity and direct or indirect impact on communities/society and the human living environment [2].

3. Intervention planning

Rapid and effective intervention in the event of a fire largely depends on proper planning and well-structured management of the teams involved. In this context, the planning process must be carried out carefully, taking into account the characteristics of each location and specific risks. Moreover, the correct management of the intervention is essential for protecting lives and property, thus minimizing the damage caused by fires [1].

Fire intervention planning involves carefully assessing risks and establishing clear procedures that guarantee a rapid and coordinated response. The first step in the planning process is **identifying possible risks**, such as fire sources, vulnerable areas of buildings, and the types of combustible materials. Based on this analysis, prevention measures and fire intervention procedures will be established [3].

Another essential element in planning is **developing an intervention plan**, which will include details about how the various stages of the intervention will be managed: *fire detection, alerting the teams, evacuating people, extinguishing the fire, and assessing the damages*. This plan must be flexible and adaptable in order to respond efficiently to different scenarios.

For the intervention to be effective, its management must rely on **rapid and clear coordination** among all the teams involved. These teams may include firefighters, paramedics, police, as well as the internal staff of the institution or building affected. It is important for each team member to know their specific role and responsibilities, and communication between teams must be well-defined to ensure a continuous and effective flow of information.

Another key aspect in managing the intervention is the **efficient management of available resources**. Each intervention team must have rapid access to necessary equipment, such as fire extinguishing devices, personal protective equipment, and intervention vehicles. Additionally, it is important that resources are distributed evenly, so that the intervention is not hindered by the lack of essential items. An intervention plan can only be effective if the personnel is well-trained [5].

Continuous training of the teams is essential to ensure that each member of the intervention teams knows the action procedures and is capable of responding correctly in the event of a fire. Furthermore, conducting **periodic simulations** helps test the intervention plan and identify any gaps in procedures. These practical exercises allow the staff to familiarize themselves with evacuation procedures, the use of protective equipment, and effective coordination in emergency situations.

After completing an intervention, it is important to conduct a **post-intervention evaluation** to analyze the effectiveness of the response. This involves a detailed review of the entire process, identifying strengths and potential weaknesses, and adopting corrective measures, if necessary. Continuous evaluation of the intervention plan allows for its improvement and ensures better preparation for future situations [9].

Fire intervention planning and management are essential for protecting lives and property. A well-structured plan, supported by efficient coordination, adequate resources, and continuous training of personnel, can make the difference between a successful intervention and one that fails to meet its objectives. In this regard, every organization, institution, or community must emphasize preparation and continuous evaluation to respond effectively to a fire [5].

In the Republic of Moldova, managing fire situations and implementing effective prevention measures are essential for protecting the lives and property of citizens. In this context, case studies from the past and best practices implemented in various fields can provide a valuable framework for improving the fire response system.

Another important area in which the Republic of Moldova has implemented prevention and intervention measures is educational institutions. For example, at the beginning of the 2020s, several schools and kindergartens in Chișinău implemented education and training programs for children and teaching staff on fire prevention and safe evacuation. In recent years, the Republic of Moldova has paid increased attention to fire prevention in residential areas, particularly in densely populated neighborhoods. Measures have been implemented to address both fire prevention and citizen training for a proper response in the event of such an incident [6].

Case studies from the Republic of Moldova, as well as best practices implemented in different fields, highlight the importance of an integrated approach to fire management. Efficient planning, continuous training, coordination among responsible institutions, and active citizen involvement are essential for the prevention and successful management of fires. The lessons learned from these cases must continue to be applied to improve fire response and protection systems throughout the country.

3. Conclusions

The management of fire prevention actions must be a constant priority, considering that most fires can be avoided through proper safety measures. Implementing effective prevention procedures, such as maintaining equipment, training personnel, and creating a safe environment, is crucial to reducing risks. Prevention projects should also include educational campaigns to raise public awareness.

Continuous training of intervention teams and the population is essential for a rapid and effective response in the event of a fire. Periodic training, organizing simulations, and practical exercises help familiarize individuals with proper evacuation procedures, the use of protective equipment, and responding to different fire scenarios. These activities contribute to increasing efficiency and reducing response time.

An effective response in the event of a fire depends on close coordination between the various authorities and institutions involved – firefighters, police, ambulance services, local administration, as well as private organizations or educational institutions. Clear and rapid communication between all parties involved can make the difference in efficiently managing an emergency situation and saving lives.

The use of advanced technologies, such as drones, thermal cameras, and fire monitoring systems, can significantly improve response time and the efficiency of intervention teams. These technologies allow for the quick identification of fire hotspots and better coordination of available resources, providing intervention teams with precise information for more effective action.

After each incident, it is essential to conduct a detailed evaluation of the response and identify areas that can be improved. The lessons learned from each intervention should lead to the modification and continuous improvement of prevention and response plans, increasing efficiency and preventing similar incidents in the future.

It is important to consider not only the physical and material risks but also the psychological and economic impact of fires on communities. In addition to prevention and response measures, authorities should also invest in psychological support for affected individuals and in rapid reconstruction measures for devastated areas.

Active community involvement in fire prevention and educational activities significantly contributes to reducing risks. Local campaigns and public education initiatives should be supported by authorities to raise responsibility levels and encourage preventive actions at the local level.

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GIS-BASED GULLY EROSION MONITORING AND SIMULATION

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Abstract: *Soil erosion, especially of valuable arable land, is a growing global issue, exacerbated by climate change. A major concern is the irreversibility of soil erosion, with annual soil loss often outpacing new soil formation. While sheet erosion leads to significant topsoil loss, gully erosion is particularly concerning due to its severe impact on landscapes. To mitigate gully erosion, identifying the most vulnerable areas is crucial. In this study, machine learning methods such as Random Forest, XGBoost, and SVM were used to map gully erosion susceptibility in Nepal. Various factors, including land use, soil, geology, and slope, were considered. The model performance was assessed using the Area Under the Curve (AUC) score, with initial results showing scores between 76% and 84%, indicating good predictive power across all methods. Beyond susceptibility mapping, simulating and predicting future gully development is essential for long-term erosion management. A QGIS plugin was developed to model gully erosion over time, requiring a digital elevation model (DEM) and soil parameters as inputs. The plugin predicts potential gullies by extrapolating drainage patterns from the DEM and calculates changes in gully depth, width, and volume. The results are then integrated into the DEM for 3D visualization. Validation of the tool on gullies in South Africa showed good alignment between predicted and observed gully dimensions, though some dynamic aspects varied. This approach provides a valuable tool for identifying at-risk areas and simulating future gully erosion, aiding in the development of effective mitigation strategies.*

Keywords: *Gully erosion, machine learning, physical modelling, GIS integration, GIS simulation*

1. Introduction

Water erosion occurs mainly when overland flow entrains soil particles detached by droplet impact or runoff, often resulting in well-defined channels such as rills or gullies. It is a serious problem in many regions of the world. [1] states that globally 72% of land affected by soil erosion is caused by water. Its impact on the productivity of agricultural land can be very damaging, eventually rendering the land completely unsuitable for agriculture [2]. The impact of water erosion is predicted to increase in the coming years due to climate change [3], with their study predicting a 13-22% increase in average soil erosion rates for the EU.

Gully erosions of particular interest not only because of their immediate visibility in the landscape. On-site damages include the direct loss of arable land as a result of significant soil losses, reduced soil fertility, loss of crops and vegetation cover, as well as damages to infrastructure such as roads, powerlines and communication networks ([4], [5]). [6] reports that in Moldova 700-800 new gullies are formed every year, with length of 50-70 km and an area of 300 hectares.

In contrast to the modelling of sheet erosion, which is typically conducted using the Revised Universal Soil Loss Equation (RUSLE) [7], different approaches are employed to model gully erosion. The initial step in mitigating the impact of gully erosion is to identify areas that are particularly susceptible to it. In the context of susceptibility mapping, classical approaches such as the weight of evidence are frequently employed ([8]). In this approach, various conditioning factors, often constrained by data availability, are utilised. These include geomorphology, soil type, land use, slope, stream power index, etc. These factors are overlaid with observed gully areas or gully heads to generate susceptibility maps. This approach has yielded promising results. For instance, [8] reported a Receiver Operating Characteristic Area Under the Curve (ROC AUC), which is used as a quality criterion for predicting the susceptibility, of approximately 68% for their study area in West Bengal, India. While the conditional independence of the factors can be tested, in this approach the correlations between them are not typically considered.

More recent approaches are using machine learning techniques for the mapping of gully susceptibility. In this context, different algorithms are employed, including Random Forest ([9], [10], [11]), XGBoost ([12], [13], [14]) or SVM ([15]) among others. Although a number of studies exist which compare different algorithms and different sets of triggering factors (e.g., [16]), the question of an optimal method for a specific study area remains unanswered. The objective of this study is to compare the efficacy of various methods for incorporating multiple triggering factors in the susceptibility mapping of gully erosion in the Nepalese context. For data collection, data preparation, visualization and validation of the results Esri's GIS environment is used.

The identification of areas susceptible to gullying represents a crucial initial step in the implementation of effective mitigation strategies. Conversely, the assessment of a gully over time, taking into account its dynamic characteristics, represents another crucial stage in the process. The dynamic of a gully depends on many factors like rainfall pattern, topography, soil properties or land use. To model gully dynamics different physical models have been proposed ([17], [18], [19]). All models are depending strongly on local characteristics and parameter like soil erodibility coefficients or the critical velocity of the discharge to initiate a gully head.

Many of the proposed models have been implemented as standalone software packages, rather than being integrated into a GIS. However, the integration offers a number of significant advantages. The input layer and parameters can be prepared and formatted for the core simulation module without any media break. The integration of the simulation results into a GIS allows for their visualization in three dimensions, for instance by overlaying them with a digital elevation model (DEM) of the study area. This enables the creation of a three-dimensional model representation or the use of animations to visualize gully dynamics over time.

The objective of the second part of this study is to integrate a physical simulation model into a GIS environment. Here the proposed model of ([20]) has been used. In order to facilitate the integration into QGIS, the core simulation model has been re-implemented using Python programming language.

2. Study Area and Data

The necessity to obtain data and the extent of the two parts of the study have resulted in the use of two different study areas. In order to ascertain the areas that are at risk, it is necessary to conduct a more extensive investigation at the regional level. For this purpose, an area of approximately 500 square kilometers within the Babai Sub-basin in Nepal has been selected. With an average elevation of 760 meters above sea level (a.s.l.), ranging from 560 to approximately 2000 meters a.s.l., the study area encompasses a diverse range of topographical features.

Climatically, the region experiences an average annual precipitation of 1670 millimeters, with an average temperature of 24.7 °C. The study area is characterized by a diverse range of land uses and land cover, with agriculture representing the most prominent feature. Additionally, the hilly landscapes to the north and south of the study area feature a substantial amount of forest coverage, while barren lands constitute a smaller portion of the region. The region's intricate river network encompasses a multitude of Strahler order streams, ranging from 1 to 5, with the Babai River representing the most significant waterway. It is worthy of note that the study area contains a widespread stream network, with a total length in excess of 900 km. In terms of geology, the region is predominantly characterized by Quaternary formations, which are further subdivided into alluvium featuring boulders, gravels, sands, and clays.

For the detection of the gully head points PlanetScope Imagery as well as the base map provided by Esri has been used, both with a ground resolution better than 3 m. The high resolution of the imagery allowed capturing of fine details, enabling the precise identification of significant features such as gully erosion heads and areas. Other layers needed to model triggering factors have been extracted from different national geospatial project databases of Nepal, specifically the Irrigation Master Plan Preparation (IMP) project from 2017 (DEM with 5 m resolution, river network, soil texture and soil layer order, land use, geology) and Hydro-power Master Plan Preparation (HMP) from 2020 (road network and rainfall data). For validation a layer provided by National Landuse Planning (NLUP) from 2021 has been used.

As second study area, a gully in the region of Kwa Thunzi, situated in Umgungundlovu District of Kwazulu-Natal, South Africa, has been used. The gully lies in the south-western catchments of the district, feeding the Umkomazi River. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures range from 16°C in June to 25°C in January. It receives the lowest rainfall (3mm) in June and the highest (201mm) in January. The average annual rainfall in this area is recorded as 1430 millimeters. The study area is highly affected from gully erosion. According to [21], deep gullies are a characteristic geomorphic feature of the hilly topography of central KwaZulu-Natal province, and pose severe constraints on the agricultural use of land, [22] found that gully erosion in this region was closely related to specific bedrock-types and characteristic terrain morphological units. Much of the current gully erosion in KwaZulu-Natal is associated with widespread colluvial sediments, which overlie the diverse bedrock lithologies in the region. Thus, as main reason for gully formation the intensive rainfall events and geomorphic characteristic are associated ([23]).

Main data input for the gully evolution simulation is a digital terrain model (DTM) with 1 m resolution. The DTM for the study area was derived from UAV images using Structure-from-Motion algorithm ([24]). The second most important input is the discharge data. The discharge data for the gully area is derived from the nearby gauging station located at Impendle (-29°44′ 37’’ N29°54′18’’) operated by the South African Department of Water Affairs. The dataset contains daily water discharge for 57 years (from1961 to 2017). Other parameter needed like erodibility and soil layer order have been taken from literature and can be adopted in the simulation model for calibration purposes.

3. Methodology

The main steps of the methodology for gully susceptibility mapping are shown in figure 1. These include data pre-processing, which encompasses the integration of diverse spatial data, such as the gully erosion inventory and conditioning factors, and the development of a coherent dataset. The utilisation of GIS tools and functionalities facilitates data alignment, exploration and preliminary manipulation, thereby establishing the foundation for subsequent analysis.

Once the data has been processed using GIS, it can be analysed using a workflow implemented as a Jupyter Notebook. This process entails the cleansing of the data, the creation of features, the selection and implementation of machine learning models, the assessment of metrics, and the undertaking of predictive analysis. Python packages like Pandas are employed for the manipulation of data and the development of models.

The results of the Jupyter Notebook analysis, namely the predicted susceptibility values, are integrated back into the GIS environment. However, to facilitate integration, the Notebook environment within ArcGIS Pro is employed, using Python to process the data and create the final map. The combination of the spatial analysis capabilities of GIS with the data science capabilities of Jupyter Notebook ensures a robust and thorough approach to gully erosion susceptibility mapping. This strategy optimises the respective strengths of both methodologies, thereby yielding accurate and insightful results.

The principal input for the analysis is the gully inventory. The delineation of gully heads was based on the interpretation of satellite imagery, with the use of a digital elevation model

(DEM) to calculate the topographic position index (TPI) [25] and subsequent field validation. A total of 213 gully head points and 213 non-gully head points have been identified and used as input for the ML algorithm, as illustrated in Figure 2.

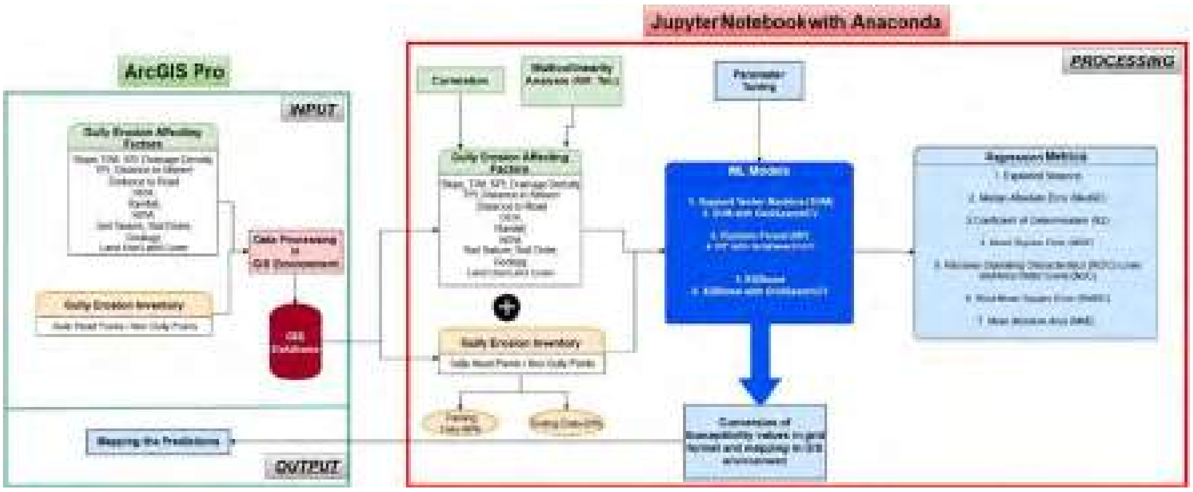

Figure 1. Workflow for gully susceptibility mapping

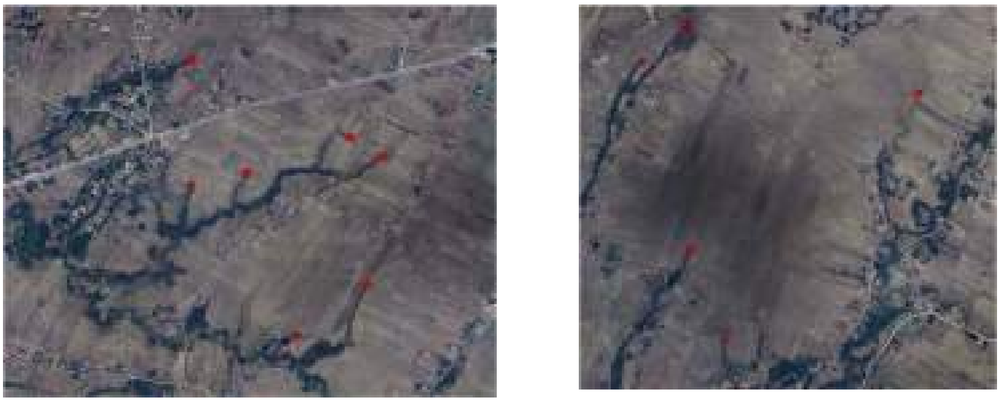

Figure 2. Examples for gully head detection

A total of 14 distinct layers were employed as influencing factors. All layers have been rasterised or resampled to a spatial resolution of 5 metres. The specific factors utilized are outlined in detail below:

- Land use /land cover: In total, seven discrete classes have been employed, namely agriculture valley/Tar/Terai (i.e., the lowland region located south of the outer foothills of the Himalayas which constitutes 60% of the study area), agriculture on sloping terrace, shrubland/grassland, sand/gravel/boulders, forest, barren land, and built-up area.
- Geology: In total, eight different classes have been identified with the Lakharpata Formation (fine-grained, light blue, grey limestones and dolomites) and Ranimatta Formation (grey greenish-grey gritty phyllites gritstones with conglomerates) covering more than 90% of the study area.
- Soil type according to the USDA soil taxonomy ([26]): The study area is comprised of three soil classes, namely entisols (very young, shallow soils with little or no recognisable levelling, covering about 50% of the study area), inceptissols (young soils with a very weak vertical profile) and aflisol (well-developed soils with a clay enrichment horizon in the subsoil resulting from lessivation).
- Soil type classified according to its clay, silt and sand fraction content with ten distinct classes. The most prevalent soil type was clay loam, which accounted for 36% of the study area.

- Normalized Difference Vegetation Index (NDVI), calculated based on PlanetScope´s near-infrared and red bands.
- Mean annual rainfall was obtained from the HMP project, taking into account the influence of elevation and aspect using the co-kriging interpolation method.
- Elevation with most gully heads observed in areas lower than 1000 m a.s.l.
- Slope with most gully heads observed in areas less than 10 degrees of slope.
- Topographic Positioning Index (TPI) as a measure of the relative relief.
- Topographic Wetness Index (TWI) and Stream Power Index (SPI) as functions of catchment area and slope.
- Drainage density.
- Stream proximity and road proximity.

Following the removal of outliers and the interpolation of missing data, a correlation and feature importance analysis was conducted. Subsequently, following the division of the data set into training (80%) and testing (20%) sets, a variety of machine learning models were trained, including Random Forest (RF), XGBoost, and Support Vector Machine (SVM). Furthermore, GridSearchCV, a tool for optimising the hyper-parameters of the various models, was employed. The method entails a systematic search through a predefined parameter grid, with the objective of identifying the optimal combination of hyperparameters that yield the highest model accuracy.

In order to simulate the evolution of gullies over time t, the transport differential equations (equation 1) are solved numerically. In this context, the coordinate x represents the longitudinal step, i.e., along the flowline, and z the relative height. These two variables define a local coordinate system, building the solution space:

$$\frac{\partial z}{\partial t} - a\frac{\partial z}{\partial x} = 0 \text{ with } \qquad a = k_E \frac{Q}{W}(W + k_b d_0) \tag{1}$$

where k_E longitudinal erosion coefficient, W flow width, Q water discharge, k_b transversal erosion coefficient, and d_0 flow depth. The equation describes the longitudinal removal of soil due to the discharge and the related changes in gully depth over time. As the gully transection shape will be not rectangular but trapezoidal, a wall correction is applied, where D_t denotes the gully depth and W_t and W_b the width of the gully at its top and bottom, respectively:

$$D_t = \left(\sqrt{W_b^2 + \frac{4V_0}{\tan\Phi}} - W_b\right)\frac{\tan\Phi}{2} \quad \text{and} \quad W_t = W_b + 2\,D_t/\tan\Phi \quad , \tag{2}$$

with V_0 as the gully volume and Φ the stable gully wall inclination, see figure 3.

In accordance with the approach outlined in reference [18], a Python program has been developed for the numerical integration of the equations.

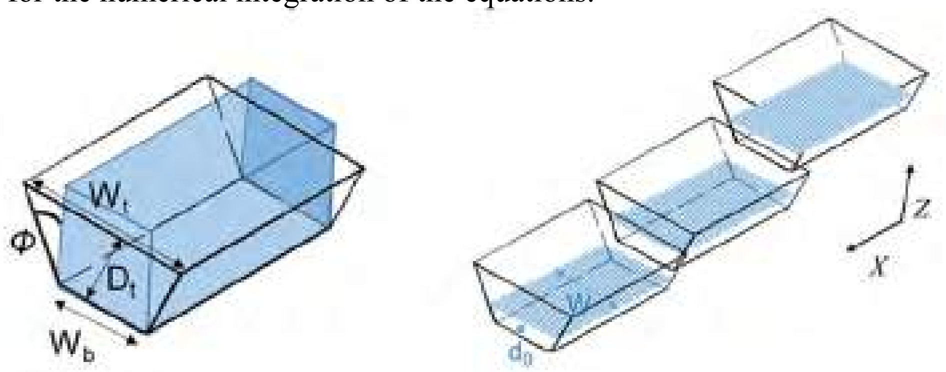

Figure 3. Gully segments calculation based on a local coordinate system

In order to facilitate the 3D visualisation, it is necessary to transfer the local calculated gully width and depth along the flowline back to a world coordinate system. One potential system for this transfer is the UTM projection. Subsequently, the overlapping portions of the "bathtub"-like elements (Figure 3) resulting from kinks in the flowline must be eliminated to ensure the meaningful incorporation of the gully boundaries into the DEM.

The complete workflow has been implemented as a plugin for QGIS, as illustrated in figure 4.

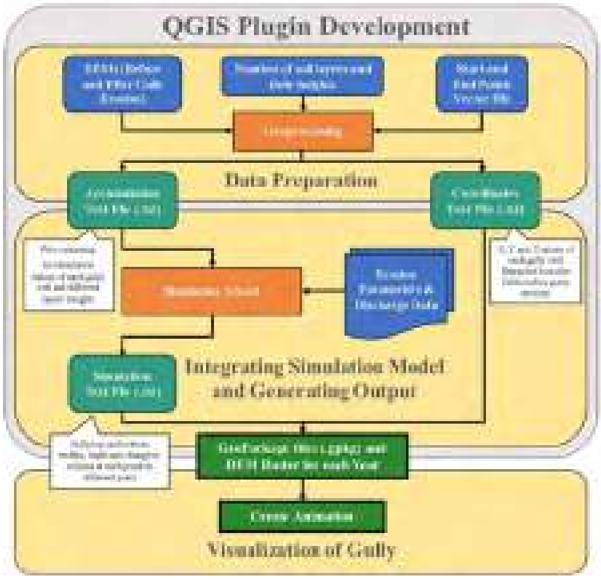

Figure 4. Workflow QGIS Plugin for gully evolution simulation

4. Results

The performance of each ML model can be evaluated based on their respective metric values, see table 1 and 2. While all models demonstrate satisfactory performance in relation to the training dataset, a closer examination reveals that the 'XGBoost with Recursive Feature Elimination (RFE) and GridSearchCV' model, exhibits best in terms of metrics across all the metrics. On the other hand, the 'SVM with RFE' model, shows comparatively lower scores in most of the metrics.

Similarly, table 2 gives an overview of the predictive performance of the models, used to predict the test data after training. While the models show similar metrics values with slight variations, a closer look reveals the standout and less favorable model. In particular, the 'Random Forest with RFE and GridSearchCV,' has superior metrics across several indicators, indicating its robust predictive capacity. Conversely, 'XGBoost with RFE', while not performing poorly, has relatively lower metric scores compared to the others.

Table 1. Metrics for different ML models (training data)

	Model	RMSE	MSE	MedAE	MAE	R^2	Explained Variance	AUC
0	RandomForest_AllFeatures	0.17	0.03	0.14	0.15	0.88	0.88	1.00
1	RandomForest_SelectedFeatures	0.17	0.03	0.14	0.15	0.88	0.88	1.00
2	RandomForest_SelectedFeatures_GridSearchCV	0.17	0.03	0.15	0.15	0.89	0.89	1.00
3	XGBoost_SelectedFeatures	0.00	0.00	0.00	0.00	1.00	1.00	1.00
4	XGBoost_SelectedFeatures_GridSearchCV	0.02	0.00	0.01	0.01	1.00	1.00	1.00
5	SVM_SelectedFeatures	0.43	0.19	0.26	0.34	0.25	0.30	0.81
6	SVM_SelectedFeatures_GridSearchCV	0.42	0.18	0.37	0.39	0.28	0.28	0.83

Table 2. Metrics for different ML models (test data)

	Model	RMSE	MSE	MedAE	MAE	R^2	Explained Variance	AUC
0	RandomForest_AllFeatures	0.44	0.19	0.38	0.39	0.24	0.24	0.78
1	RandomForest_SelectedFeatures	0.44	0.19	0.37	0.38	0.24	0.24	0.79
2	RandomForest_SelectedFeatures_GridSearchCV	0.42	0.18	0.36	0.38	0.30	0.30	0.82
3	XGBoost_SelectedFeatures	0.46	0.21	0.27	0.36	0.15	0.16	0.76
4	XGBoost_SelectedFeatures_GridSearchCV	0.46	0.21	0.27	0.36	0.15	0.16	0.77
5	SVM_SelectedFeatures	0.45	0.20	0.35	0.38	0.18	0.20	0.76
6	SVM_SelectedFeatures_GridSearchCV	0.44	0.19	0.40	0.41	0.23	0.23	0.78

The results were used to generate gully erosion susceptibility (GES) maps, see figure 5. The GES values are classified into five classes using the Jenks natural break classification system. In addition, the delineated gully erosion areas identified by the National Land Use Project (NLUP), are clearly marked. This inclusion not only adds an essential layer of credibility, but also provides a means of validating the machine learning driven results. The use of these meticulously outlined polygons serves as a critical mechanism for validating the predictive results of the models.

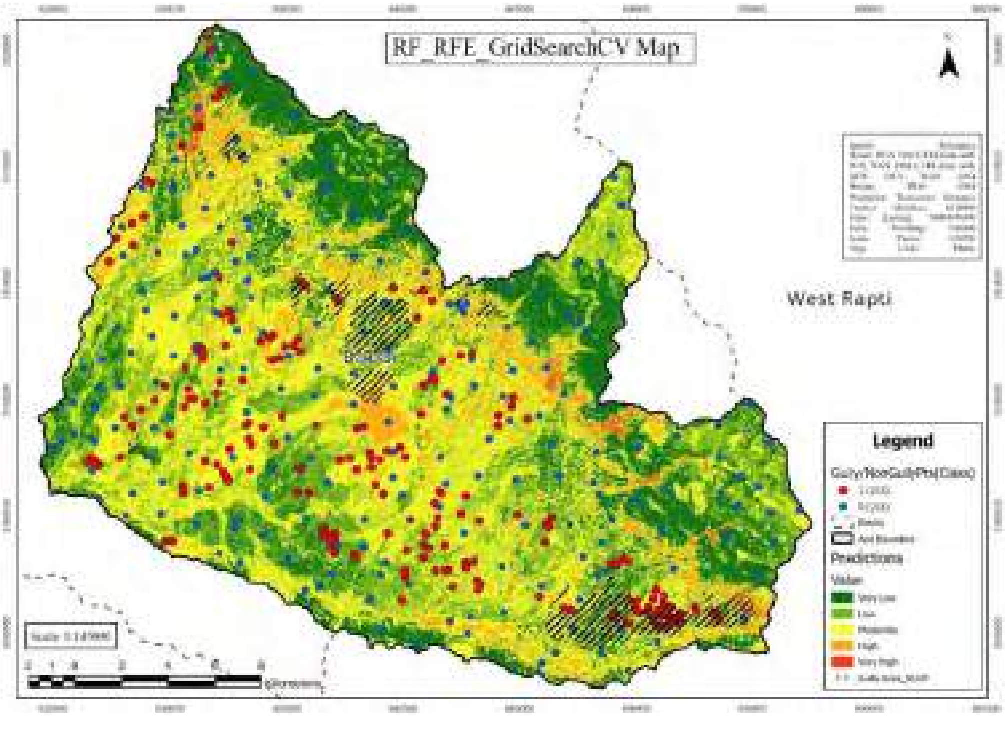

Figure 5. Gully susceptibility map for the RF with RFE and GridSearchCV model

For the XGBoost with (RFE) and GridSearchCV model, here identified as optimal for the specific study area, the majority of the study area falls within the medium risk category of GES, accounting for 44% of the landscape. This is closely followed by the low and very low classes, which together account for 29% and 18%, respectively, while the high risk class occupies 9% of the landscape. Interestingly, the very high risk class occupies a relatively small area, less than 1% (2.55 km2) of the study area. Further details can be found in [27].

To simulate the dynamics of the Kwa Thunzi gully for different soil parameters the QGIS plugin was used, see figure 6. In particular, different values for erodibility and critical velocity have been tested for the simulation.

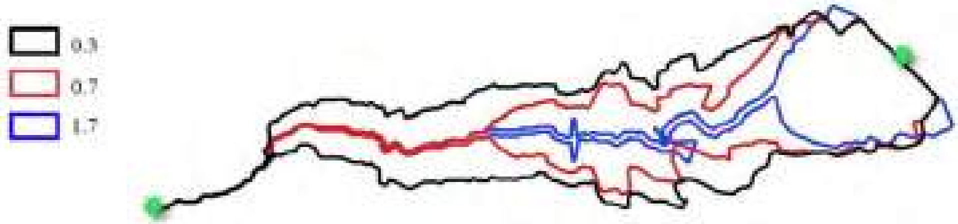

Figure 6. Simulated shapes of the Kwa Thunzi gully for different critical velocities (m/s)

As an example, for the embedding of the results in the GIS environment, figure 7 shows the simulated evolution of the Kwa Thunzi gully over 56 years as a 3D visualization. For validation purposes, the simulated gully cross-sections were compared with the recent DEM, see figure 8.

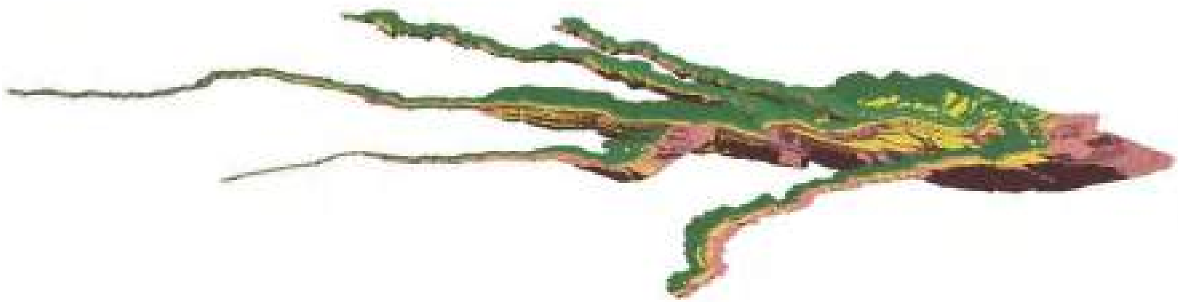

Figure 7. 3D-visualization of the Kwa Thunzi, gully after 56 years simulation, 1 and 2 denoting the location of cross sections used for validation

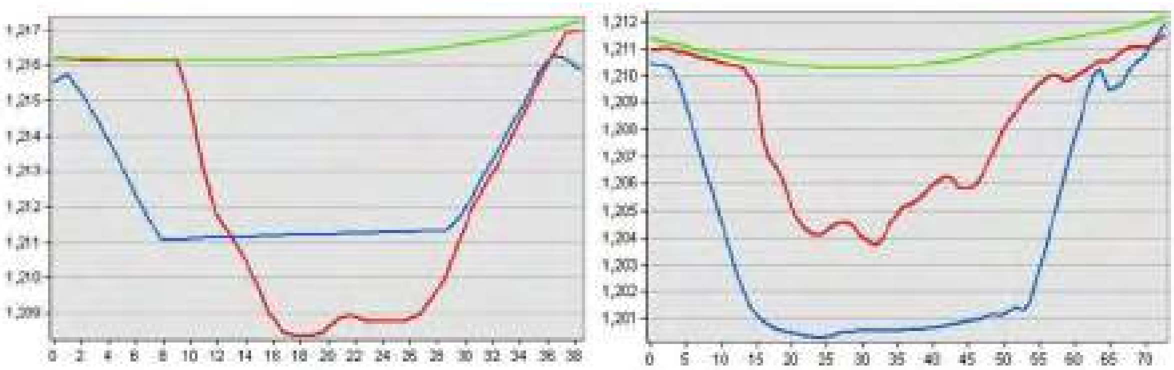

Figure 8. Simulated (blue) and DTM extracted (red) cross sections (1 left, 2 right)

Conversely, the discrepancies in gully depth and width between the simulated and the actual DTM can be employed to calibrate the model. Consequently, the model can be utilised to forecast gully dynamics under analogous soil and climatic conditions across disparate geographical regions. More results can be found in [28] and [29].

5. Conclusions

This study has shown that machine learning algorithms can be used to generate gully erosion susceptibility maps, where, in addition to training data, model parameter selection is a very important task. Physical models can be used to predict gully dynamics over time. A QGIS plugin was implemented to facilitate the work for users not familiar with sophisticated GIS workflows. The results of both parts of the study are very important for the implementation of mitigation measures against gully erosion.

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EVALUATION OF HOP VARIETIES USING SPECTRAL AND THERMAL CHARACTERISTICS DERIVED FROM UAV IMAGES

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Abstract: *Hops are a traditional crop grown in the Czech Republic. Hop varieties have different qualitative characteristics not only in terms of harvest, but also in terms of phenological development and diseases resistance. The presented study focused on varieties grown in both conventional and organic systems. Since hops are a crop grown in relatively small blocks in rows where bare soil shows through canopy in the early stages of growth, the use of UAVs is a convenient way for crop monitoring. The advantage is that the resulting images have a very high spatial resolution, and it is thus possible to separate green plants from the soil to derive accurate results. Normalized Difference Vegetation Index (NDVI), Leaf Area (LA) and Crop Water Stress Index (CSWI) were calculated to determine varieties characteristics and their response to weather, diseases pressure and agronomic interventions during the whole growing season 2023. The results showed that NDVI and LA had the same development trend for all varieties, but organic varieties had significantly lower values compared to conventional. The reason was a different response to diseases pressure. The CWSI values showed a different trend depending mainly on management system. However, it was clear from the coefficient of determination that, CWSI for organic Premiant was explained by 65% using NDVI (structure and health), while only 50% for organic Saaz. Leaf area affected CWSI in organic Premiant by 50% and in Saaz by 43%. For conventional hops, NDVI explained CWSI from 53% (Agnus), 60% (Premiant) to 63% (Sládek). In conventional hop plants, the leaf area was higher, and the diseases pressure was not significant. CWSI was affected by LA on average by 23%. The achieved results can be applied in determining the effectiveness of cultivation management and agrotechnical interventions, including hop irrigation.*

Keywords: *Hop varieties, management system, multispectral camera, photogrammetry, vegetation index, leaf area*

1. Introduction

Remote sensing is becoming an integral part of agronomy, especially in monitoring the entire process of monitoring and data collection of agricultural crops [1, 2]. Agricultural data includes important information such as the level of plant vitality, structural and qualitative parameters contained in spectral indices or water or heat stress of plants [3, 4].

In agriculture, remote sensing is applied in three methods depending on the platform used - satellite, aerial and terrestrial. They differ from each other in terms of spatial, spectral and temporal resolution of the obtained images [5]. Aerial photography using Unmanned Aerial Vehicles (UAV) equipped with multispectral or thermal camera is currently an available source of data if it is necessary to obtain data of a larger area with a very high spatial resolution and therefore with high accuracy [6, 7, 8].

Spectral indices can very quickly and efficiently provide comprehensive information about plant health and help accurately locate diseases and pests, detect water stress or predict harvest [9, 10]. One of the most widely used is the Normalized Difference Vegetation Index (NDVI), based on reflectance in the red and near-infrared part of the spectrum, which is also an indicator of the vitality, structure and biophysical processes of plants associated with health. NDVI values that are above 0.25 usually detect green plants. The most vital plants then have an NDVI value as close as possible to 1 [11]. With climate change, the detection of crop water stress is coming to the forefront of interest for both scientists and practitioners. To detect it, the Crop Water Stress Index (CWSI) developed by Idso et al. [12]. Very often, CWSI is used to derive crop irrigation rates [13].

For the purposes of precision agriculture, UAVs were used, for example, to determine the structure and vitality of vineyards [14] or orchards [15] as special crops, where it is necessary to focus on individual plants. A similar application can also be found in hop gardens. In general, hops belong to marginal crops due to their cultivation area, but their cultivation is very important especially for brewing purposes. The Czech hop plays a very important role in the breeding of quality varieties [16]. Therefore, the aim of the study is to evaluate the seasonal growth development of Czech hop varieties in organic and conventional management using UAV scanning and their response to biotic and abiotic influences.

2. Materials and Methods

Study area

The experimental hopgardens belonging to Hop Research Institute are located in Stekník (Czech Republic), at production and experimental farm of Hop Research Institute Co., LTD (HRI). The study area comprised two experimental hop gardens differently cultivated (bio and conventional hop garden) and four hop varieties. Conventional hop garden (50°19'37.32"N, 13°37'43.05"E) comprised three varieties – Agnus with the size of 1.5 ha, Premiant (2.4 ha) and Sládek (1.7 ha); varieties Saaz (1.1 ha) and Premiant (1.1 ha) were in bio hop garden (50°19'16.43"N, 13°37'50.63"E). Drip irrigation system was used in both hop gardens. Monthly precipitations and temperatures for season 2023 are given in Table 1.

Table 1. Monthly precipitations and temperatures measured at study locations for 2023 growing season

Months	May	June	July	August
Temperature (°C)	14.0	18.8	20.9	20.4
Precipitations (mm)	7.2	58.0	66.4	66.7

Data acquisition and processing

The experimental hopgardens were scanned by eBeeX fixed wing drone with MicaSense RedEdge multispectral (MS) camera and DuetT thermal camera (senseFly SA, Cheseaux-Lausanne, Switzerland) from beginning of growth (May) to harvest (August). Unmanned Aerial Vehicle (UAV) was equipped with a built-in RTK-PPK functionality with accuracy up to 4.8 cm. This service was provided by CZEPOS (GNSS Permanent Station Network of the Czech Republic services at Czech Office for Surveying, Mapping and Cadastre) – VRS.MAX-CZEPOS (master – auxiliary stations) with correction format of RTCM 3.1.

The UAV missions were carried out under the same conditions (from 11:00 a.m. to 2:00 p.m. CET) to eliminate the shadows and at low wind speeds to eliminate the crop moving. The flight height over organic hopgarden was 80 m above elevation data and 73 m for conventional hopgarden to reach 5.5 and 5 cm spatial resolution for images of MicaSense Red Edge camera, and 11 cm spatial resolution for images from Duet T thermal camera at 84 m flight altitude. The image overlaps were 75% (lateral, longitudinal) for MS camera and 80% (lateral) - 85%

(longitudinal) for thermal camera to reach very accurate results. MicaSense Red Edge camera consists of 5 spectral bands: Blue with wavelength center of 475 nm and range of 20 nm, Green 560 (20) nm, Red 668 (10) nm, Red Edge 717 (10) nm and Near Infrared (NIR) 840 (40) nm; Duet T thermal camera 7.5-13.5 µm.

Image analysis comprised data preprocessing in eMotion SW and further data analysis in Pix4D and QGIS SW. Photogrammetric procedure was carried out for orthophoto and NDVI spectral index calculation. Threshold of 0.3 NDVI value was set to separate green part of crop from bare soil. On the base of this procedure the area (in m^2) of green part of individual hop-varieties was calculated.

CWSI was derived from thermal images for the individual terms of canopy scanning (see Table 2). The calculation was done in QGIS SW using CWSI plugin [17].
The data were then statistically processed in Statistica SW (TIBCO Software Inc. (2018). Statistica (data analysis software system), version 13. http://tibco.com.).

Table 2. Meteorological, phenological and thermal information at the time of scanning

Date of scanning	Organic hop - Temperature (°C)			Conventional hop – Temperature (°C)			
	Ta	Tc Sa	Tc P	Ta	Tc A	Tc P	Tc Sl
4 May 2023	18.6	25.9	27.1	19.1	26.6	27.7	27.1
18 May 2023	14.6	17.4	17.6	14.5	14.8	14.6	14.9
22 May 2023	26.9	31.5	31.4	25.0	30.5	29.8	28.9
31 May 2023	25.5	35.1	34.5	25.8	36.9	38.8	36.1
12 June 2023	23.7	16.2	17.5	24.2	26.9	29.9	29.8
29 June 2023	28.1	29.7	31.3	29.0	26.4	25.5	25.3
7 July 2023	28.2	29.6	30.2	30.0	26.2	27.1	27.2
18 July 2023	26.4	22.5	21.3	28.3	22.8	22.6	21.5
10 August 2023	25.3	17.9	20.6	24.2	17.4	16.4	16.8
21 August 2023	31.3	-	28.3	32.8	29.7	30.3	30.6

Tc (˚C) = measured canopy temperature, Ta (˚C) = air temperature; Sa = Saaz, P = Premiant, A = Agnus, Sl = Sládek variety

Table 3. Spectral indices and parameters evaluated in this study

Spectral Index	Algorithm	Developed by	Reference
Normalized Difference Vegetation Index (NDVI)	$\frac{(NIR - RED)}{(NIR + RED)}$	Biomass, structure, vigor, health	Rouse et al. [18]
Crop Water Stress Index (CWSI)	$\frac{(Tc - Ta) - (Tcl - Ta)}{(Tcu - Ta) - (Tcl - Ta)}$	Water stress	Idso et al. [12]

Where RED = reflectance in visible red part of electromagnetic spectra; NIR = reflectance in near infrared part of electromagnetic spectra according to the MicaSense RedEdge MX sensor properties; Tc (˚C) = measured canopy temperature, Ta (˚C) = air temperature, Tcl (˚C) = canopy temperature of well transpiring or non-stressed crop (i.e., minimum Tc), and Tcu (˚C) = the canopy temperature of a nontranspiring or severely stressed crop (i.e., maximum Tc). Terms (Tcu – Ta) and (Tcl – Ta) are referred to as upper and lower limits.

3. Results and Discussion

The development of NDVI (Figure 1a) showed fluctuations in the initial growth phases of the hop stand until the end of May. Then, due to the different state of the hop crops depending on the management system, there was a significant increase in the NDVI values for the varieties in the conventional hopgarden, while the organic hop varieties showed lower values. These lower values were caused by fungal diseases (Downy mildew). The same trend can be observed on the leaf area development curve (Figure 1b). This agrees with the study of Hoffmann [19]. They found out that NDVI best represented Leaf Area Index (LAI) measurements as indicator of crop greenness and served for detection of the developmental stage of crops in the late growing season. While the conventional variety Sládek had the largest volume of leaf area, both varieties in organic management again showed lower leaf coverage in comparison with varieties in conventional management. CWSI showed differences in the response of the varieties to irrigation dates. Figure 1c shows that irrigation is not always effective enough. Organic varieties were more susceptible to water shortage (and heat stress), probably due to plant damage by fungal diseases and to a smaller leaf area (plant volume). At the same time, their response to irrigation was slower compared to conventional varieties. For the CWSI, the higher the value, the greater the stress of the plants due to water shortage. Of the varieties grown in the conventional management, the Agnus variety was the most drought-resistant (it achieved the lowest values compared to the others).

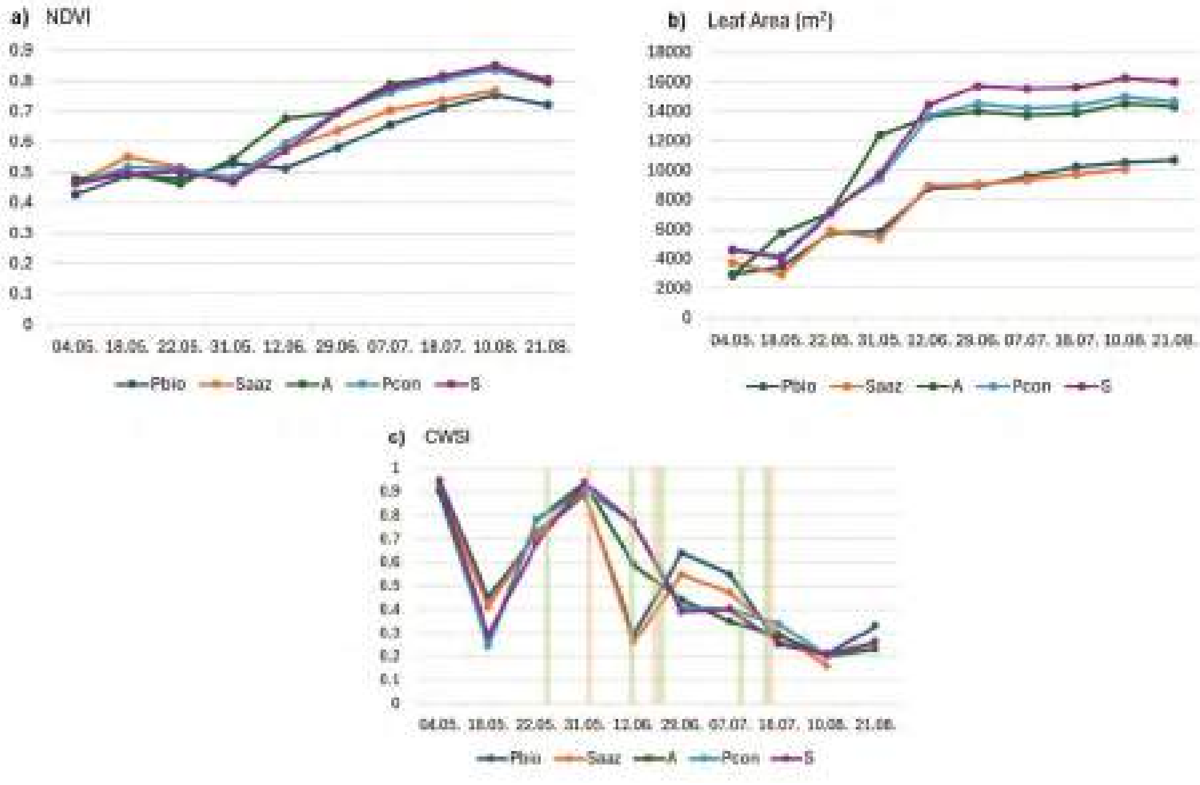

Figure 1. Normalized Difference Vegetation Index (NDVI) – unitless (a); Leaf Area in m^2 (b) and Crop Water Stress Index (c) for individual varieties. Green column = irrigation in organic hops; red column = irrigation in conventional hops

Coefficients of correlation and determination between CWSI and LA or NDVI are given in Table 4. The results showed that CWSI for organic Premiant was explained by 65% using NDVI (structure and health), while only 50% for organic Saaz. Leaf area affected CWSI in organic Premiant by 50% and in Saaz by 43%. For conventional hops, NDVI explained CWSI from 53% (Agnus), 60% (Premiant) to 63% (Sládek). In conventional hop plants, the leaf area was higher, and the diseases pressure was not so significant as in the case of organic hop garden. CWSI was affected by LA on average by 23%. The achieved results can be applied in determining the effectiveness of cultivation management and agrotechnical interventions, including hop irrigation. This statement agrees with the study of Ali [20]. They concluded that IR-based thermal imaging help to identify sensitive plants at the onset of drought stress or determine the stress tolerance of different varieties.

Table 4. Coefficients of correlation (R) and determination (R^2) between Crop Water Stress Index (CWSI) of varieties and Leaf Area (LA) or Normalized Difference Vegetation Index (NDVI)

Management	Variables	NDVI R	LA R	NDVI R^2	LA R^2
Organic	CWSI Premiant	-0.71	-0.71	0.50	0.50
	CWSI Saaz	-0.81	-0.65	0.65	0.43
Conventional	CWSI Agnus	-0.73	-0.48	0.53	0.23
	CWSI Premiant	-0.77	-0.46	0.60	0.21
	CWSI Sládek	-0.79	-0.51	0.63	0.26

4. Conclusions

The results showed that UAV remote sensing plays a significant role for structure and health evaluation of hop varieties and the efficiency of irrigation. Organic varieties generally had worse growth development (according to NDVI and LA) than varieties under conventional management during the 2023 season, especially from the beginning of June. There was more fungal pressure, which also resulted in a different response to water stress. Due to the poorer plant condition, organic hops responded to irrigation more slowly than conventional ones.

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QUALITATIVE AND QUANTITATIVE ANALYSIS OF PLÉIADES AND WORLD-VIEW 3 HIGH RESOLUTION DEMS

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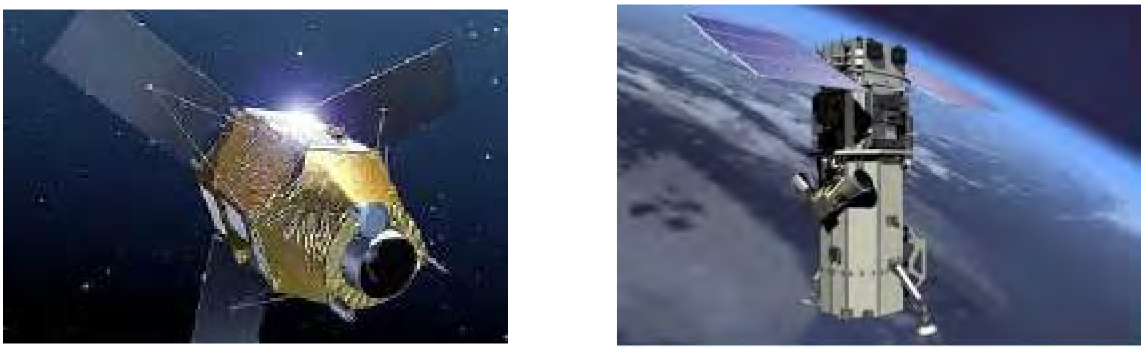
Abstract: *Recently, generating Digital Elevation Models (DEMs) from high-resolution stereo satellite imagery has gained significant interest as a research topic. The sub-meter Ground Sampling Distance (GSD) offered by these images suggests that decimeter-level accuracy can be achieved. The Pléiades and WorldView-3 sensors, advanced optical Earth observation satellites, are capable of capturing multiple perspectives of the same location in a single pass, providing valuable data for 3D modeling and extraction. Photogrammetrically derived DEMs are essential for applications in engineering, land planning, geomorphology, forestry, infrastructure, urban modeling, change detection, disaster management, and city planning. To ensure reliable analyses for the various applications, high quality elevation models are required. Therefore, the primary focus of this research investigation is to analyse and evaluate the geometric quality potential of DEMs derived from high-resolution Pléiades and WorldView-3 stereo and tri-stereo satellite imagery. The study area located in Allentsteig, Lower Austria is characterized by a hilly landscape with arable land and coniferous forests, and elevations ranging from 300 to 690 meters a.s.l. The entire photogrammetric workflow begins with VHR stereo/tri/stereo satellite imagery and includes the following processing steps: image orientation with improved Rational Polynomial Coefficients (RPCs), dense image matching, and 3D reconstruction using the forward intersection technique. The resulting 3D point clouds serve as input for deriving high resolution Digital Surface Models, whose accuracy is evaluated using reference Ground Control and Check Points (GCPs, CPs) and a LiDAR Digital Terrain Model (DTM). The vertical accuracy shows RMSE values of 0.96 m and of 0.37 m for Pléiades and WorldView-3 DSMs, respectively. To improve this outcome, the photogrammetrically derived DSMs were further aligned to the reference lidar DTM by applying an affine 3D transformation using the Least Squares Matching Technique (LSM). The results indicate improved vertical accuracy of 0.61 meters for Pléiades tri-stereo scenes and 0.24 meters for WorldView-3 tri-stereo scenes, respectively.*

Keywords: *high resolution DEMs, VHR satellite imagery, tri-stereo, dense image matching, 3D reconstruction, LSM*

1. Introduction

Digital Elevation Models (DEMs) derived from Very High Resolution (VHR) satellite imagery represent a significant area of interest in geospatial research. The rapid advancements in satellite imaging technology now enable the generation of DEMs with sub-meter Ground Sampling Distance (GSD), achieving decimeter-level accuracy. This level of precision is crucial for applications requiring detailed topographic information, such as urban planning, disaster management, and environmental monitoring. State-of-the-art sensors, such as Pléiades and WorldView-3 (Figure 1), represent a breakthrough in optical Earth observation. Thanks to their agile imaging capabilities, these advanced satellite systems are capable of capturing multiple perspectives of the same geographic location within a single orbital pass. This feature enhances the potential for accurate stereo imaging and 3D reconstruction, making them invaluable tools for creating high-quality DEMs [1-15].

The Pléiades constellation consists of two identical satellites, Pléiades-1A and Pléiades-1B, launched in December 2011 and December 2012, respectively. These satellites operate at an altitude of 694 km in sun-synchronous orbits with a 98.2° inclination. Positioned 180° apart, they enable a daily revisit capability [15]. The WorldView-3 high-resolution commercial satellite was launched in August 2014. Orbiting at an altitude of 617 km, it offers an average revisit time of less than one day and can capture up to 680,000 km² of imagery daily. WorldView-3 delivers panchromatic, multispectral, and shortwave infrared imagery with resolutions of 0.31 m, 1.24 m, and 3.7 m, respectively. It supports both stereo (forward and backward view) and tri-stereo (forward, nadir, and backward view) acquisition modes.



(a) (b)

Figure 1. VHR satellite sensors: (a) Pléiades and (b) WorldView-3 (images from: https://earth.esa.int/eogateway/missions)

Numerous studies have explored the potential of surface modeling using VHR satellite imagery and highlighted the advantages of utilizing tri-stereo images over stereo images for generating height models. For example, the findings of Panagiotakis [11] indicate that DSMs generated through tri-stereo analysis achieve superior accuracy, with an RMSEz of 1.17 m, compared to stereo-pair DSMs, which result in a lower performance (RMSEz of 1.48 m for forward-backward and 1.64 m for forward-nadir). Moreover, DEMs derived from Pléiades stereo and tri-stereo acquisitions have been utilized for estimating lava flow volumes [2] and assessing height changes caused by earthquakes [15]. The extraction of DSMs from WorldView-3 stereo images was assessed by [7], revealing elevation biases of approximately 0.62 m when compared to 7,256 LiDAR checkpoints.

Photogrammetrically derived DEMs play a significant role in many engineering, land planning, geomorphology, forestry and infrastructure applications. To ensure reliable and precise analyses in the multiple applications, surface models with high quality are required. In this study, we aim to investigate the performance of DEMs derived from Pléiades and WorldView-3 imagery, focusing on several key research questions:

(1) How do different acquisition geometries—such as stereo versus tri-stereo, variations in Ground Sampling Distance (GSD), viewing angles, and convergence angles—affect the quality of the reconstructed Digital Surface Models (DSMs)?

(2) Which combinations of scenes yield the highest accuracy in DSM reconstruction?

(3) What is the accuracy potential of DEMs derived from Pléiades and WorldView-3 sensors, both with and without Ground Control Points (GCPs), particularly in open and unobstructed areas?

(4) What are the differences in the overlap regions of DSMs produced by Pléiades and WorldView-3, and how do these differences impact the overall model accuracy?

By addressing these questions, the present study seeks to provide valuable insights into the capabilities and limitations of Pléiades and WorldView-3 sensors for high-accuracy DSM generation. The results will not only improve the understanding of the factors influencing DEM quality but also offer practical recommendations for optimizing acquisition strategies and processing workflows in diverse applications.

2. Study area and VHR datasets

The study area, situated in Allentsteig, Lower Austria (48°30'30"N; 15°08'34"E; WGS84, 33N), is characterized by hilly terrain with elevations ranging from 300 m to 690 m above sea level. The region is predominantly covered by arable lands and coniferous forests, with urban, suburban, and rural areas present but occupying only a small portion of the overall extent. For the current study area, analyses were performed using tri-stereo satellite images from two distinct VHR optical sensors: Pléiades1B and WorldView-3 (Figure 1). Each set of three images was captured from different along-track positions of the satellite: forward (F), near nadir (N), and backward (B) views.

Table 1. Pléiades and WorldView-3 VHR satellite imagery datasets acquisition

Tri-stereo Pléiades satellite imagery	Tri-stereo WorldView-3 satellite imagery
- Orbit height : 694 km - Speed: ~ 7.5 km/s - Time interval: 23 s - Travelled distance: 167.8 km - Area coverage: 159 km^2	- Orbit height : 617 km - Speed: ~ 7.5 km/s - Time interval: 37 s - Travelled distance: 279.7 km - Area coverage: 100 km^2
Pansharpened images 4 Bands: R, G, B, NIR Overlap Area ~44.5 km^2	

(a) (b)

Figure 2. Comparative view of the same area from: (a) Pléiades and (b) WorldView-3 satellite images

Figure 2 presents a visual comparison of a selected area from the pan-sharpened (near) nadir images from Pléiades (left) and WorldView-3 (right) to emphasize the difference in resolution, 0.7 m for Pléiades and 0.31 m for WorldView-3. Both images show the same features: streets, buildings, cars, and trees, but due to the higher resolution of WorldView-3, the corresponding satellite image reveals more detail, offering a sharper and more defined view. The geometric image acquisition properties are provided in Table 2.

Table 2. Acquisition properties for Pléiades and WorldView-3 data for the study area

Sensor Type & Acq. date	View	GSD [m]	Viewing Angle [^{o}]	Convergence Angle [^{o}]
Pléiades 13 June 2017	**Forward (F)**	0.71	6.47	7.5 (FN)
	Nadir (N)	0.70	3.41	6.3 (NB)
	Backward (B)	0.71	6.32	13.8 (FB)
WorldView-3 8 April 2018	**Forward (F)**	0.32	13.50	12.7 (FN)
	Nadir (N)	0.31	7.36	12.8 (NB)
	Backward (B)	0.32	13.97	25.5 (FB)

3. Methodology

The entire photogrammetric workflow applied in this study begins with VHR stereo/tri/stereo satellite imagery and includes the following processing steps: image orientation with improved Rational Polynomial Coefficients (RPCs), dense image matching, followed by 3D reconstruction using the forward intersection technique. The resulting 3D point clouds serve as input for deriving high resolution Digital Surface Models through interpolation, followed by accuracy assessment and geolocation improvement using Least Squares Matching (LSM) technique (Figure 3). The image orientation utilizes the sensor model based on eighty Rational Polynomial Coefficients (RPCs), which are provided as metadata together with the satellite images. These coefficients serve as an alternative to the rigorous sensor model and enables the conversion between image and object space coordinates (Poli et al., 2012). The Rational Function Model (RFM) was improved using Ground Control Points (GCPs).

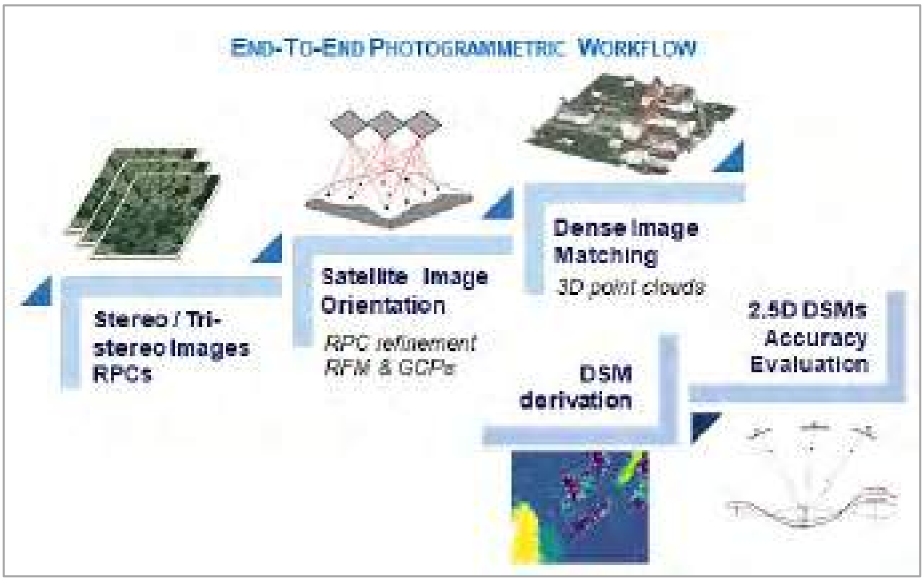


Figure 3. End-To-End Photogrammetric Workflow

To improve this accuracy of the photogrammetrically satellite-based DSMs, they were further aligned to a reference lidar DTM from 2012 (with 1 m ground resolution and 0.11 m vertical accuracy) by applying an affine 3D transformation using the Least Squares Matching Technique (LSM) with 12 parameters.

4. Results and discussion

4.1 Dense image matching results

Dense image matching was carried out for all three images (forward-nadir-backward, FNB) of the triplet, as well as for each stereo pair: forward-backward (FB), forward-nadir (FN), and nadir-backward (NB). The 3D object point coordinates were determined through forward intersections. Overall, the reconstructed point clouds exhibit a regular distribution, with one point per image pixel, resulting in densities of 4 points/m² for Pléiades and 12 points/m² for WV-3 (figure 4).

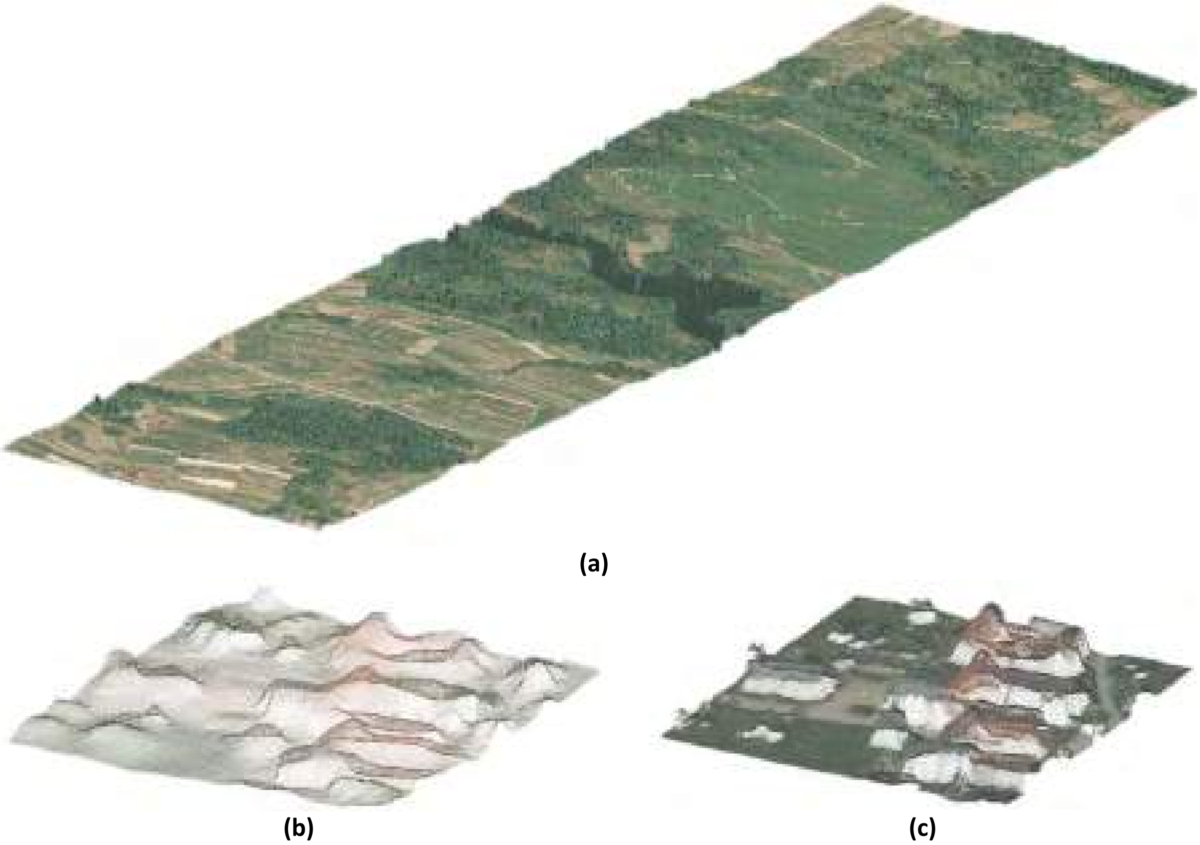
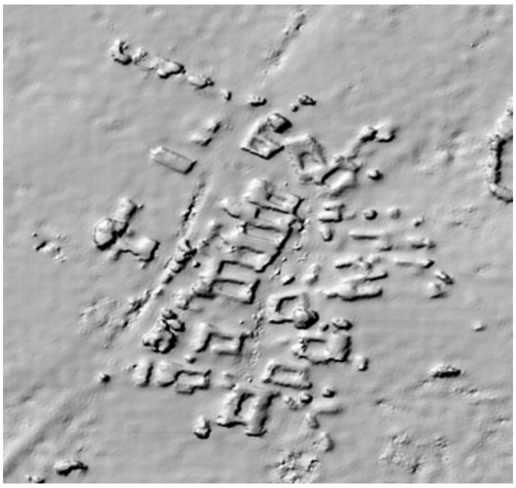


Figure 4. Image matching results: (a) Overview of the Pléiades RGB 3D point cloud in the overlap area (94 675 460 points); (b) detail view of Pléiades and (c) WorldView-3 point clouds, highlighting the different point cloud densities

4.2 Qualitative Analysis of Pléiades and World-View 3 high resolution DEMs

In the final step, regular raster models of height values (i.e., DSM) at a 0.5 m resolution were generated using a robust moving planes interpolation. Based on the input point density, this approach was selected as the optimal method for preserving surface detail. The model accuracy highly depends on the interpolation strategy and grid resolution. We used a robust moving planes interpolation with a 1 m search radius, selecting a 0.5 m grid size and 10 or 20 neighbors for Pléiades and WV-3 point clouds, respectively. This strategy balances surface fidelity with data density and accuracy. The nDSMs were derived by subtracting the reference LiDAR DTM from the Pléiades and WV-3 DEMs.

Figure 5 shows a visual comparison of the shaded DSMs over Hörmanns village located in the study area. This reveals better details in the World View-3 DSM with sharper house edges and smoother open fields compared with the Pleiades DSMs.



(a)

(b)

Figure 5. A quantitative comparative view for the same area (Hörmanns village) from: (a) Shaded view of Pléiades DSM and (b) Shaded view of WorldView-3 DSM

4.3 Quantitative Analysis of Pléiades and World-View 3 high resolution DEMs

We assessed the vertical quality of the DEMs from each image combination by comparing them to the Ground Checkpoints' elevations. Vertical accuracy in open areas was determined by calculating RMSEs between reference and obtained Z coordinates for each DEM. For each Pléiades image combination, vertical quality was evaluated using ground checkpoints, both before and after applying the LSM transformation (Table 3). RMSE values before LSM ranged from 0.27 m (FNB) to 0.35 m (NB), with the LSM transformation significantly reducing RMSEs to as low as 0.20 m (FNB).

The accuracy of the WorldView-3 DEM is evaluated by comparing the elevations of GCPs and CPs with those extracted from the computed DEM (Table 6). The results improved after applying the LSM, with the best accuracy for GCPs in the FNB combination, achieving 0.10 m (Table 4).

Table 3. RMSE values in Z-direction for GCPs and CPs for Pléiades DEMs

GCPs / CPs	RMSE [m]							
	Before LSM				After LSM			
	FNB	FB	FN	NB	FNB	FB	FN	NB
50 GCPs	0.27	0.28	0.30	0.35	0.19	0.20	0.23	0.25
50 CPs	0.31	0.31	0.36	0.38	0.25	0.26	0.32	0.34

Table 4. RMSE values in Z-direction for GCPs and CPs for WorldView-3 DEMs

GCPs / CPs	RMSE [m]							
	Before LSM				After LSM			
	FNB	FB	FN	NB	FNB	FB	FN	NB
36 GCPs	0.18	0.19	0.22	0.25	0.10	0.11	0.14	0.17
50 CPs	0.21	0.22	0.23	0.29	0.16	0.16	0.18	0.20

Finally, the interpolated DEMs for each combination in open, unobstructed areas were compared with the ALS reference data. Visual inspection shows that, after applying the LSM transformation, there is a good agreement between the DEMs and the reference DTM (Figure 6).

The statistical results indicate that the DIM terrain heights are consistently shifted by approximately 1 m, but this shift is reduced to a median close to zero after applying the LSM transformation. The FNB and FB image combinations result in slightly better accuracy than the FN and NB combinations (Table 5).

Pléiades nDSMs

Before LSM

After LSM

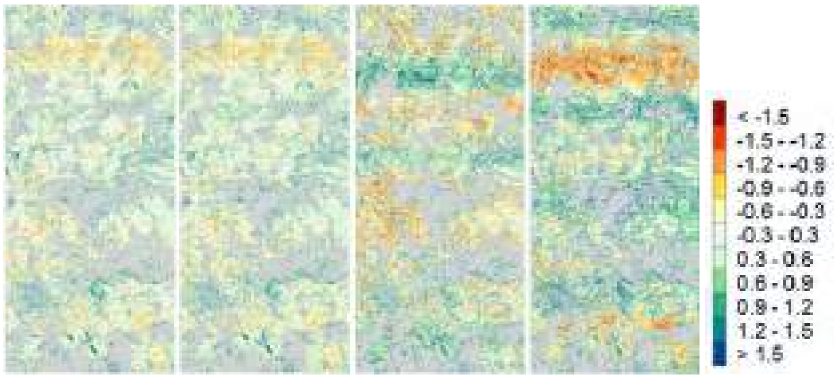
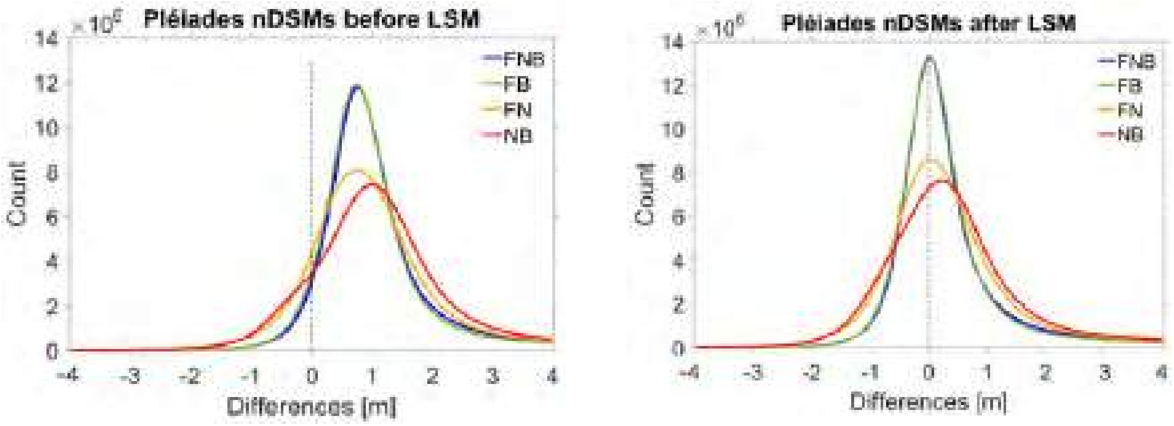


Figure 6. Pléiades nDSMs (FNB, FB, FN, NB) with color-coded elevation differences (in meters, masked areas are shown in grey)



(a) **(b)**

Figure 7. Pléiades nDSMs elevation distribution histograms: (a) before LSM and (b) after LSM

Table 5. Accuracy assessment of Pléiades DEMs in open areas (values are in meters)

Scene Comb.	Before LSM				After LSM			
	Mean	Std	σ_{MAD}	RMS	Mean	Std	σ_{MAD}	RMS
FNB	0.80	0.53	0.51	0.96	0.15	0.60	0.50	0.61
FB	0.77	0.53	0.51	0.93	0.13	0.58	0.50	0.60
FN	0.72	0.65	0.68	0.97	0.13	0.75	0.72	0.76
NB	0.78	0.70	0.73	1.04	0.17	0.79	0.80	0.81

Similar visual comparison elevation differences (Figure 9) and statistical analysis was performed for the WorldView-3 DEMs, showing improved vertical accuracies for the open, free areas, after applying the LSM transformation, to the best mean value of -0.01 m for the NB combination (Table 6). The non-Gaussian distributions of the normalized elevations (nDSM) for the tri-stereo and stereo images are shown in Figure 9, both before and after applying the LSM. Initially, the histogram for the NB combination, which had two peaks and an RMSE of 0.47 m, is corrected by the LSM transformation, resulting in a reduced RMSE of 0.34 m.

WorldView-3 nDSMs

Before LSM

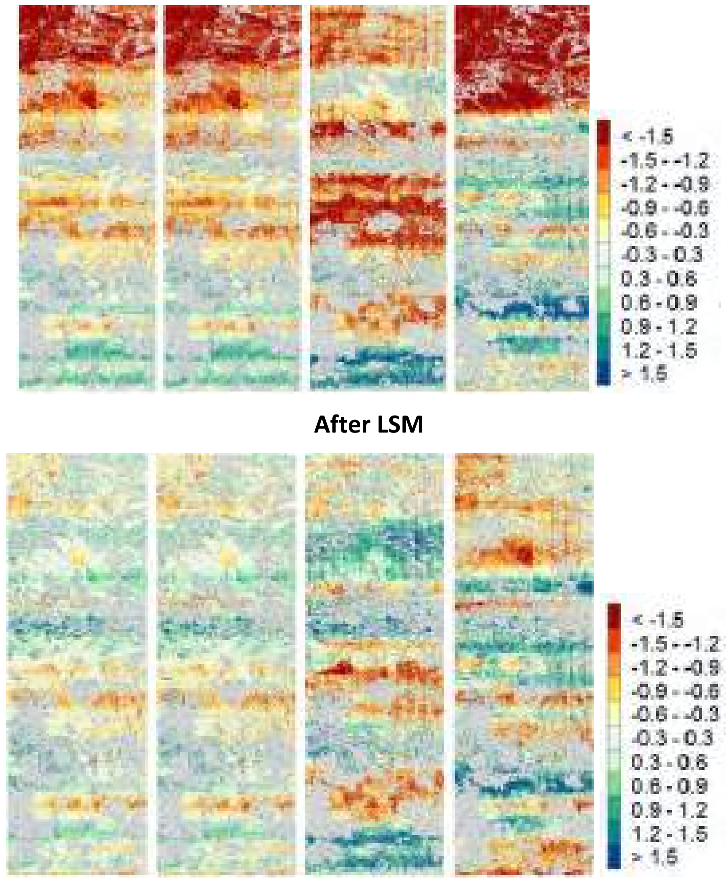
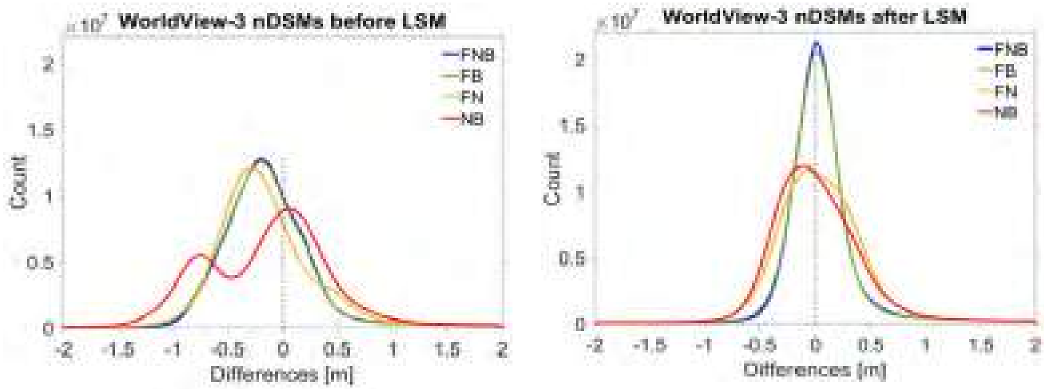


Figure 8. WorldView-3 nDSMs (FNB, FB, FN, NB) with color-coded elevation differences (in meters, masked areas are shown in grey)



(a) (b)

Figure 9. WorldView-3 nDSMs elevation distribution histograms: (a) before LSM and (b) after LSM

Table 6. Accuracy assessment of WorldView-3 DEMs in open areas (values are in meters)

Scene Comb.	Before LSM				After LSM			
	Mean	Std	σ_{MAD}	RMSE	Mean	Std	σ_{MAD}	RMSE
FNB	-0.16	0.33	0.33	0.37	0.03	0.24	0.19	0.24
FB	-0.17	0.34	0.33	0.38	0.02	0.24	0.20	0.24
FN	-0.17	0.37	0.34	0.41	0.03	0.33	0.34	0.33
NB	-0.11	0.46	0.48	0.47	-0.01	0.34	0.34	0.34

4.4 Comparative analysis of Pléiades and World-View 3 DEMs accuracy

From a comparative view of the statistical results, the impact of including GCPs in the satellite image orientation phase is crucial for improving the vertical DEMs accuracies from 18 m and 3.8 m to 0.96 m and 0.37 m for Pleiades and World View-3, respectively. Furthermore, the fractional difference in accuracy (from 0.96 m to 0.37 m) when using GCPs closely matches the fractional difference between the GSDs of the two sensors (0.7 m to 0.3 m).

Table 7. Vertical accuracy of derived Pléiades & WV-3 DEMs (RMS [m / GSD])

	Sensor	Pléiades (0.70 m GSD)	WorldView – 3 (0.31 m GSD)
Without GCPs	before	**18.0 / 25.7**	**3.8 / 12.3**
	after LSM	0.61 / 0.8	0.24 / 0.8
With GCPs	before	**0.96 / 1.4**	**0.37 / 1.2**
	after LSM	0.60 / 0.8	0.24 / 0.8

5. Conclusions

In the present study, eight digital elevation models (DEMs) derived from different satellite images pairwise combinations were evaluated for their vertical accuracy using geodetic measurements (RTK GCPs), CPs, and an ALS DTM as reference data. The quality analysis revealed systematic errors and non-normal distributions. However, the application of affine 3D LSM transformation led to significant accuracy improvements. By employing careful georeferencing with LSM over stable areas, change detection between Pléiades and WorldView-3 satellite images was achieved with an accuracy of only 0.50 m, demonstrating the high potential of these VHR satellite images.

Key findings include: the differences between Tri-stereo and FB stereo pairs were minimal, although the tri-stereo combination showed slightly higher accuracy, the small acquisition convergence angles (FN & NB) negatively affected vertical accuracy by reducing the geometric intersection quality, WorldView-3, with its smaller ground sampling distance (0.31 m), provided higher accuracy than Pléiades, offering more reliable representation of surface details.

Overall, VHR satellite images, with accuracies comparable to airborne photogrammetrically derived DEMs, present a valuable complementary solution to aerial datasets for generating high-resolution digital elevation models over large areas.

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ANALYSIS OF THE IMPLEMENTATION OF THE NATIONAL CADASTRE AND LAND REGISTRATION PROGRAM IN THE NORTH-EAST DEVELOPMENT REGION

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Abstract *The National Cadastre and Land-Registration Program (PNCCF) is one of Romania's most comprehensive governmental initiatives, aiming to systematically register properties in both the national and land registries. This paper seeks to evaluate the implementation of the PNCCF in the North-East Development Region—one of the country's largest and most diverse areas—by identifying the progress, challenges, and impact on economic and social development. The paper begins with a detailed overview of the program's legislative and institutional framework, highlighting the significance of cadastral registration for efficient land management, property security, and economic growth. It outlines the stages of PNCCF implementation, with a focus on the counties of Bacău, Botoșani, Iași, Neamț, Suceava, and Vaslui, each possessing unique geographic and demographic traits that shape the program's advancement. A key element of this analysis is the integration of Geographic Information Systems (GIS) technologies, which facilitate the collection, storage, and analysis of cadastral data. By incorporating cadastral information into GIS platforms, authorities can visualize and manage property data in real-time, improving decision-making in territorial planning. This technology enhances accuracy and transparency, reduces errors in the land registration process, and ensures more efficient management of cadastral data.*

Keywords: *land administration, GIS, land registration*

6. Introduction

The systematic cadastre and the National Cadastre and Land Book Program (PNCCF) represent significant initiatives aimed at the free, complete, and uniform registration of all properties in Romania within the integrated cadastre and land book system. The PNCCF is regulated by Law No. 7/1996 on cadastre and real estate publicity, as subsequently amended and supplemented and supported by Government Decision No. 294/2015. Its primary goal is to align the Romanian cadastral system with European requirements and standards [1]. By implementing this program, the objectives include protecting property rights, reducing disputes over property boundaries, facilitating real estate transactions, and supporting economic development and investments [2].

The implementation of the PNCCF is coordinated by the National Agency for Cadastre and Real Estate Publicity (ANCPI) in collaboration with 40 county offices and the National Cartography Center, ensuring the standardization of procedures nationwide [3]. The systematic cadastre process involves multiple stages, conducted both in the field and in the office. The field stage includes measuring properties within a cadastral sector or an entire administrative-territorial unit, identifying owners and holders of real rights, and collecting the necessary legal information for opening land books. In the case of Sector 20 in the extravillan area of the Bălțați Administrative-Territorial Unit (ATU), these operations included detailed topographic measurements, the use of orthophoto plans, and the summoning of property owners to clarify the legal status of their properties.

The office stage includes processing the data collected in the field, correlating technical and legal information, and generating essential cadastral documents such as the cadastral plan, the property sheet, and the cadastral register of properties. The cadastral plan represents the graphic component of the records, while the property sheet contains the legal and technical data associated with each property. These documents are integrated into the national IT system managed by ANCPI, facilitating the updating and querying of cadastral databases [3].

The use of specialized software applications in the systematic cadastre process contributes to optimizing the time required to generate technical documents and reducing data processing errors. However, significant challenges persist, such as the lack of ownership documents, identifying deceased property owners, or discrepancies between current measurements and the legal data recorded in land books [5].

The PNCCF's implementation offers significant advantages, such as clarifying property legal status, enhancing transparency in property management, and promoting economic growth by improving access to financing and investments. Furthermore, the program supports agricultural development, modernizes infrastructure, and simplifies the allocation of subsidies for agricultural land. As a result, the systematic cadastre under the PNCCF plays a pivotal role in advancing sustainable development and ensuring the effective management of national real estate assets.

7. Materials and Methods

Data collection for systematic cadastre works in the North-East Development Region was carried out by extracting information from the websites of the National Agency for Cadastre and Land Registration (ANCPI) and the ANCPI Geoportal. This information was organized into a database containing tables for each administrative-territorial unit (ATU) in the counties of Bacău, Botoșani, Iași, Neamț, Suceava, and Vaslui. The collected data were used to assess the progress of systematic cadastre works by calculating the percentage of completion based on the number of cadastral sectors in progress or finalized relative to the total number of sectors for each ATU. This calculation facilitates a clear evaluation of progress, and the results were graphically represented on thematic maps, providing a clear overview of the cadastral works' status.

This study utilized documentary materials regulated by national and European legislation on cadastre and land registration, namely Law No. 7/1996 on cadastre and real estate publicity, as subsequently amended, and Government Decision No. 294/2015, which details the implementation of the National Cadastre and Land Book Program (PNCCF) [1][2]. Additionally, ANCPI's technical manuals and guides [6] were employed, offering detailed instructions for carrying out systematic cadastre.

Relevant literature was also consulted for the study. Ion et al. (2018) discuss the application of modern technologies in cadastre and cartography, including the use of high-precision GNSS and total stations for topographic measurements [7]. Popescu et al. (2015) examine the integration of cadastre and land book data into a national IT system, emphasizing the importance of continuously updating cadastral data to align with European Union requirements [8]. Văduva (2017) provides a detailed analysis of the technical and administrative procedures involved in a systematic cadastre, with examples from various regions of Romania [9].

Regarding the equipment used, high-precision topographic measuring instruments, including total stations and high-precision GNSS devices, were employed to ensure the accuracy of the data collected in the field. Additionally, for updating cadastral maps and integrating graphic data, orthophotoplans were utilized and subsequently vectorized [3].

The applied methodology was carried out in two main stages: the field stage and the office stage. During the field stage, topographic measurements were performed to delineate properties, and the necessary information was collected to identify owners and holders of real rights. These activities aimed to complete land books and update existing cadastral data [5]. Property owners were summoned to clarify any discrepancies between field data and cadastral records [5].

After completing the field measurements, the process transitioned to the office stage, which involved processing the collected technical data and integrating it into the national IT system managed by the National Agency for Cadastre and Real Estate Publicity (ANCPI). In this phase, cadastral plans and property data sheets were generated and supplemented with detailed technical and legal information, reflecting the current status of properties in the studied sector [3][6]. Where discrepancies between measured data and existing land book records were identified, appropriate corrections were made by ANCPI regulations.

The final documents generated included cadastral plans, technical property sheets, and cadastral registers, which were used to update land books and create a unified and comprehensive cadastral system at the level of the entire administrative-territorial unit [3]. These data were processed and analyzed using specialized IT systems, enabling the generation of statistical reports and the visualization of information through thematic maps, thereby facilitating the interpretation and analysis of results [6].

To evaluate the progress of cadastral works, the following formula was applied:

Progress Percentage = $(b/a) \times 100$

where a represents the number of cadastral sectors in progress or completed, and b represents the total number of cadastral sectors in each administrative-territorial unit (ATU). The result was expressed as a percentage and represented on thematic maps for each ATU in the studied counties, providing an overview of the status of cadastral works.

In the counties of the North-East Development Region, the distribution of ATUs based on the progress of systematic cadastral works varies significantly, reflecting differing levels of implementation of the National Cadastre and Land Book Program (PNCCF) across these territories (Figure 1).

Vaslui stands out with the highest percentage of ATUs without ongoing systematic cadastral works, at 56.98%. This indicates that in more than half of the county's ATUs, no contracts have been signed for cadastre works under PNCCF. A significant percentage of ATUs without systematic cadastre is also observed in Neamț County, where 40.96% of total sectors lack cadastral works. In Bacău and Suceava counties, the percentage of ATUs without cadastre works is also considerable, at 35.48% and 21.93%, respectively. Meanwhile, in Iași and Botoșani counties, the percentage of sectors without cadastre works is smaller but still noteworthy, at 11.54% and 16.33%, respectively. These figures suggest slower implementation of the PNCCF in certain areas, which may hinder access to a complete and unified cadastral database.

In the category of ATUs with up to 50% of sectors contracted, Botoșani County leads with 85.90%, indicating significant progress in systematic cadastral works in most ATUs. This suggests that, overall, Botoșani benefits from a more advanced implementation of the PNCCF compared to other counties in the region.

Regarding ATUs with more than 50% of sectors contracted, Iași stands out with 24.49%, indicating substantial progress in systematic cadastral works. This reflects a strong commitment to the program's implementation in this county, signaling faster alignment with national cadastral objectives.

Finally, Bacău County reports 10.75% of ATUs where all sectors are contracted, signifying that systematic cadastral works are fully underway in these ATUs. This highlights remarkable progress in the implementation of the PNCCF.

These data underline significant differences in the pace of program implementation across the North-East Development Region, which could impact property management and economic development in these territories.

To assess the progress of cadastral works, the following formula was applied:

Progress Percentage = $(b/a) \times 100$, where a represents the number of cadastral sectors underway or completed, and b represents the total number of cadastral sectors in each administrative-territorial unit (ATU). The resulting percentage was expressed as a value and visualized on thematic maps for each ATU within the studied counties, providing an overview of the cadastral work status.

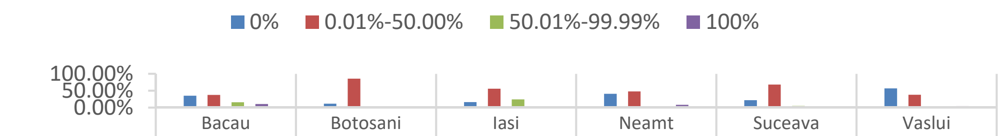
In the counties of the North-East Development Region, the distribution of ATUs based on the status of systematic cadastral works varies significantly, reflecting the uneven progress in implementing the National Cadastre and Land Registration Program (PNCCF) across these areas (Figure 1).

Vaslui stands out with the highest percentage of ATUs lacking ongoing systematic cadastral works, at 56.98%. This indicates that more than half of the county's ATUs have not signed contracts for cadastral works under the PNCCF. A significant proportion of ATUs without systematic cadastral works is also observed in Neamț County, where 40.96% of sectors do not benefit from such works. In Bacău and Suceava counties, the percentage of ATUs without cadastral works is also considerable, at 35.48% and 21.93%, respectively. Meanwhile, in Iași and Botoșani counties, the percentage of sectors without cadastral works is lower but still noteworthy, at 11.54% and 16.33%, respectively. These figures suggest a slower implementation of the PNCCF in certain areas, potentially impacting access to a complete and unified cadastral database.

In the category of ATUs with up to 50% of sectors contracted, Botoșani County leads with a percentage of 85.90%, indicating significant progress in systematic cadastral works in most ATUs. This suggests that, overall, Botoșani County benefits from more advanced PNCCF implementation compared to other counties in the region.

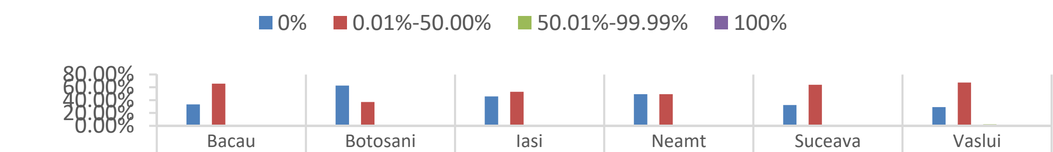
Regarding ATUs with more than 50% of sectors contracted, Iași stands out with a percentage of 24.49%, signaling substantial progress in systematic cadastral works. This reflects a strong commitment to implementing the program in this county, indicating a faster alignment with national cadastral objectives.

Finally, Bacău County shows that 10.75% of its ATUs have all sectors contracted, meaning that systematic cadastral works are fully underway in these ATUs, a sign of remarkable progress in PNCCF implementation. These data highlight significant differences in the program's implementation pace within the North-East Development Region, which may influence property management and economic development in these areas.



	Bacau	Botosani	Iasi	Neamt	Suceava	Vaslui
0%	35.48%	11.54%	16.33%	40.96%	21.93%	56.98%
0.01%-50.00%	37.63%	85.90%	56.12%	48.19%	68.42%	38.37%
50.01%-99.99%	16.13%	0%	24.49%	2.41%	5.26%	0%
100%	10.75%	2.56%	3.06%	8.43%	4.39%	4.65%

Figure 1. The percentage of ATUs in each county with ongoing systematic cadastral works



	Bacau	Botosani	Iasi	Neamt	Suceava	Vaslui
0%	33.33%	62.82%	45.92%	49.40%	32.46%	29.07%
0.01%-50.00%	65.59%	37.18%	53.06%	49.40%	64.04%	67.44%
50.01%-99.99%	0%	0%	0%	0%	1.75%	2.33%
100%	1.08%	0%	1.02%	1.20%	1.75%	1.16%

Figure 2. The ATUs in each county completed systematic cadastral works for each study

Analyzing the diagram regarding the status of systematic cadastral works in the counties of the North-East Development Region, it is observed that Botoșani County has the highest percentage of ATUs with no completed works (62.82%), followed by Neamț and Iași, where nearly half of the ATUs are in the same situation (Figure 2).

In the category of ATUs with up to 50% of sectors contracted, Vaslui, Bacău, and Suceava show the highest percentages, indicating moderate progress. Vaslui and Suceava also have a small percentage of ATUs with more than 50% of sectors contracted, while Suceava leads in ATUs fully completed (1.75%). Botoșani has no ATUs with fully completed works (Figure 3).

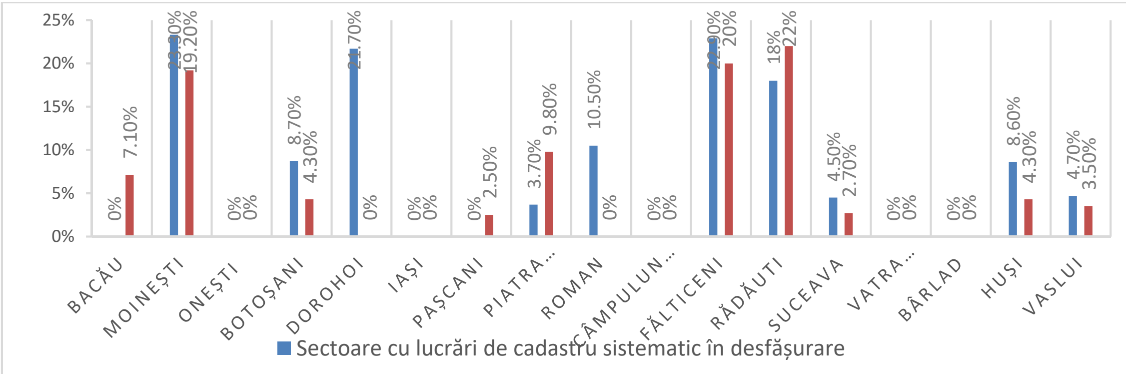


Figure 3. Systematic cadastral works in progress and completed at the municipal level

8. Case Study – General Cadastre in Baltati Commune

The North-East Development Region is the largest and most populated development region in Romania, encompassing Bucovina and a significant part of Moldova. This region includes six counties: Bacău, Botoșani, Iași, Neamț, Suceava, and Vaslui (Figure 4.).

The study area is represented by Sector 20, located in the extravillan area of the Baltati ATU. Unlike sporadic cadastre, which is carried out only at the request of landowners, systematic cadastre is generalized and mandatory, aiming to achieve a complete and unified mapping of real estate properties.

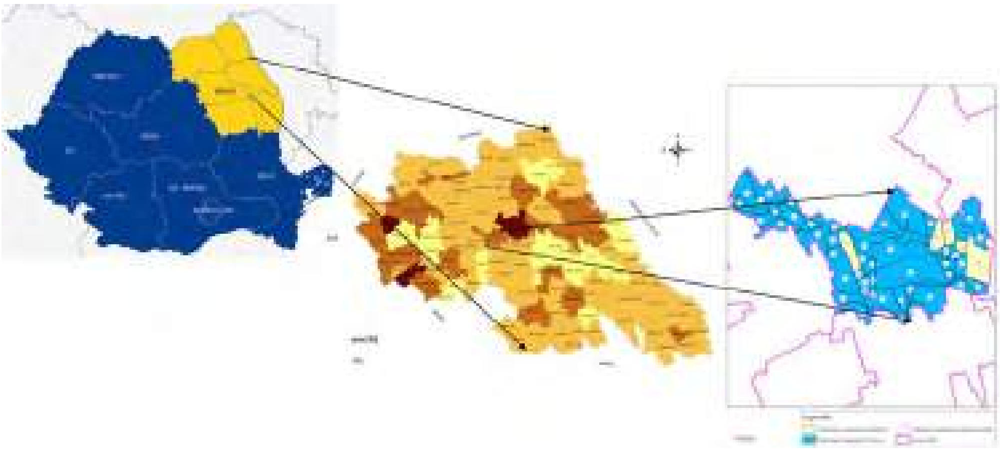


Figure 4. Classification of Sector 20 – rural area of Baltati commune

The completion of the general cadastre in Sector 20, located in the extravillan area of Bălțați Commune, involved conducting topographic surveys for all properties within the administrative-territorial unit. The aim was to accurately identify property boundaries. According to the Cadastre Regulation, property delimitation was carried out through topographic measurements of detail points or a combined method, including measurements of linear details and orthophotoplan vectorization (Figure 5.).

This phase also focused on identifying property owners or holders of real rights over the properties to open land books for each property through a single procedure, either at the cadastral sector level or for the entire administrative-territorial unit. For unfenced properties or cases requiring clarification, owners were summoned. In their absence, the procedure continued with the participation of municipal representatives.

The implementation of this system for recording and inventorying properties is an exclusive responsibility of the Romanian State, carried out through the National Agency for Cadastre and Land Registration (ANCPI), which manages the integration of properties, the opening of land books, and their ongoing records.

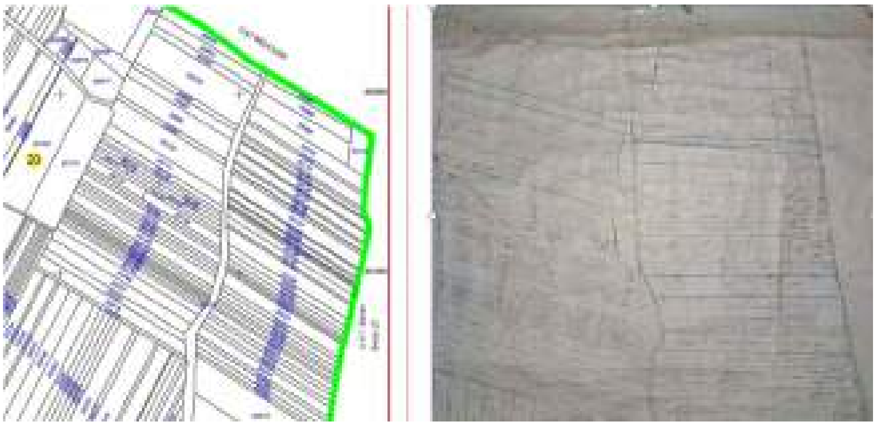


Figure 5. The creation of the parcel plan for Sector 20 using parcel plans correlated with property deeds

The office stage involved processing the data collected in the field and performing the necessary checks to ensure the accuracy of the information. The property boundaries were taken from existing cadastral records, and in case of discrepancies with the new measurements, the graphical representation was adjusted accordingly. These modifications could affect the geometry and placement (through translation or rotation), as well as the area of the property recorded in the land book. If the information in the existing land book did not match the reality on the ground, owners from the old land books were not directly transferred to the new records (Figure 6.).

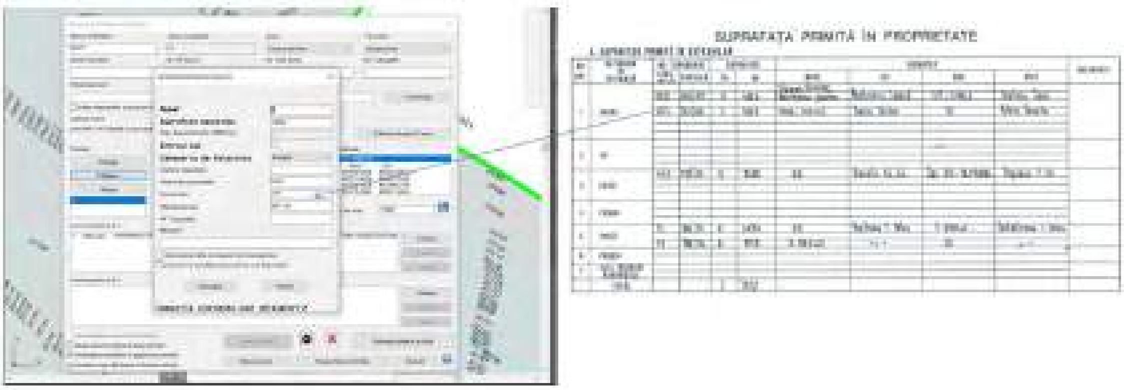


Figure 6. Entering data related to parcels

In such cases, the contractor carried out the necessary adjustments based on the specifics of each situation (Figure 7.). For example, the following cases were managed:

- Deceased owners without a certificate of inheritance;
- Possessors who purchased the land from a previously registered owner;
- Lack of property documents;
- Discrepancies between measurements and the data in the documents.

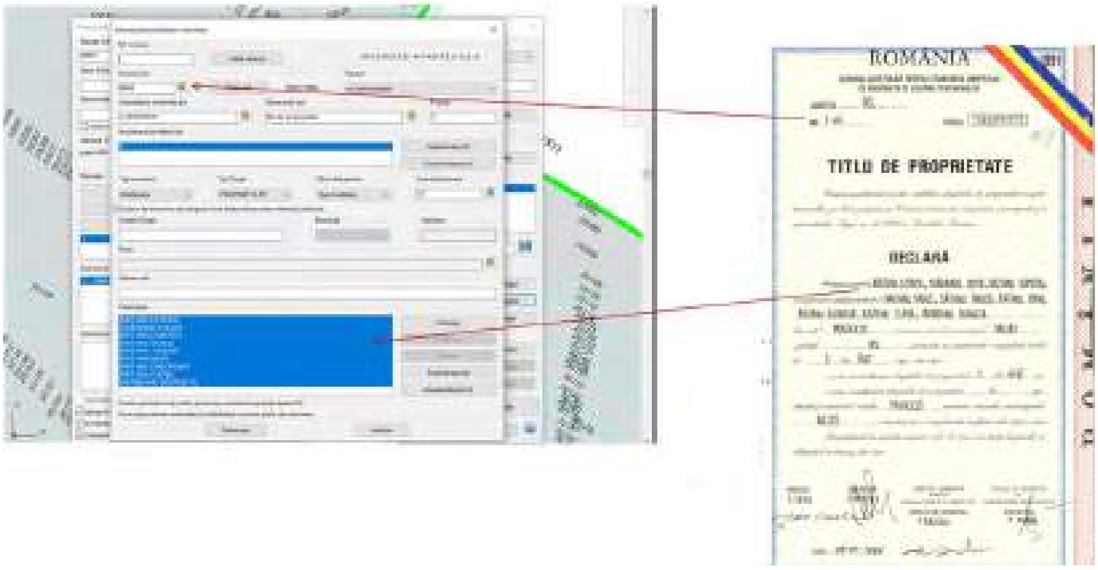
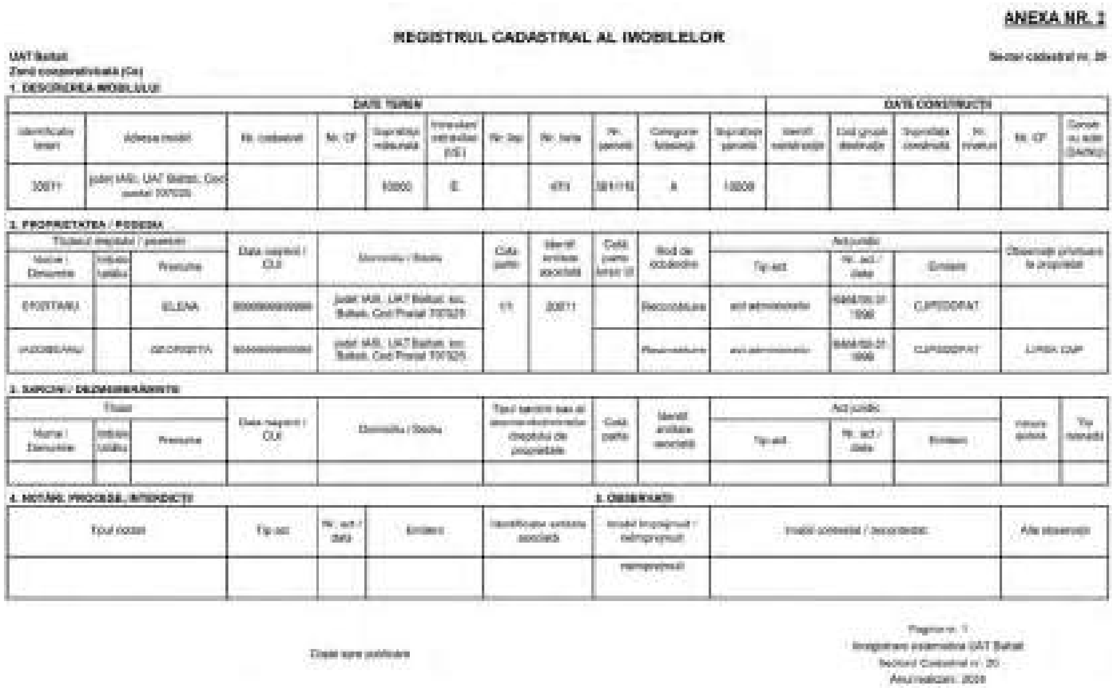


Figure 7. The introduction of data regarding registration (legal aspect)

The technical documents associated with systematic cadastral works represent the results in tabular and graphical format obtained through querying the database of the information system developed at the level of the administrative-territorial unit [10]. These documents serve to provide the necessary technical support for the automatic registration of properties in the land book. They are developed by cadastral sectors and must reflect the current situation of the properties within the administrative-territorial unit, both from a technical and legal perspective (Figure 8).

Figure 8. The cadastral plan of Sector 20 and the property data sheet for the property with cadastre number 20071

The cadastral register of properties is a tabular technical document prepared for each cadastral sector, containing technical and legal information related to each registered property (Figure 9).


ANEXA NR. 2

REGISTRUL CADASTRAL AL IMOBILELOR

UAT Baltati

Sector cadastral nr. 20

1. DESCRIEREA IMOBILULUI

2. PROPRIETATEA / POSESIA

3. SARCINI / DEZMEMBRĂMINTE

4. NOTĂRI, PROCESE, INTERDICȚII

5. OBSERVAȚII

Figure 9. The cadastral register of the property with cadastre number 20071.

The holders of real property rights, possessors, and other holders are registered in alphabetical order, and for each of them, all properties held exclusively and/or jointly within the administrative territory are listed (Figure 10).

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ANEXA Nr. 3

OPISUL ALFABETIC AL TITULARILOR DREPTURILOR REALE DE PROPRIETATE, AL POSESORILOR ȘI AL ALTOR DEȚINĂTORI

judet IASI
UAT Baltati

Nr. crt.	Nume / denumire deținător	Data nașterii / CUI	Identif.	Planșa	Sector cadastral	Adresa imobilului	Suprafața în proprietate	Suprafața în posesie	Observații deținător
1	AA AGRICULTURE FARM SRL	29173083	20019	1	20	judet IASI, UAT Baltati, Cod postal 707025	10000		
2	AA AGRICULTURE FARM SRL	29173083	20104	1	20	judet IASI, UAT Baltati, Cod postal 707025	6400		
3	AA AGRICULTURE FARM SRL	29173083	20159	1	20	judet IASI, UAT Baltati, Cod postal 707025	13559		
4	AA AGRICULTURE FARM SRL	29173083	20202	1	20	judet IASI, UAT Baltati, Cod postal 707025	2319		
5	AGAFITEI EUGENIA	9999999999999	20121	1	20	judet IASI, UAT Baltati, Cod postal 707025	5379		LIPSA CNP
6	AGAFITEI EUGENIA	9999999999999	20125	1	20	judet IASI, UAT Baltati, Cod postal 707025	2009		LIPSA CNP
7	AGRICOVER CREDIT IFN SA	22940237	20266	1	20	judet IASI, UAT Baltati, Cod postal 707025	4875		
8	ANASTASOAIE GHEORGHE	9999999999999	20241	1	20	judet IASI, UAT Baltati, Cod postal 707025	4465		LIPSA CNP
9	ANASTASOAIE GHEORGHE	9999999999999	20243	1	20	judet IASI, UAT Baltati, Cod postal 707025	3435		LIPSA CNP
10	ANTICA DUMITRU	9999999999999	20224	1	20	judet IASI, UAT Baltati, Cod postal 707025	8375		LIPSA CNP
11	ANTICA DUMITRU	9999999999999	[illegible]	1	20	judet IASI, UAT Baltati, Cod postal 707025	[illegible]		LIPSA CNP

Figure 10. The alphabetical list of holders of real property rights, possessors, and other holders

From the data analysis, queries were made regarding the number of registered properties, how many property titles were issued within Sector 20, and how many properties have unidentified owners (Figure 11, Figure 12, Figure 13).

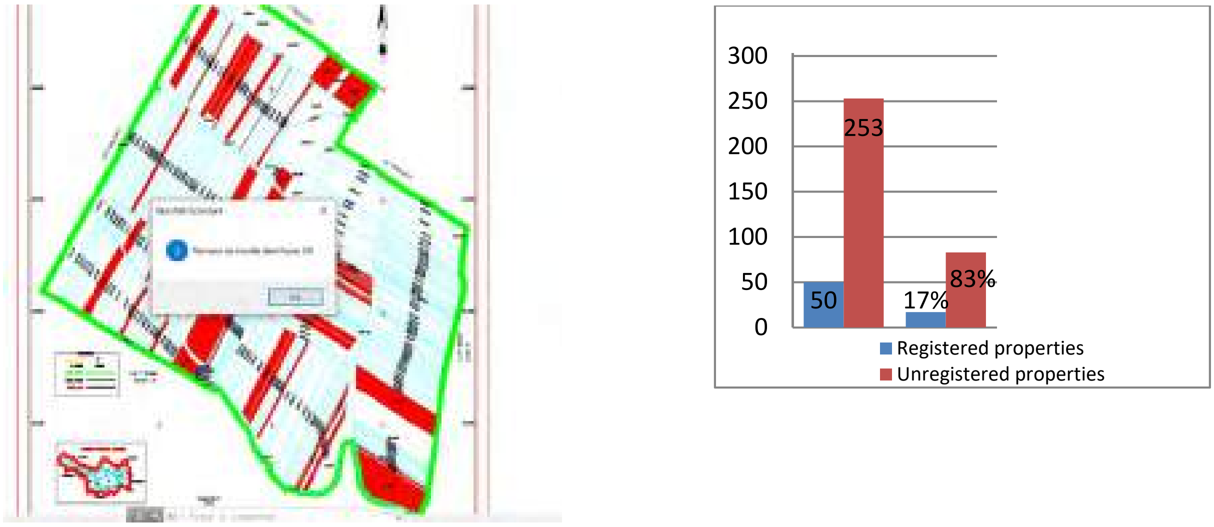

Figure 11. The situation of registered properties

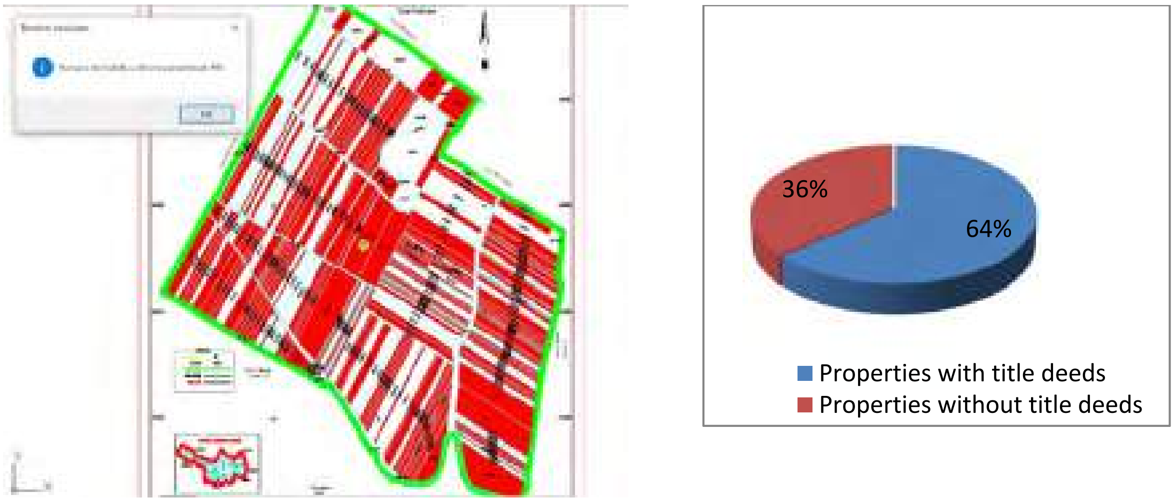

Figure 12. Properties for which property titles have been issued

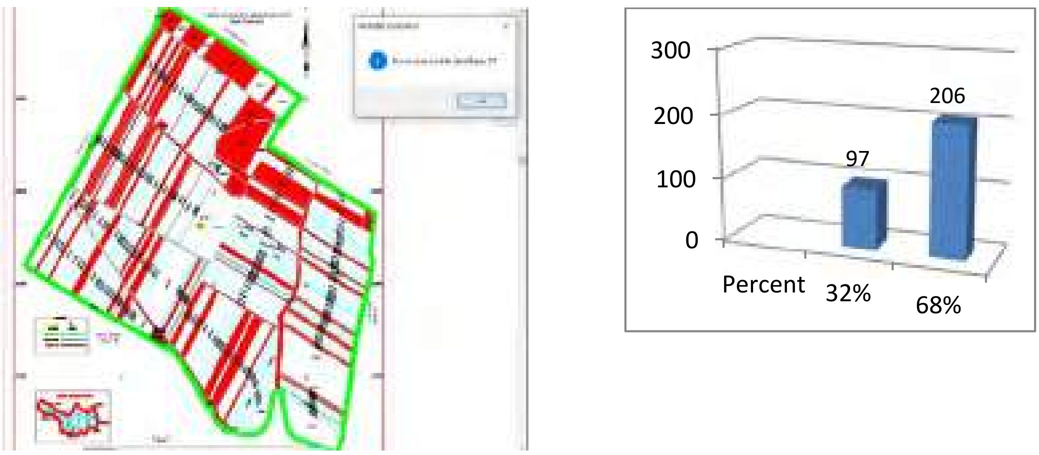

Figure 13. The situation of unidentified properties

9. Conclusions

To accelerate the systematic registration process of properties, the National Agency for Cadastre and Land Registration (ANCPI) implemented a series of legislative and operational measures starting in 2015, facilitating the contracting of cadastral works at the cadastral sector level. An essential role was played by multiannual financing and constant monitoring, which supported both agricultural development and national infrastructure projects.

Local authorities received support in integrating agricultural land (from the Agency for Payments and Intervention in Agriculture - APIA) and infrastructure projects into the cadastral registration program. At the same time, ANCPI periodically updated working procedures, providing guidance and training to local authorities through territorial offices.

The introduced legislative changes simplified administrative processes and allowed for an increase in co-financing levels, contributing to the registration of over 24 million properties by October 31, 2024. The use of specialized software had a positive impact on efficiency, significantly reducing the time required to generate cadastral technical documentation.

However, for approximately 32% of properties, the procedure for possession and issuing property titles is still not completed. Additionally, discrepancies have been identified regarding the names of owners and cadastral identifiers.

A major advantage of the implementation of the National Program for Cadastre and Land Registration (PNCCF) remains the automatic registration of properties in the land book, eliminating the need for subsequent corrections of errors in legal documents.

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METHODOLOGICAL PECULIARITIES WHEN DELIMITING REAL ESTATE IN THE REPUBLIC OF MOLDOVA

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Abstract: *The first declaration of the "2014 Cadastre" mentions the importance of identifying the complete legal situation of all immovable property, both private and public rights. In order to ensure state protection of property rights, all rights to immovable property must be registered in the cadastral system. At the initial stage of the implementation of the land reform, in the Republic of Moldova the main focus of the normative framework was placed on the identification and registration of private property, while public property was neglected. Within this study, the methodological particularities of the delimitation of public property for the purpose of registration in the Real Estate Register are identified.*

Keywords: *delimitation, public property, real estate, cadastral registration*

1. Introduction

The current situation regarding the process of delimitation and registration of public land can be easily interpolated with other periods in the history of the Republic of Moldova, as well as in the history of other countries. The registration of real estate is an important component within the cadastral information system. In the process of maintaining the Real Estate Register, it is important to respect and protect the right of public ownership of land to the same extent as that of private property.

In order to ensure the right of ownership and efficient use of public property of the state and administrative-territorial units, initially, the Republic of Moldova approved the "Law on Public Property Lands and Their Delimitation" no. 91 of 05.04.2007, which allowed the delimitation of land only. By Law no. 91/2007 were massively delimited [1]:

- the publicly owned land related to the national public roads (according to the contract: 3344.70 km of M and R roads) and the land related to the local public roads (according to the contract: 2725.33 km of L roads) from the account of the S.E. "State Administration of Roads";
- the land related to the railways, from the account of the S.E. "Railway of Moldova";
- the lands publicly owned by the State and at the level of UAT II in the Hîncesti district, ATU Găgăuzia, Sîngerei district and Rezina district, from the state budget.

Subsequently, on 05.04.2018, Law no. 91/2007 is repealed and approves the "Law on the delimitation of public property" no. 29 of 05.04.2018 through which delimitation works can be carried out on land, buildings and isolated rooms [2]:

⇒ massively – within the State Program;
⇒ massively – outside the State Program;
⇒ selectively – at the request of the public administration authorities.

The delimitation of public property on a massive scale, outside the State Program, is carried out at the initiative of:

- local public administration authorities, on the territory of an administrative-territorial unit for the achievement of its purposes, from the financial means planned in its budget or obtained from other legal sources [1];

- central public administration authorities, within administrative-territorial areas/units, with the administered lands, from the financial means planned in their budget or obtained from other legal sources.

The manner of delimitation of public immovable property is established in the Regulation approved by Government Decision no. 63 of 11.02.2019 [3]. The structure of property rights according to national legislation is shown in Figure 1, and the legal instruments for the protection of property rights are shown in Figure 2.

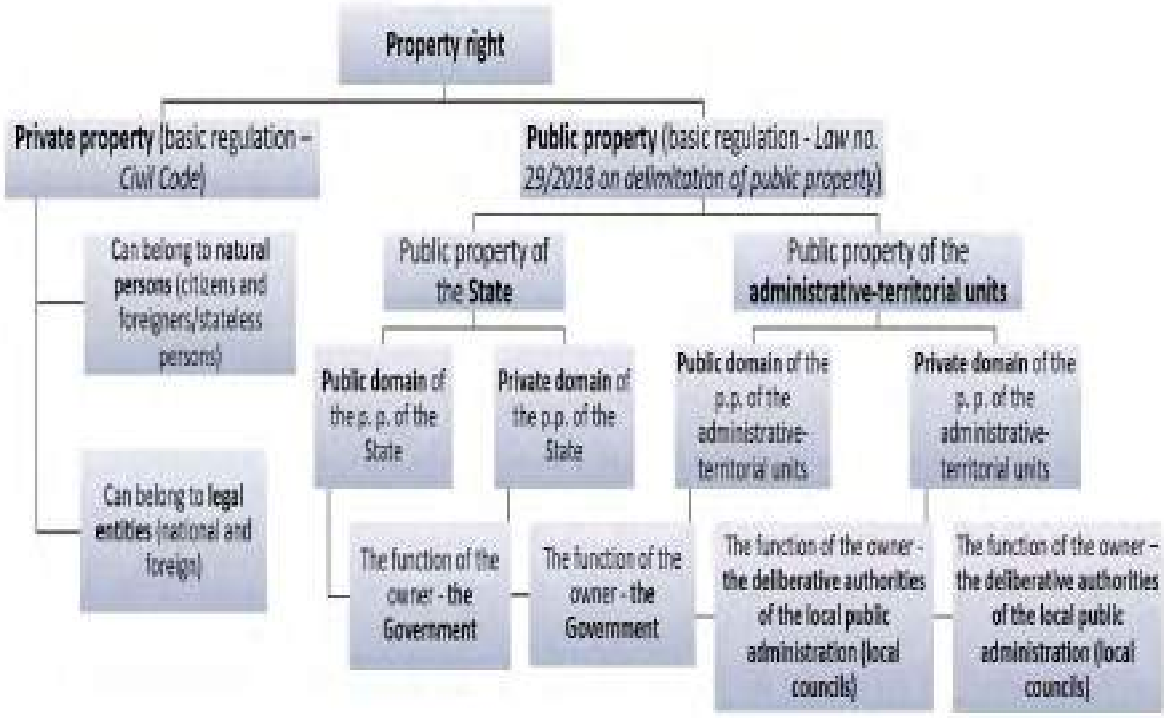

Figure 1. Structure of property rights under national law

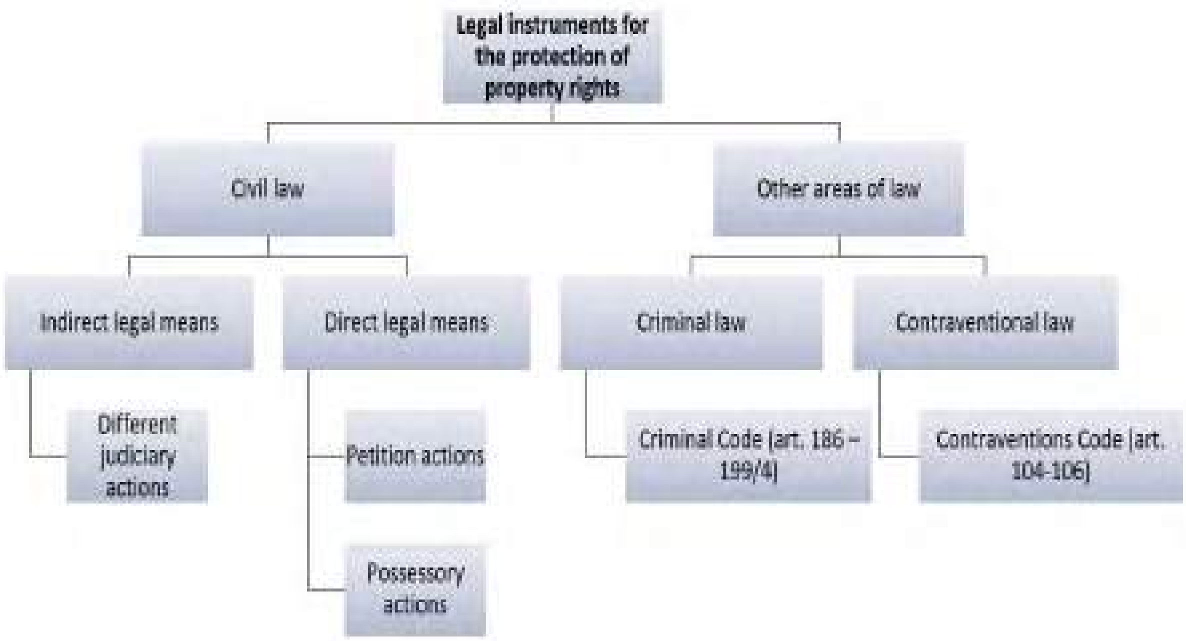

Figure 2. Protection of property rights

2. Delimitation of public property in a massive way, within the State Program

For the purpose of registering privately owned and publicly owned real estate, as well as for the valuation of real estate for taxation purposes, the Republic of Moldova implements the "Land Registration and Valuation Project" (PIEF), in accordance with the "Financing Agreement between the Republic of Moldova" and the "International Development Association", signed in Chisinau on September 17, 2018 and ratified by the Parliament of the Republic of Moldova on November 8, 2018 (Law no. 240/2018), initiated in order to ensure the implementation of the following state programs:

- ⇒ State Program for the creation of the cadastre of real estate for the years 2020-2023 (Government Decision no. 1030/1998, 2020 draft);
- ⇒ State program for the delimitation of real estate, including publicly owned land, for the years 2019–2023 (Government Decision no. 80/2019);
- ⇒ Program of measures regarding the implementation of the new system of valuation of real estate for taxation purposes (Government Decision no. 670/2003).

In order to adjust the scope of the project activities, reduce the target indicators, and cancel part of the funds allocated to the project, at the proposal of the Government of the Republic of Moldova (March, 2022) together with the World Bank team, the PIEF was restructured and extended until April 30, 2026.

Project implementation period:

- ⇒ Initially: January 14, 2019 – June 30, 2024;
- ⇒ After enlargement: January 14, 2019 – April 30, 2026.

Approved budget:

- ⇒ According to initial data – €30.1 million
- ⇒ After restructuring in March 2022 – €23.65 million

The progress of the implementation of the PIEF as of June 30, 2024 under the component "Primary registration of immovable property" is presented in Table 1.

Table 1. Progress of the implementation of the PIEF as of 30 June 2024 under the component "Primary registration of immovable property"

Type of work	Contracted UAT number	UAT number completed on 30.06.2024	Including, the completed UAT number 2024	% cumulative realization
Delimitation of public property	492	57	*8*	12%
Registration of private property	273	98	*56*	36%
Error correction	487	252	*90*	52%

Initially, the PIEF was implemented by the Public Services Agency, as an implementing agency, with the support of the support agencies – the Public Property Agency (APP), on the activities of delimitation of public property and the Geodesy, Cartography and Cadastre Agency (AGCC) on the activities of real estate evaluation and development of the National Spatial Data Infrastructure.

Currently, the AGCC, through the Public Institution "Cadastre of Real Estate", with the support of the APP, are responsible for implementing the delimitation of public property.

One of the main problems that arose within the PIEF program is the failure to meet the deadline for the execution of the works.

In order to solve some issues due to which the deadline for the execution of the works is delayed, the period of public consultation of the materials (more than the deadline of 10 days), the non-approval of the materials by the local councils due to the non-meeting of the councils, the disagreement on the topics addressed, the non-coordination of the delimitation materials by the managers of the public lands at central level (Ministry of Environment, Apele Moldovei), between

July 2023 and September 2024, 24 meetings were organized by the AGCC to inform local public authorities about the progress of the cadastral and delimitation works, with the participation of 288 local authorities and central public authorities involved in this process.

Another solution was proposed that the PIEF should contract only eligible enterprises, which have experience and positive recommendations regarding the execution of the delimitation works and do not have arrears within the Project and the contracting of the UAT for which it is necessary to execute the delimitation works, priority being given to the municipalities in which the massive cadastral works for the private property real estate have not been executed, municipalities that have the necessary documentation and capacities to carry out cadastral works for delimitation and correction of errors, as well as those for which infrastructure investment projects are planned.

An example of the contour plan and geometric plan drawn up during the massive delimitation works is shown in Figure 3.

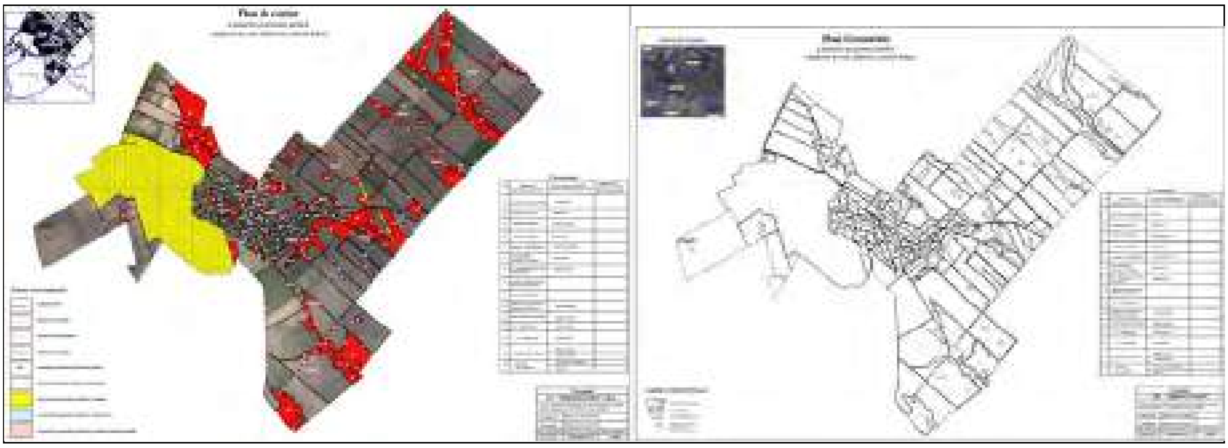

Figure 3. Example of "Contour Plan" and "Geometric Land Plan" drawn up during the massive delimitation works with the help of the MapInfo program

Within the works of delimitation of public property in a massive way, the problem arose: "where and how do we register the area for the protection of waters, roads, forests when it overlaps with private property?".

As usual, to solve a problem, we turn to the practice of developed countries.

In Europe, in order to control land use and activities, „Public Law Restrictions” are registered, abbreviated as PLR *(public-law restrictions).*

Twenty-two countries already have PLRs. PLRs can be registered in the Cadastre (e.g. in Niderland), in separate registers (in the detailed cadastre, e.g. in the archaeological cadastre in Greece), or in both (e.g. Denmark).

3. Delimitation of public property selectively, to land

The delimitation of public property in a selective manner is carried out at the request of the local or central public administration authorities, for a plot of land, building or isolated room, from the financial means of these authorities.

By Order of the Chisinau Municipal Council no.19 of 05.07.2022, the municipality of Chisinau initiates works of selective delimitation of the real estate publicly owned by the UAT mun. Chisinau, the executor being I.S. "INGEOCAD". The land to which the "List of public property of the administrative-territorial unit of level I, subject to delimitation by belonging and by domains" (example is presented in Fig.4) are subject to selective delimitation (example is presented in Figure 4).

Lista

bunurilor imobile proprietate publică a unității administrativ-teritoriale de nivelul I, supuse delimitării după apartenență și pe domenii

aflate în administrarea APL mun Chișinău conform situației la 30.06.2022

amplasate în mun. Chișinău, sect. Botanica, str. Trandafirilor, 0100101

Nr. crt.	Tipul bunului imobil	Categoria de destinație, modul de folosință	Adresa bunului imobil	Numărul construcției de teren	Numărul cadastral	Suprafața	Numărul de niveluri ale construcției	Domeniul	Denumirea entității care gestionează bunul imobil
1	2	3	4	5	6	7	8	9	10
1	Teren	II (din intravilanul localităților); 2.3 [illegible]	mun. Chișinău, sect. Botanica, str. Trandafirilor, 8/1	-	[illegible]	1,13 ha	-	public	APL mun. Chișinău

Figure 4. Example of "List of public property real estate of the administrative-territorial unit of level I, subject to delimitation by belonging and by domains"

At the selective delimitation of the lands, the land graphics sent by the municipality of Chisinau were used. Chisinau, where the topology was checked with the land already included in the graphic database of the cadastre and whether the area in the graph corresponds to the area in the List.

If the graphics of the demarcated land correspond to the requirements, the Contour Plan (example is shown in Figure 5), the List of immovable property, the Minutes regarding the delimitation of the immovable property of the public property and the Geometric Plan of the land (example is presented in Figure 5) are drawn up, which are coordinated by the members of the delimitation commission.

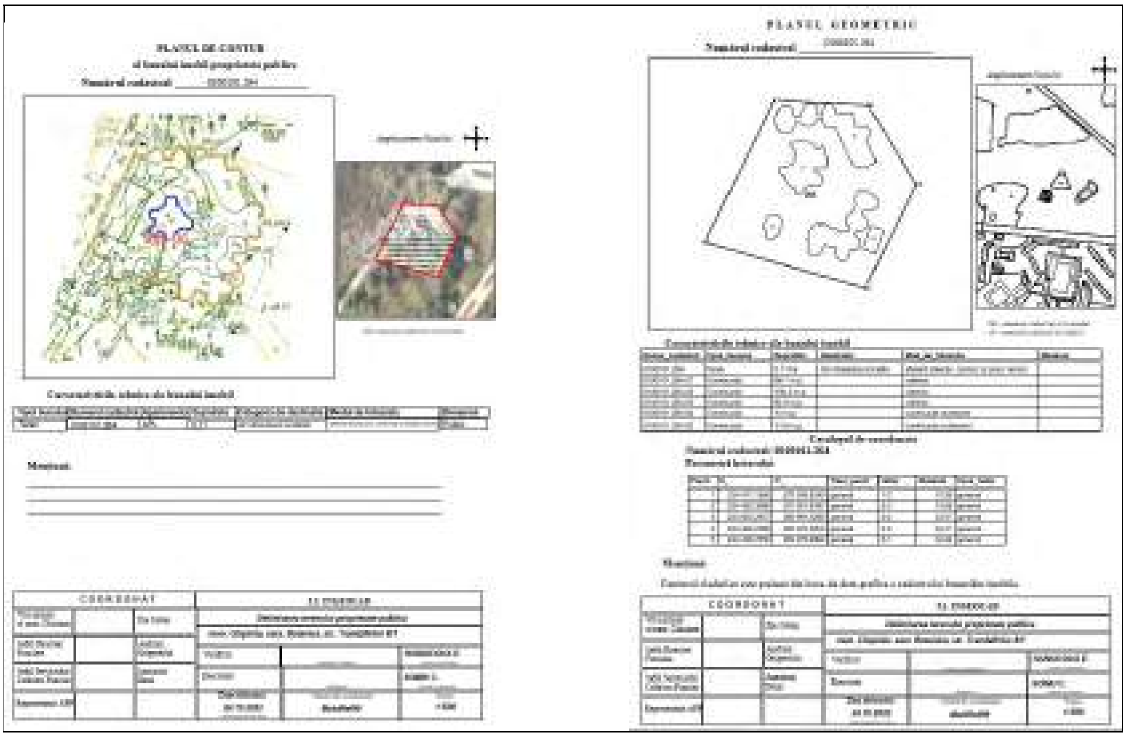

Figure 5. Example of "Contour Plan" and "Geometric Land Plan" drawn up with the help of the MapInfo curriculum

4. Selective delimitation of public property, to isolated rooms

For the first time in the Republic of Moldova, works on the selective delimitation of public property isolated rooms were initiated by the Municipality of Chisinau. Chisinau, through the Order of the General Directorate for Economy, Trade and Tourism no. 09 of 28.03.2023 and by the Provision of the mayor of mun. Chisinau no. 609-d of 13.12.2022, the representatives of the Commission for the selective delimitation of isolated rooms publicly owned by the municipality of Chisinau were appointed.

The executor of these works was I.S. "INGEOCAD", which, according to the cadastral number indicated in the "List of public property real estate subject to delimitation by belonging and by domains" (example is shown in Fig.6), requested from the IP "Cadastre of Real Estate" the level plans existing in the archive and in the graphic database (FloorPlan) of the cadastre.


LISTA

Figure 6. Example of "List of public property immovable property subject to delimitation by belonging and by domains"

When delimiting the isolated rooms, the identification is carried out with the mandatory exit to the site because many spaces/rooms have been modified/replanned by the managers or taken over by private property.

After identifying the isolated room, the contractor draws up the contour plan (example is shown in Figure 7), the List of real estate (example is shown in Table 2), the report on the delimitation of the real estate public property and the geometric plan of the isolated room (example is shown in Figure 7) which is coordinated by the members of the delimitation commission.

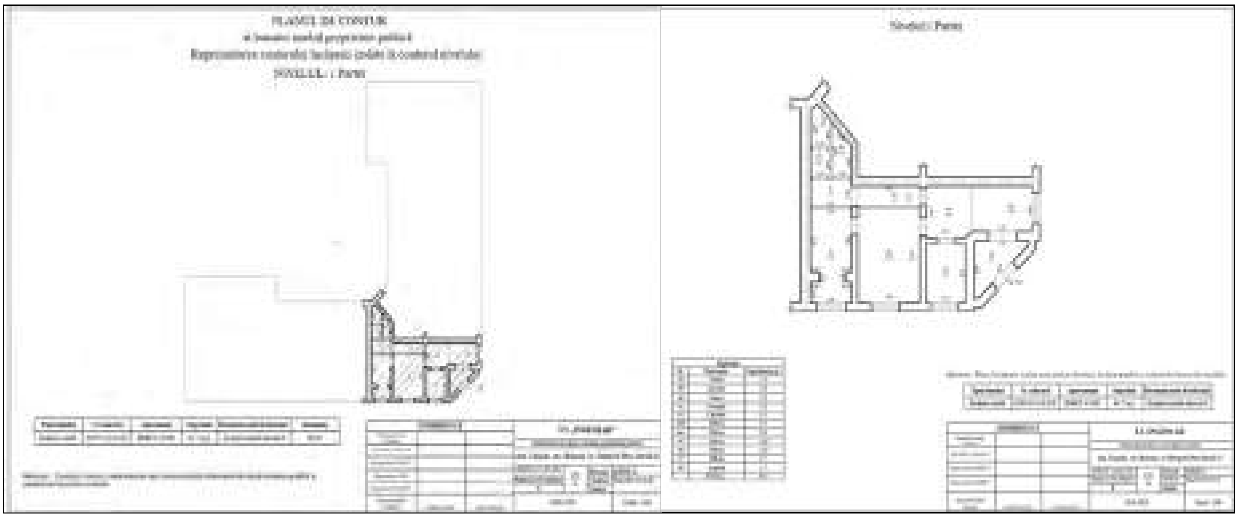

Figure 7. Example of "Contour Plan" and "Geometric Plan of the Isolated Room" prepared using the Inventory 11 program

Table 2. Example of "List of public property real estate of the administrative-territorial unit mun. Chisinau"

No. d/o	No. d/o from the LPA List	Type of immovable property *(land/ building, isolated room)*	Destination category/ How to use.	Address of the good immobile	Nr. Cadastral *(land/ building/ insulated room)*	Suprafaţa *(ha./ m.p.)*	The number and type of the level where the insulated room is located	Name of the entity managing the immovable property	Field *(public/ private)*
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1	Isolated room	Non-residential isolated room	mun. Chişinău, sect. Buiucani, str. Vissarion Belinski 61	0100515.116.01.066	134,0 m.p.	1 Parter	DGECT a CMC	Private
2	2	Isolated room	Non-residential isolated room	mun. Chişinău, sect. Buiucani, str. Mitropolit Petru Movilă 41	0100519.124.01.028	84,7 m.p.	1 Parter	DGECT a CMC	Private
3	3	Isolated room	Non-residential isolated room	mun. Chişinău, sect. Rîşcani, str. Matei Basarab, 10	0100414.138.01.134	160,9 m.p.	-1 Demisol	DGECT a CMC	Private
4	4	Isolated room	Non-residential isolated room	mun. Chişinău, sect. Botanica, str. Independenţei, 30/5	0100113.222.01.003	108,4 m.p.	1 Parter	DGECT a CMC	Private
5	5	Isolated room	Non-residential isolated room	mun. Chişinău, sect. Centru str. Grenoble, 106/4	0100214.104.01.092	79,5 m.p.	1 Parter	DGECT a CMC	Private

During the work of delimitation of isolated rooms, many questions arose that are not regulated by the legislation, namely:

1. What do we do when a part of the surface of the isolated room indicated in the "List of real estate public property of the administrative-territorial unit" is seized and registered in private property *(for example: part of the corridor)*?
2. How do we proceed when the surface of the isolated room indicated in the "List of public property of the administrative-territorial unit" is dispersed in several separate rooms, which do not have access from one to the other?
3. What do we do when the surface of the isolated room indicated in the "List of public property of the administrative-territorial unit" includes the area of the common room of the building *(for example: corridor, hall, stairwell)*?
4. What do we do when the surface of the isolated room indicated in the "List of public property of the administrative-territorial unit" is changed because replans have been carried out in the isolated room?
5. What do we do when the surface of the isolated room indicated in the "List of public property of the administrative-territorial unit" is modified because an annex has been built?

5. Conclusions:

- The cadastral registration process in the Republic of Moldova is under the influence of world practice. At present, special attention is paid to the registration of rights over publicly owned land, the main purpose being to raise the level of property protection and the implementation of economic policies.
- The success of the implementation of the cadastral registration process depends on the synchronization of the legislative framework and social and economic problems.
- In order to protect the protection area of waters, roads, forests, etc., it is necessary for the Republic of Moldova to develop a new register where it can register " *public-law restrictions"*.

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THE IMPORTANCE OF NATIONAL SPATIAL DATA INFRASTRUCTURES IN THE CONTEXT OF THE GEOGRAPHIC INFORMATION GLOBALIZATION

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Abstract: *The aim of the paper is to analyze the impact of the phenomenon of geographic information globalization, that represents the current process through which geographic data and information are collected, integrated, shared and used on different platforms at a global level, compared to the current status of the National Spatial Data Infrastructure (NSDI) in the Republic of Moldova. The objectives of the study were: to approach the phenomenon of globalization of geographic data that has a significant impact on society through standardization, interoperability, access of the general public to a huge amount of geographical data, unimaginable a few years ago; to provide an overview of the spatial data infrastructure in the Republic of Moldova; to highlight the importance of adapting to new realities. Thus, it should be specified that in the context of technological development and the ever more persistent promotion of global spatial platforms and databases, NSDI will play a key role in providing verified official data, ensuring data standardization and interoperability, completing and updating data for areas where voluntary contributions are limited or hard-to-reach sectors, protecting confidential data and not lastly, planning, development and implementation of policies in the field.*

Keywords: *Free and Open Data, National Spatial Data Infrastructure (NSDI), Metadata, Interoperability, Standardization.*

1. Introduction

Accurate and up-to-date map products and spatial analysis are fundamental resources for a wide range of applications. Producing and updating maps in a rapidly changing world is, however, a major scientific and practical challenge [1], especially for public institutions, where the process is very cumbersome and bureaucratic. The involvement of citizens in the collection of geographic data has greatly influenced the development and use of spatial data and maps, impacting daily routine such as economic activities, gaming, transportation, tourism, but most importantly science and technology. Resources such as Google Maps, Google Earth, Bing Maps, and even maps that are generated by citizens through projects such as OpenStreetMap (OSM) are now widely used by various amateur and professional communities. OSM was founded in 2024 by Steve Coast [2], and currently it is known and used all over the world as the most eloquent example of volunteered geographic information (VGI). This is a free geographic database, updated and maintained by a community of volunteers through open collaboration. Thus, contributors collect data from surveys, aerial imagery, import from other freely licensed spatial data sources.

At the same time, we are assisting the development of national or regional spatial data infrastructures, which are also based on recognized international standards and following technological evolution [3]. Since the 1990s, advances in mapping and geospatial technology have been largely driven by the public organizations, agencies and ministries playing a major role in developing and coordinating the data, products and services available today. The origins for many of today's innovations in the field and operational successes are rooted in past government initiatives in research and implementation of computing and communications technology, geospatial data standards, initial data collection for NSDI, sensors, and of course the Global Positioning System.

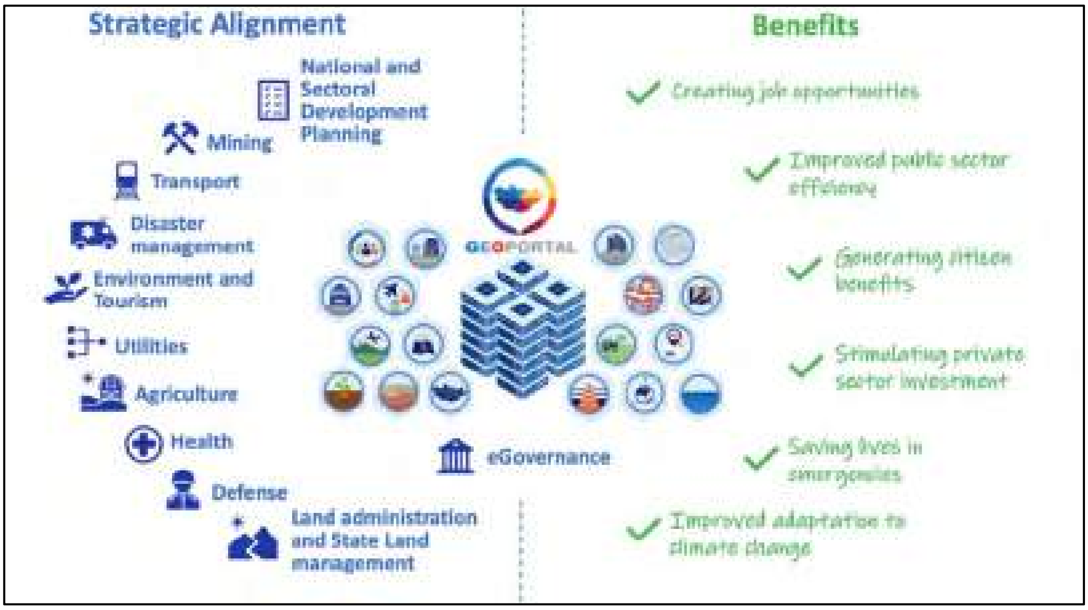

Figure 1. Benefits of Strategic Alignment [4]

Such infrastructures have been implemented in most countries of the world with many advantages (Figure 1), for example European countries having separate infrastructures and infrastructure at the level of the European community [5], USA [6], Republic of Moldova [7], India, Bangladesh [8], Malaysia [9], Mongolia [10], etc.

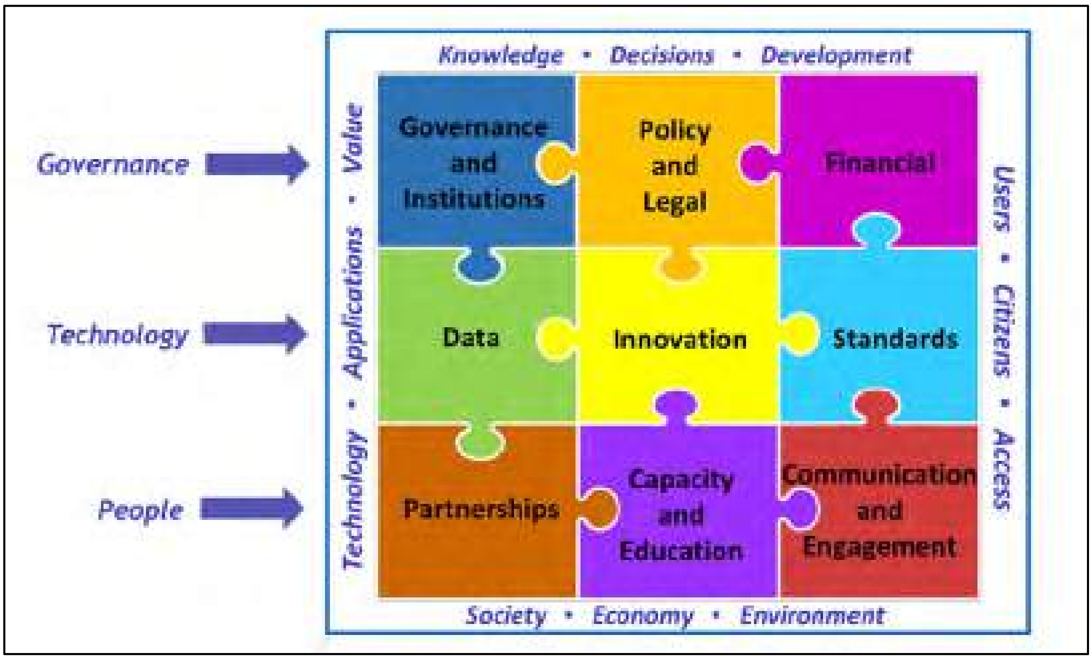

Figure 2. IGIF 9 Strategic Pathways [11]

Geospatial technologies will be required in much wider fields, aimed at providing an analysis of complex "big data" and correctly communicate location-based information so that it can be turned into operational efficiency taking into account the three pillars (Figure 2). The "Internet of Things" already connects billions of stationary and mobile sensors with human users

[12]. Thus, in the context of the realities we live in today, the basic vision of working group 3.1 of the International Federation of Surveyors (FIG) - Geospatial Data: Professionalism, Technology, and Services is Transforming data into information by combining (open) geospatial data and using analysis geospatial and GeoAI in domain-specific contexts.

2. Materials and methods

Both, Global Spatial Data Platforms and NSDIs are frameworks for the collection, management, distribution and use of spatial data. Among the most important research and analysis methods used in the context of approaching the topic can be specified: Study of specialized literature, especially those developed by the United Nations Integrated Geospatial Information Framework (UN-IGIF); INSPIRE Knowledge base of the European Commission, national legislation; The case study by describing the situation of the spatial data infrastructure of the Republic of Moldova; Analysis of standards and technical requirements in the field.

For the presented research the Venn diagram comparing various mapping and Earth observation platforms: Google Maps, Google Earth, Bing Maps, OpenStreetMap (OSM), Copernicus Platform, NASA to SDI from the Republic of Moldova was used.

3. Discussions

At the end of the 20th century, technological innovation entered an era of high-speed information transmission and globalization. Socio-economic development and protection of environmental components are based on the use of updated geographic data, therefore, research on spatial information becomes an important aspect of contemporary activities. As it is known, the purpose of creating and developing spatial data infrastructures (Figure 3) is to reduce duplication of data and efforts between responsible institutions, improve quality and reduce costs related to the creation and maintenance of geographic data, and furthermore SDIs are becoming more mature worldwide nowadays [13]. The NSDI is a framework that enables the efficient sharing and use of geospatial data within and between countries. There is little research demonstrating the effect of potential interventions, such as open data policy, changes in funding and coordination structures, and private sector participation, on the effectiveness and efficiency of SDI. That trend will continue in the future due to technological advancement, the development of industry-specific standards (OGC, ISO) and the growing demand for location-based information. Thus, modern technologies (satellites, drones, GPS, GIS software and platforms) ensure the collection, storage and visualization of geographic data, but also contribute to their improvement.

Figure 3. The creation and continuous evolution of the United States National Spatial Data Infrastructure (NSDI) (ESRI, 2014)

In the Republic of Moldova, the NSDI Geoportal is the platform that provides the national framework for storing metadata related to existing spatial data in the country and also implementing standards in this field. It was established in 2016 through the Law 254 on the national spatial data infrastructure [14] which partially transposes the INSPIRE Directive 2007/2/EC of the European Union establishing an Infrastructure for Spatial Information in the European Community [15]. Efforts have been made in recent years to develop NSDI and maintain metadata for spatial data and network services for efficient management and sharing of geographic data. The responsible entity, namely the Agency for Geodesy, Cartography and Cadaster from the Republic of Moldova, has developed guidelines for approving metadata creation requirements within Government Decision no. 738/2017 for the approval of the Regulation on the rules for creating and updating metadata for spatial data sets and services [16], that transposes Commission Regulation (EC) No 1205/2008 implementing Directive 2007/2/EC as regards metadata [17]. Normative acts were adopted to establish data sharing mechanisms, implementation and adoption of interoperability practices. At the same time, Commission Regulation (EC) No 976/2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the Network Services [18] is partially transposed by Government Decision no. 737/2017 for the approval of the Regulation regarding the rules for creating services of the network and the term of their implementation [19].

Furthermore, efforts are being made to establish interoperability in NSDI by developing and implementing standards for data formats, metadata and exchange protocols through Government Decision no. 683/2018 for the approval of the Regulation regarding the rules of application which establish the technical modalities of interoperability and harmonization of spatial data sets and services, as well as the implementation deadline, act that transposes Commission Regulation (EU) No 1089/2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services.

Despite all these efforts, the level of knowledge and understanding of INDS by citizens is limited. Definitely, for everyday activity, people will use one of the global geographic data applications because they provide free and open access to up-to-date high-quality spatial data, democratizing access to data and without financial or conceptual restrictions. Of course, it must be specified that in relation to global platforms also the interfaces are much more user-friendly and intuitive. It is certain that only experienced users (surveyors, cartographers, geographers, etc.) will use the thematic available national geoportals to use reference information for specific purposes.

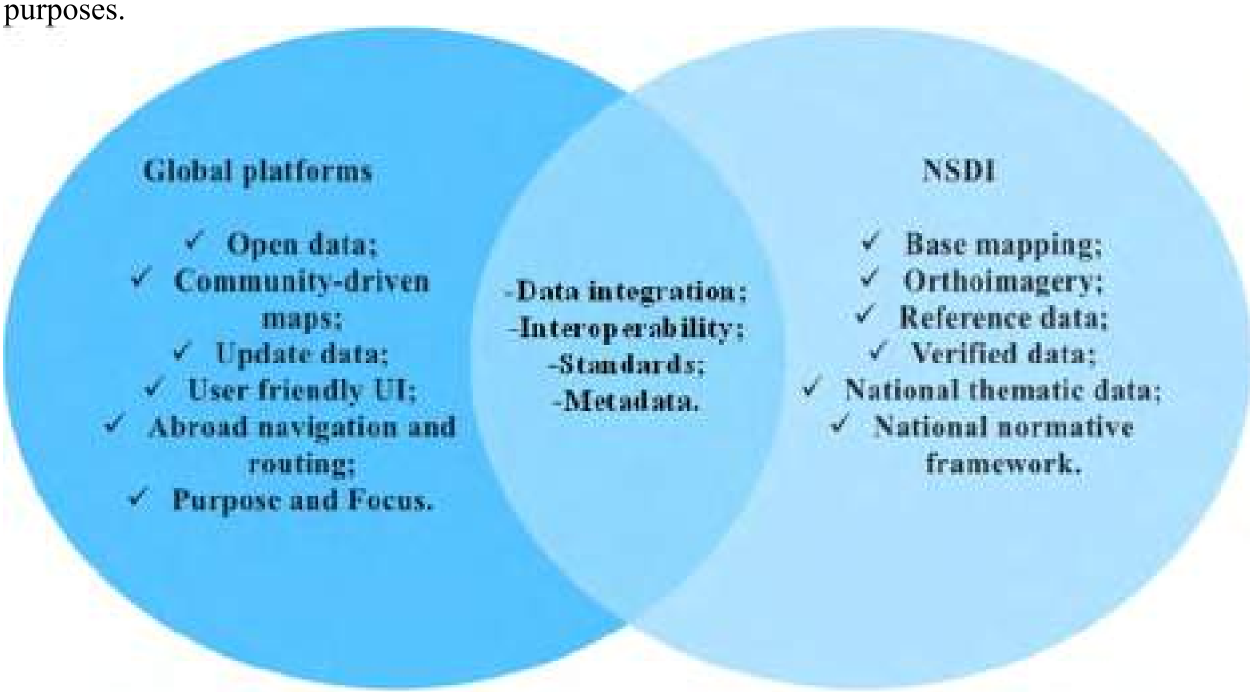

Figure 4. Venn diagram analysis on global platforms and NSDI

The collaborative model, involving all stakeholders regardless of GIS level of understanding [20], inspired new methods of spatial data collection through the participation of the 'citizen science' community, providing a viable alternative to traditional sources of spatial data that were centralized and controlled by governments or large corporations. OSM provides a free alternative to commercial spatial data, reducing costs for businesses and organizations. Besides all the fields dependent on open data, international projects such as Humanitarian OpenStreetMap Team [21] that use OSM data including to support humanitarian interventions. OSM data is continuously updated by the global community of volunteers, meaning that information can be more accurate and up-to-date than that available from commercial or government sources. From a pedagogical point of view, of course, global open sources are always more available for the teaching-learning process in various fields: transport, tourism, demography, remote sensing, GIS, land management, geography related disciplines. Moreover, there is a large community of users who will always find the answer to any problem or any troubleshooting teachers or student can encounter in their GIS problem solving process.

4. Conclusions

Globalization of geographic information represents a complex irreversible process through which any spatial data becomes available and accessible worldwide, overcoming national borders and enabling international collaboration in various fields. The NSDI is an essential framework for the management and sharing of spatial data between different national entities and sectors, but also the integration of data in different regional or international structures.

Following the current trend, we must specify that open data must be found in government initiatives, and these initiatives must be balanced with the necessary specifications for information security and risk management. Currently new challenges are AI and machine learning, which are increasingly being used to analyze complex geospatial data, providing new insights for all types of geographical data.

Therefore, the role of INDS, in the context of the development of global giants for spatial data collection and distribution, will be to provide the citizens with verified and safe high-quality spatial data, promote interoperability and their standardization, support for the development of policies in the field, thus contributing to a more efficient and responsible use of spatial data both nationally and globally. Collaboration and access to up-to-date information sources available to all contributes in solving global challenges by providing accurate and reliable spatial data essential for informed decision-making in any field.

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CURRENT PERSPECTIVES AND FUTURE TRENDS IN SCHOOL CARTOGRAPHY IN THE REPUBLIC OF MOLDOVA

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Abstract: *The main goal of this paper is to present and discuss an area called School Cartography in the Republic of Moldova that corresponds to the National Geography Curriculum. This study intends to support further research in the field of School Cartography given the development of Geographic Information System (GIS) technologies in our country. Beginning with the analysis of events related to the production of school atlases using new technologies, which began in 2013 at the State Enterprise Institute of Geodesy, Technical Surveys, and Cadastre INGEOCAD, the main themes and difficulties were pointed out. The results presented here emphasize the importance of all stages of using GIS technology in the production of atlases for geography education, from traditional paper versions to digital versions, during the last decade. The article also focuses on some of the research and contributions of the author and contains a list of publications and examples related to digital mapping. Finally, perspectives and future trends in School Cartography are based on the creation of interactive thematic maps of the Republic of Moldova. The relevance of this study is dictated by the main trends in digitization of education worldwide.*

Keywords: *computerization of education, Geographic Information Systems (GIS), Information and Communication Technologies (ICT), National Geography Curriculum, Geoinformation Technologies, School Cartography.*

1. Introduction

The computerization of education and new technologies has led to a pluralization of information, extensive baggage, and difficulty in mastering and managing. What remains important is not only the information itself but also its assimilation and disposition [1]. That is why teachers try not only to present information to students but also to organize it in an interesting and attention-grabbing way. School lessons using a computer allow the creation of a base of teaching materials that can be used in the following years, with the possibility of constantly improving it, saving time, vivid color illustrations, and individual learning. Students are focused during the lesson; at any time you can return to previously studied material, etc. [2]. These new possibilities allow teachers to spend less time preparing a lesson plan and to teach effectively. To improve schools performance in the Republic of Moldova, all suitable teaching and learning resources for schools are available in a digital format now. These can be downloaded from the website of the Center for Information and Communication Technologies in Education of the Republic of Moldova [3]. Some recommended software programs for Programming Languages and Information Technologies have also been presented on site. In addition to computer science, there is a list of electronic resources for teachers of other school subjects. For example, the platform phet.colorado.edu [4] is an open educational resource with many interactive simulations for physics, chemistry, biology, and mathematics lessons. The students' impressions indicate that the project realized using this platform motivated them to study the subject and even influenced them to choose the right option in the career guidance process. Simultaneously, the applied methodology, with the use of ICT, emphasizes attention to the subject of study and develops personal creativity [5]. The KAHOOT application [6] is one of the most successful applications in studying geography at any stage of learning: gaining new knowledge, summative assessment of learning and formative assessment [7]. For Romanian-speaking schools of Republic of Moldova it may also be useful eLearning educational portal atlas-edu.ro [8] with a collection of over 500 titles for interactive whiteboards and PCs for most school subjects. Geographic information systems (GIS), may be very useful in geography education too. For example, some of the topics of the National Geography Curriculum in the Republic of Moldova are common with English schools and can be accessed on site teachwithgis.co.uk [9]. This platform supports student learning with high-quality curated map content and powerful mapping tools. One of the biggest Free GIS platforms for schools [10] contains many interactive maps of Average Annual Rainfall, Tree cover gain (2000-2012), World Bioclimates, The Human Footprint (2009), Sea Surface Temperature (°C), World Elevation GMTED, Latest Earthquake Monitoring Dashboard, etc. This platform for exploring and downloading GIS data is very useful for the general development and formation of knowledge about the global world.

Along global geography topics, the National Geography Curriculum of the Republic of Moldova contains several topics related to the physical and social geography of the native land. Therefore, there is a need to create interactive thematic maps of the Republic of Moldova in free access for students and teachers. The main prerequisite for creating interactive geographic maps of the Republic of Moldova is the transition of the technological process of creating thematic maps for school paper atlases to the field of geographic information systems during 2013 [11]. Since 2013, in State Enterprise Institute of Geodesy, Technical Surveys and Cadastre INGEOCAD school atlases have been elaborated using ArcGIS software for mapping and Adobe Illustrator to prepare pages for print. Thus, a new period began for school cartography in the Republic of Moldova, a period of geoinformation technology implementation for mapping paper atlases. The experience of creating an electronic map of the Chisinau municipality in 2011 was used to develop the implementation methods [12].

From 2013 to 2016, scientists from the Institute of Ecology and Geography carefully crafted the contents of school atlases. These educational resources, intended for secondary schools, were subsequently published and disseminated to educational institutions throughout Moldova. To enhance the learning experience, a collection of blank maps was also produced, enabling students to engage in practical exercises and strengthen their geographic understanding.

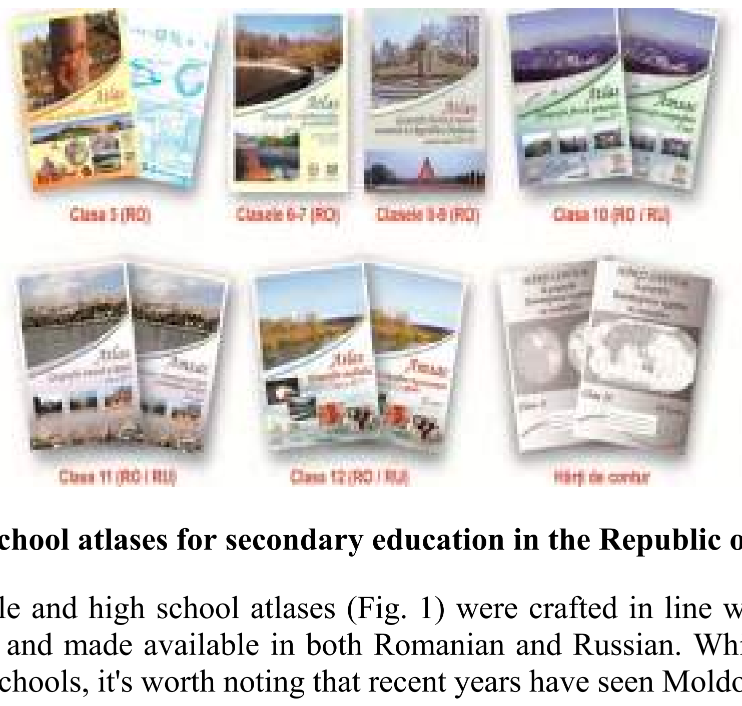

Figure 1. School atlases for secondary education in the Republic of Moldova

Moldovan middle and high school atlases (Fig. 1) were crafted in line with the national Geography Curriculum and made available in both Romanian and Russian. While these atlases remain widely used in schools, it's worth noting that recent years have seen Moldovan classrooms equipped with laptops and interactive whiteboards, which excel at displaying dynamic maps. Consequently, in 2020, a proposal emerged to develop a collection of digital thematic maps for Moldova [13]. This initiative led to the design of a database framework for an electronic school atlas [14], as well as the creation of interactive maps illustrating land use patterns and soil erosion across the country [15].

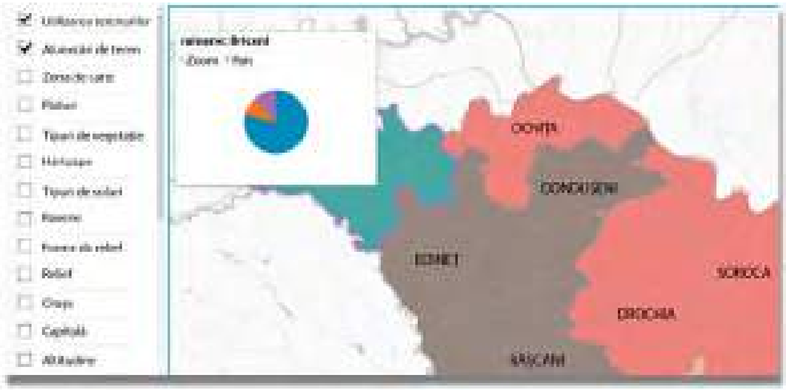

Figure 2. Land Use map of the Republic of Moldova

In March 2024, the Land Use map of the Republic of Moldova (Fig. 2) underwent testing at the "Academician Constantin Sibirschi" Theoretical School in Chisinau. During the class, students individually interacted with the map on computers, while the instructor had the capability to display the interactive map on the whiteboard. The utilization of this interactive Land Use map for Moldova facilitated the implementation of certain geographic curriculum objectives:

- Explanation of socioeconomic processes and phenomena observed directly or indirectly using geographical terminology;
- Classification of land-use types;
- Tasks focused on identifying and analyzing socio-economic elements, processes, and phenomena on maps;
- Creating graphic representations using statistical data from the land fund of the Republic of Moldova;
- Analyzing and establishing relationships between natural processes (e.g., landslides) and socio-economic factors (e.g., land fund), utilizing statistical, graphical, and cartographic resources.
- Identifying trends in the dynamics of socio-economic elements, such as the development of the wine industry, through the analysis of cartographic resources;
- Recognizing environmental challenges at both local and national levels by studying the interactive map of land use in the Republic of Moldova;
- Forecasting the dynamics of socio-economic challenges, such as land funding and landslide processes, at local and national scales;
- Formulating and expressing solutions for environmental issues at local and national levels through discussions;
- Completing exercises focused on analyzing the structure of the land fund across different districts of the Republic of Moldova.

The test lesson validated that the interactive map Land Use of the Republic of Moldova was developed in accordance with the geography learning efficiency standards for secondary education and aligned with the competency-based assessment practices outlined in the curriculum.

Another important advancement in school cartography is the publication of thematic layers on the National Spatial Data Infrastructure portal (geoportalinds.gov.md). In December 2024, as part of the Biogeographic Regions of the Republic of Moldova dataset submitted by the Institute of Ecology and Geography [16], pedogeographical zones for the territory of the Republic of Moldova were integrated into the Infrastructure for Spatial Information in the European Community (INSPIRE). The state geographic information system, referred to as the Thematic Geoportal for Spatial Data of the Agency for Geodesy, Cartography, and Cadastre (hereinafter "Geoportal"), provides access to all spatial datasets managed by the agency through its network services [17]. This thematic portal offers detailed information on the physical and social geography of the Republic of Moldova, making it a valuable resource for use in the education system.

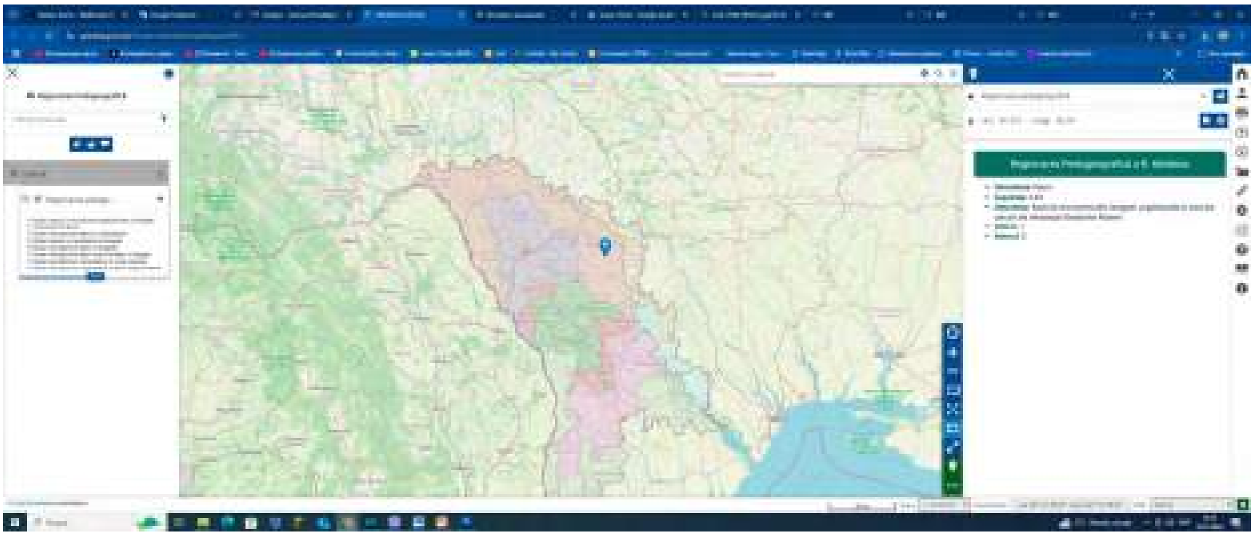

Figure 3. Pedogeographical zones of the Republic of Moldova

The map of Pedogeographical zones of the Republic of Moldova (Fig. 3) is available at https://geodata.gov.md/?locale=ro#/viewer/openlayers/2913 and represents a set of vector objects with attribute data and metadata. The primary advantage of this map lies in its ability to overlay thematic layers onto other maps, enabling comprehensive spatial analysis. This feature not only enhances its utility for geographic studies but also serves as an engaging tool for fostering critical thinking and analytical skills among students.

2. Results and Discussion

The history of school cartography in Moldova can be split into two distinct eras: pre-2013 and post-2013. The latter period began when the State Enterprise INGEOCAD began utilizing GIS software for paper atlas creation. The methodology for developing thematic maps for the "Atlas grade 8-9 Physical and human geography of the Republic of Moldova" [18] using GIS technology, along with an examination of this process's outcomes, is detailed in scientific publications [19, 20]. This approach can be effectively applied to generate interactive maps for various social and geographical topics.

As a result, a spatial database containing thematic layers for Moldova's territory was established. This layer collection incorporates findings from research conducted by the Institute of Ecology and Geography, which also contributed to the content development for school atlas pages. This development served as a key foundation for creating an interactive land use map of Moldova in 2023. The creation of this map was driven by several factors: the unique relationship modern children have with technology, improved computer facilities in schools across Moldova (not limited to the capital), and the global trend towards digital education.

The transition from a classical to a computerized lesson creates certain difficulties for teachers because of the following disadvantages: poor management of working time, noise, and disorder, which require additional effort from the teacher [21]. In addition, the utilization of learning platforms requires computer literacy and English to be at a good level for teachers of different school subjects. By effectively applying information and communication technologies in the initial training process, teachers have the opportunity to form/develop their professional skills [22].

3. Conclusions

As highlighted in the brief historical overview provided in the introduction, the development of school cartography in the Republic of Moldova, particularly in advancing the digitalization of geography educational materials, has occurred over relatively short periods during the past decade. This indicates a rapid pace of development and favourable conditions. Efforts are underway to create a digital school atlas, marking a significant step forward in modernizing educational cartographic tools. Perspectives and future trends for school cartography in the Republic of Moldova consist of supplementing basic educational materials with accessible interactive thematic maps of Republic of Moldova.

Advantages of the Digital School Atlas created based on modern geoinformation technologies:

- Helps students to understand and analyze spatial concepts;
- Facilitates the learning process by allowing students to interact with information by adding spatial components and facilitating the assimilation of concepts using visual tools such as thematic maps;
- Can be used to teach any material that contains spatial components such as geography, history, and natural sciences.

Thematic layers derived from research by the Institute of Ecology and Geography will be accessible on the National Spatial Data Infrastructure portal, providing a dual benefit for scientific research and educational applications. These advancements will not only enhance geographic education, but also foster a deeper understanding of spatial data among the younger generation.

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DEVELOPMENT OF THE DIGITAL NATIONAL FARMERS REGISTRY AND IMPLEMENTATION OF THE PILOT PHASE, AS A COMPONENT OF THE VISION FOR INTEGRATED ADMINISTRATION AND CONTROL SYSTEM

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Abstract: *The Republic Moldova has gained the EU candidate status in June 2022. On the basis of 2023 progress report, the EU commission has recommended and the European Council adopted on 15.December 2023, the decision on European Council to open accession negotiations with the republic of Moldova. Despite the fact that the negotiation process in Chapter 11 has not been started, it has to be taken into account, that for its closure, all of the Common Agricultural Policy requirements need to be met in full. For fully operational Integrated Administration and Control System that would means:*

- *Intervention framework aligned, including intervention budgeting and conditionality;*
- *Legal and institutional framework aligned, paying agency accredited, supporting information systems certified;*
- *Mandatory Integrated Administration and Control System elements established and operational;*
- *the Common Agricultural Policy strategic plan developed and envelopes defined, at the time of accession.*

Keywords: *information system, agriculture, land, ecological farms, subsidies.*
JEL Classification: Q15, Q18, Q24, Q28, Q57

1. Introduction

In 2022, the Republic of Moldova obtained the status of candidate country to the European Union, an opportunity that will allow harmonization of legislation to EU requirements and which offers a wide range of mechanisms to stimulate business in agriculture and rural areas.

In order to be able to access pre-accession or accession funds, the Republic of Moldova needs to designate the authority that will be entrusted with these tasks, create information systems that will ensure the transparency of financial funds, but also provide information, statistical data on farmers.

Although the negotiation process between the Republic of Moldova and the European Union for Chapter 11 has not yet started, it should be borne in mind that for its closure, all the requirements of the Common Agricultural Policy must be fully met. The European Union will not be able to monitor the financial sources allocated if the Republic of Moldova does not apply the Integrated Administration and Control System.

The Integrated Administration and Control System (IACS) is the core software solution for processing agricultural subsidies in the European Union. It provides standardized management and control of the additional support granted to farmers in the Member States by the European Agricultural Guarantee Fund.

To have a fully operational IACS, this would mean:

- Aligned intervention framework, including intervention budgeting and conditionality;

- Aligned legal and institutional framework, accredited agricultural intervention and payment agency, certified supporting IT systems;
- IACS mandatory elements established and operational;
- Common Agricultural Policy Strategic Plan developed and ceilings defined, at the time of accession.

The intensity of progress in meeting the requirements set by the EU environmental agreement, the Farm to Fork and Biodiversity Strategies and the digital transformation as a key enabler of these depend to a large extent on carefully planned and coordinated actions.

The new Common Agricultural Policy framework for the years 2023-2027, taking into account digitization and data collection, foresees new levels of agri-food information system design, with improved integration, use of advanced monitoring technologies, data sharing, horizontal unification (such as unique farm IDs across the system) and data re-use for better e-governance and smart villages (such as cooperation between farmers and rural services). To this end, the new regulation on the strategic plan for the Common Agricultural Policy envisages a single integrated programming framework for the European Agricultural Guarantee Fund and the European Agricultural Fund for Rural Development and the description of the digitization strategy for better implementation of interventions in food production and rural areas and the description of the use of digital advisory services to support farmers.

2. The degree of coverage of the topic in the scientific literature

The topic is a relatively new one, which is analyzed in the research with the commitments to harmonization of legislation. In fact, Law No. 71/2023 on Subsidization in Agriculture and Rural Development [2] regulates the "registration of the subjects of subsidization in agriculture and rural development", drawn up in accordance with the requirements on the Integrated Administration and Control System, provided for by Regulation (EU) 2021/2116 of the European Parliament and of the Council of 2 December 2021 on the financing, management and monitoring of the common agricultural regime. policy and repealing Regulation (EU) No 1306/2013, as well as its constituent elements [3, 4].

To achieve this objective, the United Nations Development Program in Moldova, with the financial contribution of the Government of Japan, is implementing the Project "Multidimensional Response to Emerging Human Security Challenges" and provides support to the Ministry of Agriculture and Food Industry for the development of the National Digital Farmers' Register (hereinafter - SI "Farmers' Register"), an intrinsic element of the Integrated Administration and Control System (hereinafter - IACS).

In fact, UNDP Moldova is coordinating the development and implementation of the National Digital Farmers' Register and the necessary basis for further development of the large-scale Integrated Administration and Control System. The SI "Farmers' Register" is a key requirement for EU accession. Such a register will serve to achieve the following objectives:[1]

- ✓ will serve as one of the bases for verification and registration of beneficiaries of agricultural subsidies granted to farmers;
- ✓ will create a unique system of identification of subsidy beneficiaries, which is a component of the CIS;
- ✓ will ensure the management and monitoring of interventions and beneficiaries of subsidies from the National Fund for the Development of Agriculture and Rural Environment, as well as of financial means from development partners.

The Integrated Administration and Control System is intended for the management and monitoring of interventions and beneficiaries of subsidies from the National Fund for the Development of Agriculture and Rural Environment, as well as of financial means from development partners before accession to the EU, as well as EU funds post-accession.

The Integrated Administration and Control System consists of several elements, as described in Art. 31 of the Law No. 71/2023 on Subsidies in Agriculture and Rural Development [2] and will be implemented in stages.

The implementation of this system requires a regulation both at the level of law and at the level of Government decision, which orders the implementation of the system, with its various elements, in different stages. The first stage consists in creating the necessary regulatory framework and, in this regard, two inherent actions must be implemented:

1) making amendments to the Law No. 71/2023 on subsidies in agriculture and rural areas,
2) adoption of the Government Decision on the Concept of the Information System "Farmers' Register" and the Regulation on its organization and functioning.

The first action was accomplished on June 27, 2024 with the approval by the Parliament of the Republic of Moldova of Law No. 159/2023.

The second action was successfully completed with the Government Decision on IACS implementation being approved on August 28, 2024.

The Information System "Farmers' Register" is an element of the Integrated Administration and Control System and is a system for the identification of single applicants and beneficiaries of state interventions and support measures and a system for the identification of applicants and beneficiaries of other interventions and measures managed by the National Fund for the Development of Agriculture and Rural Environment and processed by the Agency for Interventions and Payments in Agriculture [1].

In addition to the objectives set out above, the Farmers Register Information System will also serve as one of the sources of agricultural statistics, in accordance with EU Regulation 1091/2018, Art. 4(2), which integrates information on all agricultural production assets used by farmers.

Research aim.

The aim of this work is to analyze at what stage is the Republic of Moldova in the development of the Farmers' Register and the Integrated Administration and Control System in order to see the readiness to access pre-accession funds for the development of agriculture and rural environment.

Research methodology.

The research is based on analysis of the regulatory framework governing the development of information systems to manage EU pre-accession sources, data analysis, survey and questionnaires

Research results.

In the new Common Agricultural Policy context, the Farmers' Register Information System plays a significant role in aligning pre-accession agricultural policies with the Acquis Communautaire in several opportunities such as: [3,4]

- ✓ Central point for policy development, monitoring and promotion,
- ✓ Updated administrative source for statistical databases related to the Farm Structure Survey,
- ✓ Updated source for pre-completed Integrated Administration and Control System forms for simplifying the application and check register for checking eligibility criteria,
- ✓ Central data sets of agricultural integration points, linking farm holders to holdings and holdings to their assets, production, output and geographical particularities.
- ✓ Enabling environment for improved e-government and smart villages (non-governmental IT systems supporting cooperation and local strategy initiatives - LEADER).

The Information System "Farmers' Register" of Moldova is an important initiative for the modernization of the agricultural sector, providing a digital platform for the collection and management of data on farmers and farms. This information system is a database designed to collect essential information about Moldovan farmers and farms, promoting transparency and efficiency in the agricultural sector.

Its main purpose is to simplify access to resources, subsidies and relevant information for farmers, thus contributing to improved farming practices and increased productivity.

By centralizing data, the Farmers' Register Information System facilitates better planning and implementation of agricultural policies, providing a clear picture of the agricultural sector in Moldova.

By facilitating access to up-to-date information and financial support, the Farmers' Register Information System aims to improve the efficiency of farming practices and contribute to evidence-based policy making.

This marks the beginning of a new era in Moldovan agriculture, laying the foundations for sustainable development adapted to European standards.

The regulatory framework in force outlines the objectives of the Farmers' Register Information System, which include: [5,6]

- strengthening the capacity of the Agency for Intervention and Payments for Agriculture to apply the principles of good governance in the field of subsidization of agriculture and rural environment;
- efficient management of the resources of the National Fund for the Development of Agriculture and Rural Environment;
- increase transparency in the use of the resources of the National Fund for Agriculture and Rural Development;
- streamlining the institutional framework in order to increase the efficiency of corporate governance, correspond to best practices and respond to the recommendations of development partners;
- integrating the Integrated Administration and Control System and keeping it exclusively in electronic form;
- digitization and automation of record keeping and reporting systems;
- eliminating the human error factor caused by handling documents and entering them manually into multiple registers and systems;
- recording, storing, using information on farmers from registration to archiving;
- optimizing the use of human capital resources through digitization, i.e. reducing repetitive activities such as printing information from the interface of one application and then manually entering the same information into another application or repetitive generation of reports for the purpose of informing various state institutions with the same information;
- the generation of organized electronic archives that can be accessed by authorized personnel and the digitization of existing archives in physical format;
- ensuring the capacity to provide the necessary information in real time through a dedicated platform;
- streamlining organizational processes within the Agency for Agricultural Intervention and Payments;
- providing all data with network services (visualization, generation and modification);
- minimizing human errors when entering primary information and reducing the risks of data loss caused by a register kept in manual form in the absence of an IT system;
- strictly controlling access to data and ensuring information security in the formation and operation of the information resource Farmers' Register Information System.

The outlined objectives can be achieved by accomplishing the following tasks: [3,4]

1) Creating an interface for users to access the information systems and its electronic services for data recording;

2) providing access to the information systems at the level of the central office of the Agency for Intervention and Payments for Agriculture, through which the territorial subdivisions of the Agency for Intervention and Payments for Agriculture will obtain the necessary rights for data management related to the information objects;

3) implementation of mechanisms for the integration of the Farmers' Register Information System with other state information systems and resources, in order to facilitate the exchange of data between users and other public entities;

4) ensuring access to data on subsidies granted by the Agency for Intervention and Payments for Agriculture, the file examination stage, etc.

To ensure proper functioning, the Information System "Register of Farmers" interacts, through the Interoperability Platform (MConnect), with the following state information systems:

- Automated Information System "State Register of Population"- for the automatic exchange of data on individuals associated with a legal entity subject to registration, individuals applying for registration as a holder of a farm, sole proprietor, peasant household, individuals practicing licensed or authorized professional activity regulated by the relevant legislation, individuals engaged in activities in the field of procurement of horticultural and/or plant engineering products and/or objects of plant origin;
- Information system of the State Tax Service - on the debtor status;
- Automated information system "Real Estate Cadastre" - for obtaining data on real estate owned by legal entities or individuals of the group of legal entities and individuals for the purposes of land ownership control;
- Automated system for obtaining data on animals, property subject to control by the National Food Safety Agency;
- Machinery and equipment data from the Register of Agricultural Machinery managed by Intehagro;
- Other information systems established by the applicable regulatory framework.

If for the administrative and control needs of applicants / beneficiaries of agricultural support, the normative act provides for the holding of a document whose data are available in the information resources of other state institutions, they will be consumed or provided through the interoperability platform (MConnect).

At the same time, the Farmers' Register Information System will consume data and act as a data provider for the following shared information systems:[1]

- ➢ Interoperability Platform (MConnect) - for data exchange with other IT systems and registers;
- ➢ Integrated Government Electronic Signature Service (MSign) - for signing electronic documents;
- ➢ Government Electronic Authentication and Access Control Service (MPass) - for authentication and access control in the system;
- ➢ Government Electronic Logging Service (MLog) - to ensure the record of operations (events) produced in the Farmers' Register Information System;
- ➢ Government Electronic Notification Service (MNotify) - to notify users;
- ➢ Automated information system "Register of Powers of Attorney based on electronic signature" (MPower) - for verifying user's powers of attorney before granting access to the user interface;
- ➢ The Government Electronic Payment Service (MPay) - for paying and collecting payments from individuals and businesses;
- ➢ Government Delivery Service (MDelivery) - to provide a single mechanism for the physical delivery of the results of public service delivery to individuals and organizations.

The following is the indicative model for the realization of the mechanism for the integration of existing information systems with the Information System "Farmers' Register":

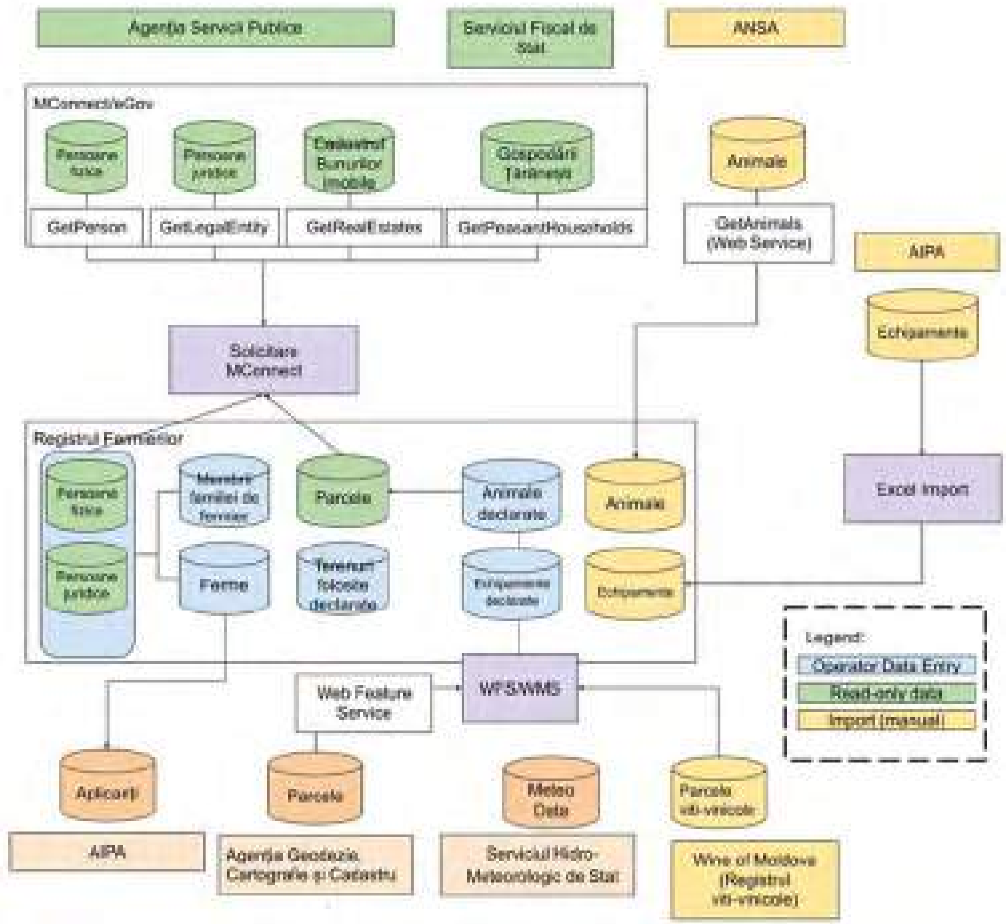

Figure 1. Information systems integration mechanism [5]

At the moment, the Information System "Farmer's Register" is being developed and needs to be populated with data on economic entities in the Republic of Moldova, being collected data on the entity, areas worked by the farmer, number and species of animals, real and movable property owned by farmers, including family members working in the economic entity.

Figure 2. The interface of the Integrated Administration and Control System with the "Farmers Register" Information System component, developed [6, 7]

The information presented shows that the process of development of information systems is underway and the Information System "Farmers' Register" is already connected to the Integrated Administration and Control System.

It should be noted that the Farmers' Register Information System is also developing the platform for online submission of applications for direct payments for the development of the livestock sector, which is to be tested and piloted in the 2025 budget year.

3. Conclusions and recommendations:

1) The Republic of Moldova faces difficulties and vulnerabilities in the effective management and monitoring of agricultural and rural subsidies. These difficulties include administrative inefficiency:
   - It manifests itself in inefficient or ineffective administration of agricultural subsidies and excessive bureaucracy in the application, approval and reporting processes. Risks of fraud and errors: There are gaps in the monitoring and control process, increasing the risk of fraud and errors in the use of agricultural subsidies;
   - Non-compliance with EU rules: upon accession to the EU, Moldova has to demonstrate compliance with EU rules and requirements in the use of EU funds. Lack of an integrated system may lead to non-compliance and delay in EU accession;
   - Difficulties in reporting and evaluation: central public authorities face difficulties in collecting and analyzing relevant data for reporting and evaluation, which affects the institution's ability to assess its progress and improve its policies and programs. Without intervention these problems are likely to persist and worsen over time. Negative impacts can include financial losses, lack of confidence in the management of allocated funds, and undermining the state's policy objectives in the area of agriculture and rural development.

2) The development of the Farmers' Register Information System will facilitate the removal of several vulnerabilities, namely:
   - Improving transparency - ensuring full visibility on how public funds are used, including the distribution and impact of subsidies in agriculture. This would help identify and prevent fraud, corruption and inefficient use of resources.
   - Increasing accountability by establishing clear reporting and accountability mechanisms, the intention is to ensure that all actors involved in the management and control of public funds are held accountable for their actions. This includes implementing sanctions for inefficient management and setting performance standards.
   - Effective monitoring and evaluation aim to develop and implement tools and methodologies for continuous monitoring and evaluation of the impact of funded projects and programs. This would facilitate rapid and informed adjustments to strategies and budget allocations, maximizing the impact of public investments.
   - Strengthening administrative capacity which consists in reinforcing the competences and resources of the Agency for Intervention and Payments for Agriculture in order to manage public funds efficiently. This includes training staff, improving IT systems and providing the necessary resources for effective implementation of agricultural policy.
   - Ensuring compliance with European regulations - The Integrated Administration and Control System aims to align the practices and procedures for managing agricultural funds with European standards and regulations, facilitating access to funding and improving the efficiency of the use of funds. This includes adaptation to EU audit and reporting requirements as well as to the principles of good governance.

3) By effectively supporting the agricultural sector, the Farmers' Register Information System contributes to increased productivity and competitiveness, which can have a positive economic impact in the long term. This will contribute to improved budgetary planning.

Accurate and up-to-date data allows more accurate budget planning and anticipation of the needs of the agricultural sector. By promoting sustainable farming practices, the long-term costs associated with environmental degradation and climate change can be reduced.

In order to urgently develop information systems, it is proposed to ensure the following tasks:

- Data collection with the use of the Farmers' Register Information System software, pre-filled with official data;
- Elaboration of the documents for the implementation of the Information System "Farmers' Register" and of the manuals of procedures for the system's operation;
- Operationalize interoperability and automatic registration of potential beneficiaries;
- Appointing the staff responsible for the Farmers' Register Information System and setting up the Unit that will manage the Integrated Administration and Control System;
- Urgent need: launch the LPIS (Land Parcel Identification System) pilot.

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USE OF AERIAL LASER SCAN DATA IN THE DEVELOPMENT OF THE TOPOGRAPHIC PLAN

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Abstract: *The authors highlight the advantages of using unmanned aerial vehicles (UAVs) and laser scanning as a modern approach in terrestrial surveying, comparing it with traditional data collection methods. The potential to derive topographic products from the point cloud generated by the survey is examined. This technology represents the latest innovation in modern cartographic data acquisition methods. UAV systems stand out for their flexibility and high efficiency in data capture. In this paper, the authors aim to showcase the benefits of employing UAVs and aerial laser scanning technology (Lidar) as a methodology to generate a 1:500 topographic plan derived from a point cloud. An overview of topographic and geodetic products is provided, emphasizing their significant economic potential, which remains regrettably underutilized in the Republic of Moldova.*

Keywords: *UAV, GPS, GNSS, GIS, Lidar, 3Dsurvey,*

1. Introduction

Laser scanning-is a technique by which the geometry of a structure can be measured completely automatically (more or less), without the aid of a reflective medium, with high accuracy and very high speed [1].

The information assurance of the analysis and decision-making process has spatial data acquired by terrestrial measurements as a component. Correct and timely available information is one of the essential requirements in informing decisions viz:

- Urban and rural management and sustainable development cannot be conceived without adequate resource management tools;

- Solving problems related to urban modeling, damage assessment for different purposes, agricultural property, application of agricultural policies, subsidy issues, etc. [1, 2].

In the last period of time in the Republic of Moldova special attention has been paid to the modernization of terrestrial measurements. Aerial surveys have occupied an important place in the field of land surveying [1].

This technology has revolutionized topographic mapping by providing highly accurate and detailed terrain data. Aerial laser scanning involves aircraft-mounted sensors that emit laser pulses toward the ground. These pulses reflect off surfaces and return to the sensor, providing precise measurements of terrain elevation and surface features. The system simultaneously records GPS coordinates and aircraft orientation, enabling accurate georeferencing of the collected data [1, 2].

The raw point cloud data undergoes several processing steps to create usable topographic information. First, the data is classified to separate ground points from vegetation, buildings, and other features. Sophisticated algorithms filter noise and eliminate erroneous readings. The cleaned data then undergoes interpolation to create a continuous surface model. The processed laser scan data serves as the foundation for creating detailed topographic plans. Modern software systems convert the point cloud into precise contour lines, spot elevations, and three-dimensional surface models. These elements form the basis of comprehensive topographic plans that accurately represent terrain characteristics, including slopes, drainage patterns, and surface features.

Using aerial laser scan data for topographic planning offers several significant benefits:

- Enhanced accuracy with vertical precision typically within 10-15 centimeters;
- Rapid data collection over large areas, reducing project timeframes;
- Ability to penetrate vegetation canopy to measure ground elevation.

Comprehensive coverage of terrain features, including areas difficult to access by traditional survey methods.

The resulting topographic plans integrate seamlessly with modern CAD and GIS systems, enabling further analysis and design work. This compatibility makes the data particularly valuable for infrastructure planning, environmental assessment, and construction projects [1, 2].

In fact, UAV has changed the way that the data has been collected in traditional land surveying methods such as theodolite, tacheometry, and total station traversing, and so on, and as well as in modern land surveying methods such as robotic total stations, RTK GNSS surveying, and so on [3]. By the UAS photogrammetric surveying, the surveying crew, time and cost required for land surveying methods have been fully changed while preserving the product accuracy similar to the field surveying [3,4].

Aerial laser scanning has revolutionized topographic mapping through its ability to capture highly accurate, three-dimensional data of terrain surfaces. The primary applications in topographic development can be categorized into several key areas.

Aerial laser scanning enables the creation of highly detailed Digital Elevation Models (DEMs) and Digital Terrain Models (DTMs). These models provide precise representations of ground surface topography, with vertical accuracies often reaching 10-15 centimeters. The technology excels at capturing both macro and micro topographic features, making it invaluable for understanding landscape characteristics at multiple scales.

In urban environments, aerial laser scanning proves particularly valuable for creating detailed topographic maps that include both natural and built features. The technology can accurately capture building heights, road networks, and other infrastructure elements while simultaneously mapping the underlying terrain. This comprehensive data aids in urban planning, infrastructure development, and the creation of 3D city models.

The unique capability of aerial laser scanning to penetrate vegetation canopy makes it exceptional for mapping forested areas. The technology can simultaneously capture both the forest canopy surface and the ground beneath, enabling the creation of detailed topographic maps in areas where traditional photogrammetric methods struggle to provide accurate ground measurements.

For coastal areas, aerial laser scanning provides precise measurements of shoreline topography, beach profiles, and coastal infrastructure. This data is crucial for coastal zone management, erosion monitoring, and flood risk assessment. The technology's ability to rapidly cover large areas makes it particularly effective for monitoring dynamic coastal environments.

The high-resolution data from aerial laser scanning enables detailed mapping of geological features and landforms. This includes the identification and measurement of fault lines, rock outcrops, landslides, and other geological structures. The technology's ability to create bare-earth models by removing vegetation cover has revolutionized geological mapping in heavily forested areas.

When used for temporal monitoring, aerial laser scanning provides precise measurements for volume calculations and change detection. This capability is particularly valuable for monitoring earthwork operations, quarry volumes, erosion processes, and landscape changes over time. The technology enables accurate quantification of topographic changes, supporting both planning and monitoring applications.

The detailed topographic information provided by aerial laser scanning is instrumental in identifying and mapping areas susceptible to natural hazards. This includes flood-prone areas, unstable slopes, and potential landslide zones. The high-resolution data supports more accurate risk assessments and the development of mitigation strategies.

These applications demonstrate the transformative impact of aerial laser scanning on topographic mapping and modeling. The technology's ability to provide accurate, comprehensive, and rapid terrain mapping has made it an indispensable tool in modern geospatial applications.

2. Materials and Methods

Aerial laser scanning operates on the principle of LiDAR (Light Detection and Ranging) technology. The system emits rapid pulses of laser light toward the ground from an aircraft-mounted scanner. These pulses reflect off surfaces and return to the sensor, which measures both the time of flight and intensity of the returned signal. By precisely recording the time between pulse emission and return, the system calculates the distance to the reflected surface.

The ALS system comprises several integrated components working in concert. The primary components include:

The laser scanner unit generates and receives laser pulses while measuring their return time and intensity. A precise positioning system combines GPS (Global Positioning System) and IMU (Inertial Measurement Unit) technologies to track the aircraft's position and orientation. The data recording system captures and stores all measurements, including laser returns, GPS positions, and IMU data. Supporting software processes and integrates these various data streams.

During a typical aerial survey, the aircraft follows predetermined flight lines while the scanner emits thousands of laser pulses per second. The laser beam typically scans in a side-to-side pattern perpendicular to the flight direction. Modern systems can emit up to 2 million pulses per second, creating dense point coverage of the surveyed area.

The scanning process records multiple returns from each pulse, as the laser beam may partially reflect off various surfaces before reaching the ground. This capability allows the system to capture information about multiple surface levels, such as vegetation canopy, building structures, and the ground surface.

Raw data processing involves several sophisticated steps. Initially, the system combines GPS and IMU data to establish the precise position and orientation of each laser pulse. This information, combined with the measured ranges, allows calculation of precise XYZ coordinates for each reflected point. The resulting dataset, known as a point cloud, undergoes classification to identify different types of surfaces (ground, vegetation, buildings, etc.).

Advanced filtering algorithms remove noise and unwanted data points while preserving essential surface information. The classified point cloud then serves as the foundation for generating various topographic products, including digital elevation models, contour maps, and 3D surface models.

Several factors influence the accuracy of aerial laser scanning data. These include:

Flying height and scanning angle affect point density and measurement accuracy. GPS and IMU performance impact positional accuracy. Atmospheric conditions can influence laser pulse transmission. Surface characteristics affect the strength and quality of return signals.

Modern ALS systems typically achieve vertical accuracies of 5-15 centimeters and horizontal accuracies of 15-25 centimeters, depending on operating parameters and conditions.

Regular system calibration is essential for maintaining data quality. This includes:

Laboratory calibration of the laser scanner unit to ensure accurate range measurements. Boresight calibration to determine precise alignment between system components. In-field calibration using control points to verify system performance. Regular maintenance and monitoring of all system components.

The purpose of the research is to establish the possibilities of using UAV techniques equipped with Lidar systems in the collection of geospatial data and digital photogrammetry in image processing, with a view to creating topographic plans [2].

Considering the purpose (revitalization) and the objectives of the work, the location of the French Park in the city of Ungheni was chosen (figure 1).

Figure 1. French Park

Source: Google Earth

The area of the study object is about 15 ha. At the request of the Ungheni City Hall, the implementation project for the development and modernization of the French Park, stage I, was carried out, which provides for the development of a 4ha site.

A UAV type DJI MATRICE 350 RTK [6] unmanned aerial aerian vehicle (figure 2) was used for the flight and data acquisition, equipped with positioning sensors (GNSS and IMU inertial navigation unit), a imaging sensors (aerial digital camera) and a Zenmuse L2 type Lidar frame [7].

Figure 2. DJI MATRICE 350 RTK

The working methodology involves the use of the mentioned technologies (GNSS, UAV, Lidar) and involves the following stages [5]:

-recognition of the land area under study;

-establishment of the number and location of photogrammetric markers;

-performance of GNSS observations for the bridges that serve as a support network;

-taking digital images using the UAV equipped with a digital camera;

-taking the point cloud using the UAV equipped with Lidar equipment;

-preparation of orthophotomaps for the studied area;
- extraction of the dense point cloud;
- classification of the dense point cloud;
-verification of data accuracy;
-obtaining the topographic plan.

The initial phase focuses on preparing the raw data for processing. This begins with importing the raw laser scan data, GPS trajectories, and IMU measurements into specialized processing software. The system performs quality checks on the data streams, identifying any gaps or anomalies that require attention. Timing synchronization between all data components is verified to ensure proper temporal alignment.

The next critical step involves processing the aircraft's trajectory data. This combines GPS and IMU measurements through sophisticated Kalman filtering algorithms to produce a precise trajectory solution. The trajectory data provides the exact position and orientation of the scanner at every moment during data collection. Any GPS base station data is incorporated to enhance positional accuracy through differential correction techniques.

With a refined trajectory solution, the system combines this information with the laser range and angle measurements to calculate the precise three-dimensional coordinates of each reflection point. This process, known as georeferencing, transforms all measurements into a common coordinate system. The resulting point cloud typically contains millions of points, each with associated attributes such as intensity values and return number.

When multiple flight lines are involved, strip adjustment procedures are necessary to ensure consistency between overlapping data strips. This process identifies and corrects systematic errors that may cause misalignment between adjacent strips. Advanced matching algorithms analyze overlapping areas to optimize the relative and absolute positioning of all data strips.

The classification phase categorizes each point based on the type of surface it represents. Advanced algorithms analyze the geometric relationships between points to identify ground points, vegetation, buildings, and other features. This process typically occurs in multiple iterations, with each pass refining the classification results. Manual editing may be required to correct misclassified points in complex areas.

Rigorous quality control procedures are implemented throughout the processing workflow. This includes checking point density distributions, identifying data voids, and verifying classification accuracy. Automated and manual filtering procedures remove noise and erroneous points while preserving essential surface detail. The data undergoes validation against ground control points to verify absolute accuracy.

3. Results and Discussion

This article discusses the possibility of developing a topographic plan based on the dense cloud of points obtained with the Lidar system Zenmuse L2. The flight mission planning was carried out in the controller (figure 3). The flight was carried out at an altitude of 100 m.

Figure 3. Flight itinerary

Figure 4. Data processing time.

After the flight, the raw data was downloaded into the DJI Terra software, the data processing time is shown in the figure 4.

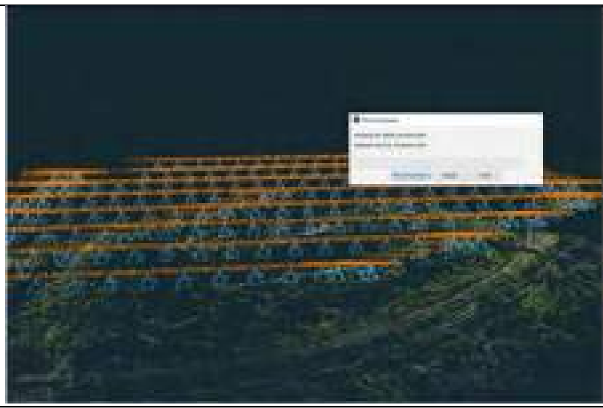

Figure 5. Point cloud DJI Terra.	Figure 6. Import data

As a result of the data extraction from the equipment, the point (figure 5) cloud was generated in the *.las extension to be imported into the 3DSurvey software (figure 6). In order to colorize the point cloud, the photo images resulting from the flight were also imported.

As a result of the processing, a dense cloud with a density of about 580 points/m2 was obtained.

For the purpose of developing the topographic plan, were generated the digital terrain model (DTM) and the elevation model (DEM) (figure 7), which is a mathematical representation, a model of the terrain surface in digital format.

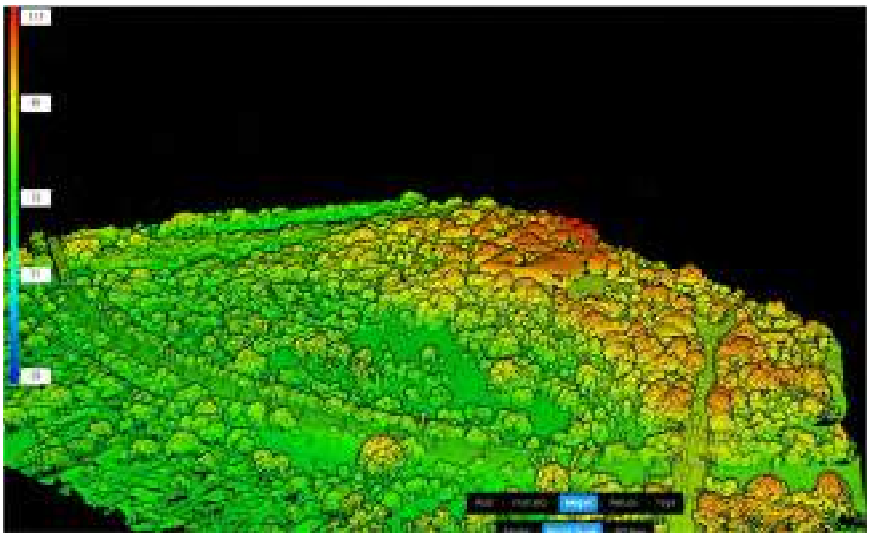

Figure 7. Altitudes

The interpretation is usually done separately in post-processing and can be adapted to each individual application. In order to generate the DTM based on these automatically generated data, it is essential in this post-processing step to extract the relevant terrain data from all the collected information.

This task is a classification of the automatically obtained topographic data into information about the terrain and objects located on it. In the airborne laser scanning environment, this process is usually referred to as filtering (figure 8).

For the purpose of developing the topographic plan, point cloud classification was performed. From the data obtained in the result of the classification, the characteristic points of the terrain (figure 9) were extracted for generating the contour lines (figure 10).

Figure 8. Point cloud of terrain

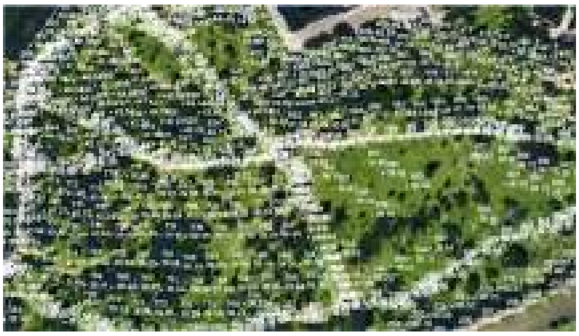

Figure 9. Characteristic points of the terrain

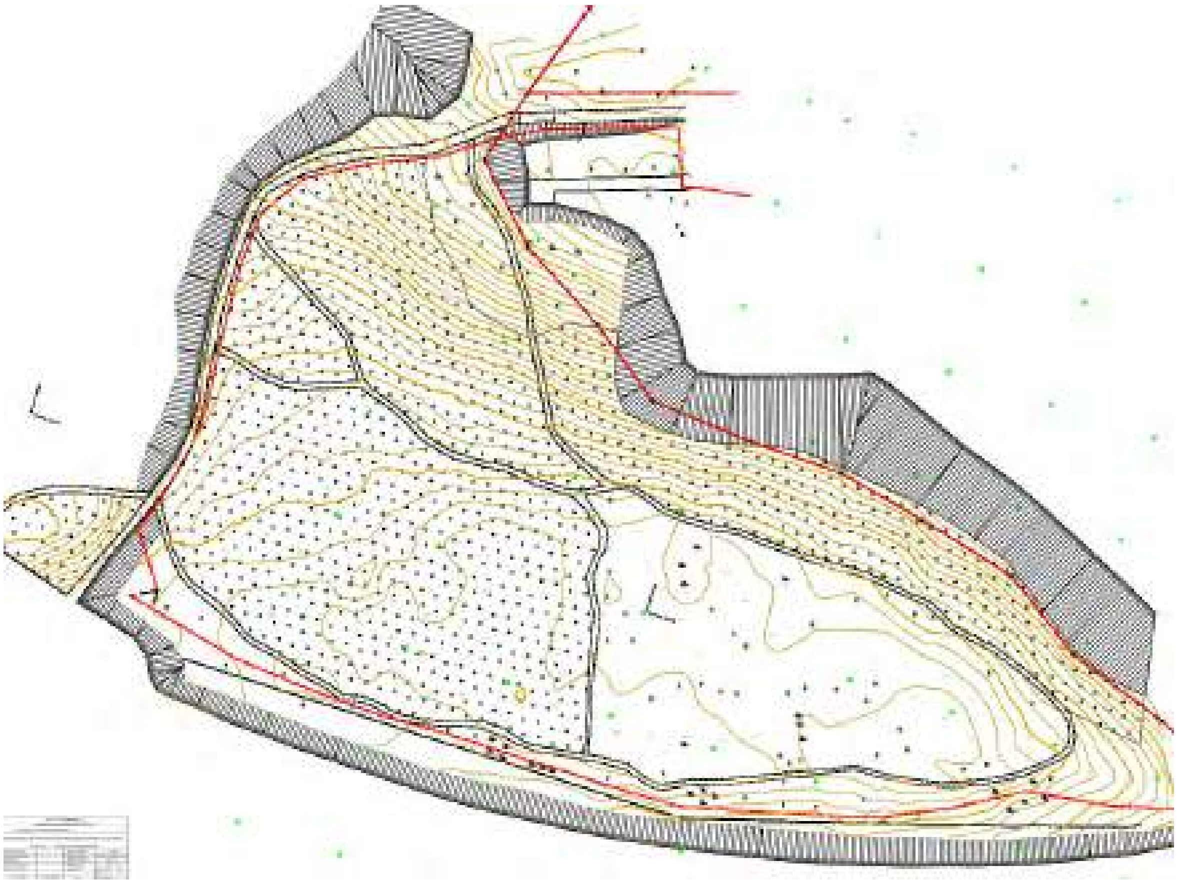

Figure 10. Topographic plan

4. Conclusions

In conclusion, for better mapping of large-scale urban areas, it is preferable to use a fusion of Lidar data and photogrammetric point clouds, because Lidar can penetrate dense vegetation and produce accurate ground points, while image-based matching of point clouds can provide dense datasets with high texture and high spatial resolution. With this in mind, the author hopes that new software will soon become available for fusing photogrammetric point clouds with Lidar point clouds into an improved final dataset.

The advantage of using Lidar technology compared to classic topographic surveys is obvious, namely for their application in hard-to-reach areas. High-resolution and accurate 3D data expands the areas of application of Lidar technology.

The areas in which drones with Lidar equipment are applied are infinite. Currently, drones with Lidar equipment can be successfully applied to develop topographic plans applied in various branches of the national economy.

Advantages of UAV technology with Lidar:

- Efficiency;
- Enhancing the accuracy of topo-geodetic data;
- Developing and updating different types of maps and plans;
- Developing 3D models of localities;
- Developing digital models of terrain

The geospatial profession must continually evolve to respond to global challenges, societal impacts, and rapid technological change. The factors outlined in this article have a profound impact on this profession. It is important to ensure that professional standards and practices, including valuation, construction, and other global standards under which the industry operates, are still relevant. It is also essential that the next generation of professionals is educated and competent and able to contribute responsibly to global challenges.

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MONITORING AQUATIC BODIES USING GOOGLE EARTH GIS APPLICATIONS

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Abstract. *In the RM more than 5,000 smaller dams have been built on rivers. The lifespan of them is usually 30-50 years. Considering that most of them were built in the years 1960-1980, many of them have an expired exploitation period and the others are at the limit of the exploitation period. Another important aspect is the fact that their maintenance in the last 30 years was far below the requirements. The latest analyzes and findings highlight the precarious state of the hydrotechnical constructions, as well as the lack of an effective tool for periodic monitoring of aquatic bodies, which represents an environmental risk, especially floods. About the 126 reservoirs, have a capture capacity of more than one million m*^{3} *volume, which are used for fishing, irrigation, water supply, recreation. The effects of climate changes in recent years, marked by pronounced droughts on the one hand and torrential rains on the other, estimate the state of high risk of hydrotechnical constructions, especially the regularization systems. In this context the goal of this research is the monitoring and assessing of the current conditions of water body through a simple geo-informational application, easily accessible to officials, employees in the field. In this scope monitoring and administrate to assure the visualization and transparency of water body the application on the "blogspot.com" platform was created with properly configured geographic interest patterns. Cartographic data were published on Google Maps and integrated in blog. Thus, by accessing the blog, the views of the lake, the hydrotechnical constructions, the points of interest, with the necessary attributes is accessing with the possibility for the spatial analyses. The preliminary results show the positive effects and high interest of the stakeholders concerning of WEBGIS technology for the assessment of environmental conditions of water body.*

Keywords: water body, *hydrotechnical constructions*, flood risk, monitoring, BlogSpot GIS application

1. Introduction

The monitoring of the state of lakes/ponds including the inventory of the resistance structures of hydro-engineered constructions has an essential role in the overall integrated management of aquatic resources. Thus, by monitoring and inventorying the state of lakes as an indivisible good [1], the following objectives are pursued:

- Efficient management of surface water resources (lakes/ponds) which are valuable freshwater resources used for drinking water supply, irrigation, recreation and hydropower generation. Inventory helps to monitor their status and plan for sustainable management, including in situations of natural disasters;
- Biodiversity conservation, which is expressed in the fact that lakes can harbour complex ecosystems, including rare or endangered plant and animal species. Their inventory allows the identification of vulnerable ecological zones and the implementation of protection measures to ensure the balance in the ecosystem evolution;

- Monitoring of climate changes, which have become increasingly noticeable in recent times, which may affect the physical-chemical characteristics of lakes (e.g. temperature, water level, acidity, pollution, etc.). Regular inventories help to assess their impact;
- Pollution and water health assessment, including analysis of pollution, eutrophication (nutrient over-supply, infection). The inventory enables the detection and assessment of these problems, contributing to remedial solutions.

In general, inventory/monitoring of ponds/lakes plays a crucial role in ensuring sustainable management of water resources and protecting the environment.

2. Lakes, ponds - technical aspects

More than 5 thousand ponds/water reservoirs have been built in Moldova. Ponds - are water accumulations with a volume up to 1 mln. m³. Water accumulations with a volume of more than 1 million cubic metres are called lakes [2]. Most of the ponds/lakes were built in the period 1960-1980, corresponding to today there are large differences in the useful volume of water compared to the projected dates and the period of the beginning of operation. Of the 126 of the total number of lakes with a catchment volume of more than one million m3 are in the category of reservoirs.
Assessment and inventory activities were carried out in 1995 on the state of 1253 ponds/lakes (source ACVAPROJECT). As a result, the degree of hazard to settlements located downstream of the dams in case of high risk (dam failure, cascade effect) was determined. Within the project EPTATF 2013-2016 “Management și suport pentru Asistență Tehnică privind protecția teritoriului RM împotriva inundațiilor”, financed by the EIB - *Service contract No TA2011038 MD EST* (TA-MDFRM 2013-2016), an assessment has also been carried out for cases of dam failure for several lakes [3].

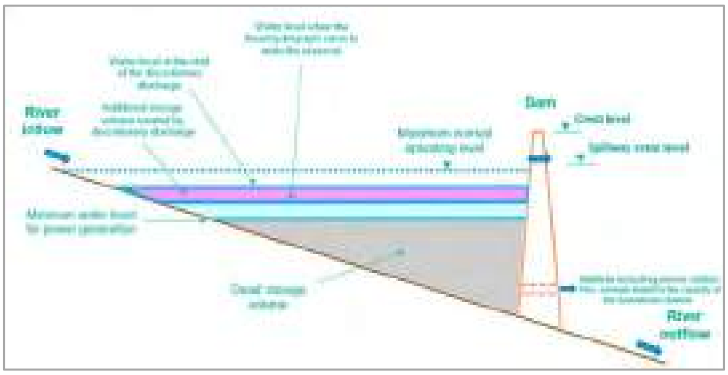

Figure 1. Main components of a pond/lake located on a watercourse (river)

Analyses have revealed that a good part of the ponds/lakes were built with deviations from the rules in force (СНИИП), corresponding to about 40% of them pose a real danger to the population in case of dam failure. The predominant dam height varies from 5 to 11 metres. The hydrotechnical constructions (dams) of ponds and reservoirs are predominantly made of quality earth (clay), usually located in the immediate vicinity of the dams. The ponds/lakes designed and constructed were intended for irrigation, fish-farming, with potential for water supply, power generation, soil erosion control, recreation. The hydro-technical nodes (the systems for operating and regulating the water level) of ponds and reservoirs (Figure 1) have the following main components:

Dam;
Discharger;
Bottom outlet;
Water intake.

High (storm) water dischargers are designed to discharge excess water above the normal retention level (NNR) automatically. Dischargers of type:
- Mine (mining galleries/channels in the lower part of the dam body);
- Open canal (Svetlâi, Ulmu etc.);
- Sluice gates (Comrat, Sărata Noua, etc.).

Bottom drains serve as the basis for draining ponds/lakes and are of the closed and siphon type. The closed type variants are usually realised with an inlet through a concrete inlet, located at the minimum level of the pond, to which is connected the water transport pipe, which ends at the downstream end of the dam, where the mine is made with a valve on the pipe. The valve is used to drain the water, thus adjusting the water level.

The inventory carried out by joint commissions (representatives of central and local authorities) examined the current state of the hydro-technical constructions of reservoirs/river basins (dam, spillway, bottom spillway) as well as the documentation of reservoirs/river basins. Analysis of existing materials, finds the following:

a large number of hydro-technical constructions of ponds/lakes are in a damaged state;

the projected operational life of the lakes is 45-60 years.

Bearing in mind that most of them were built in the years 1960-1980, it follows that many of them have expired their period of exploitation, and the others are at the limit of their exploitation period. Estimates show that due to the high level of clogging, the volume of reservoirs has declined on average by 0.50 per cent per year [source report - World Bank].

In the process of monitoring, assessment of the state of the lakes as a whole, it is important to know the types of water bodies existing in the Republic of Moldova, their use and technological processes of exploitation. Thus, in the Republic of Moldova ponds/lakes are classified as follows:

- Natural lakes - mainly located in the Prut valley. They are usually small in area, shallow and often covered with marsh and hydrophytic vegetation. Very few of these lakes are larger than 2 km²;
- Flood lakes - the characteristics (area, depth, hydrological regime, etc.) are largely determined by the regime of large rivers (e.g. the lower Prut and Danube). The hydrological improvement works carried out in the 1970s have drained many of the meadow lakes. Prior to this, the lakes in the Prut valley extended like a garland for about 100 km between Cantemir and Giurgiulești. Today the lakes in the segment from Cahul to Giurgiulești are protected. The largest lake within the Prut River basin is Lake Beleu, located in the lower Prut between the villages of Valeni and Slobozia Mare. During droughts, the lake has a surface area of about 6.26 km2 and a maximum depth of 1.2 m. During floods, it has a maximum surface area of 9.5 km2 and a maximum depth of 2.8-3.0 m;
- Ponded lakes - formed as a result of landslide processes. They do not exceed several hectares in area and are 1-1.5 m in depth. As an example they can be found in the Suta de Movile landscape reserve;
- Man-made lakes - created by man to fulfil various economic needs (e.g. fishing, irrigation, power generation, recreation, etc.) as well as to regulate river flows and control floods.

3. The place and role of ponds/lakes

Ponds and reservoirs play a significant role in natural disaster risk management and risk prevention, with the main role being the protection of communities and infrastructure from flooding. Thus, in the totality of water management objectives, the process of water flow regulation and flood prevention is of particular importance. Reservoirs are built to capture water from watercourses, which can help prevent flooding. During heavy rainfall or sudden snowmelt, reservoirs can hold excess water, preventing rivers from surging and flooding [4,5]. Also, by using lake outflow operation/regulation systems, authorities can regulate the flow and direction of water, reducing flood risks on land downstream of dams/ dykes. In times of crises, droughts or other disasters affecting water sources, reservoirs can become a crucial source of drinking water for communities. As such, they play a vital role in providing water to people in emergency situations.

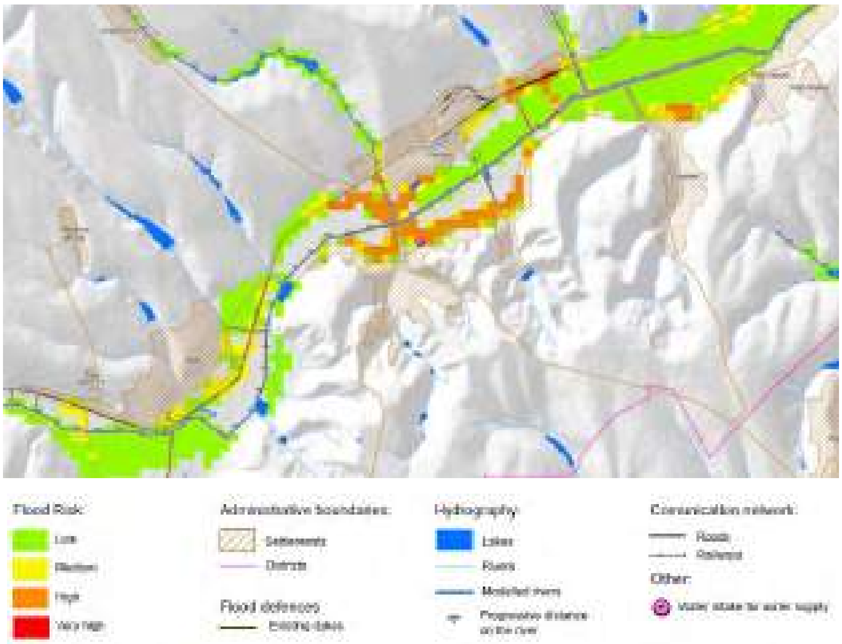

Figure 2. Flood risk assessment (source: Management and Technical Assistance Support Project on Flood Protection of the territory of the Republic of Moldova)

The presence of a reservoir can influence the microclimate in an area, which can help reduce the risk of fire in prolonged drought conditions. Vaporisation of water from lakes can help to maintain air humidity and cool the area during hot periods. They can be used as water sources for fire-fighting or other rapid response activities in case of natural disasters (e.g. flood response, forest fires, etc.).

Figure 3. Property, land affected by heavy rains

The condition of dams (the dominating asset of reservoirs) could be a problem during major rainfall related events, in fact, as is known, dams can be used to stop stormwater and then release it in a controlled way into the river through regularisation system, or to store it or divert it for other uses. Within the framework of the project Management and Technical Assistance Support on the protection of the territory of the Republic of Moldova from floods 2013-2016 [3], a flood risk map was made covering the entire area of the Republic of Moldova, thus allowing the possibility to assess whether a dam could be used as a flood risk storage volume, corresponding to which area (Figure 2).

Thus, the condition of ponds/lakes is essential in the process of risk management in the face of natural disasters, providing not only protection against floods and droughts, but also an ecological defence system and aquatic infrastructure [6].

The latest risk situations, caused by the heavy rains of September 2024, which occurred in the RM, especially in the south-western part, have highlighted the weak moments with reference to the state of the dams in their entirety and of the operating/regulation systems in particular, corresponding to the flood management capacity.

The bursting of some dams, the cascade effect generated by the non-functioning of the regularisation systems led to floods affecting large areas of land in the urban and rural areas (Figure 3). In the context of heavy rainfall, the order of the Minister of Environment was issued on the inventory of hydro-technical constructions of reservoirs with an area of more than 50 ha and a catchment volume of more than 500 thousand m3.

4. Methodology for inventory and monitoring of aquatic bodies

Our approach focused on the idea of an empirical study (based on observations and field measurements) on the of the structural state of hydrotechnical constructions (dams, spills) and the environmental quality in the protection strips of the lakes so that the results obtained are also transferable to other spaces, processes or phenomena of the same type. We have proposed an integral analysis of the territory of the water fund including the protection strips, the processes and phenomena taking place within them, in order to obtain a clear picture of the state of the environment. It insisted on highlighting cause and effect relationships, while the study was both descriptive and relational (determining relations that were established between the components of peri-coastal ecosystems). The analysis of the structural and of the environment state focused on the current state, while trying to give the study and a temporal perspective, by trying to predict the evolution of the state of the environment under current conditions and under conditions of changing environmental factors. The following steps were taken in the study:

1) study of cartographic and bibliographic materials;
2) data collection in offices and in field conditions;
3) processing and interpretation of collected data;
4) developing proposals and finding solutions;
5) preparation of reports.

The structural and environmental data collection has taken into account the target objectives and the availability of the information, and the approach scale has been selected in line with them. Thus, environmental data from the administrative flow, existing studies and research, maps, photographs, satellite imagery, etc. and were used data collected during the course of the study using an own methodology. The data collected is accompanied by metadata in order to be able to be properly processed. The collection of data was done by measurements, sampling, analysis and interpretation of field samples, mapping, observation and questioning.

At the initial stage of data collection, materials from the entities responsible for water management, including project documentation, technical passports, operating regulations etc., were examined and systematised. Additional information was also collected through Moldova Map (https://moldova-map.md/mapstore/#/) carried out by INGEOCAD and the Institute of Territorial Organisation Design (http://soluri.md/adapt/dist/#/layers). Based on the knowledge of the entire territory of the Republic of Moldova, provided by specialists in the field, through the available data and information, it is proposed to develop a questionnaire that would include the following criteria:

1. Pond/lake size, location;
2. Safety conditions (condition of construction and regularisation systems);
3. Socio-economic development, mode of operation;
4. Ecology and environment.

The criteria cover a wide range of issues and are intended to be as objective (tangible) as possible. From each criterion is derived a set of characteristics/parameters that are considered necessary for a better description of the water body.

Figure 4. Photographic images taken during the field examinations

After analysing the material from the enterprises, filled in questionnaire-forms, visits, corresponding measurements and observations were carried out at the aquatic objectives. Small- and large-scale photographs were collected (figure 4), taken with smartphones, reflecting the state of the constructions, the ground and the seabed at the time of inspection. The photos have been geo-referenced, which allows their import/export into geo-information applications. Data collection was realised through a combination of digital and manual methods. Lake vector layers were extracted from official sources and processed using the QGIS platform. Each lake was identified and vectorised to ensure an accurate geospatial representation. Photography and post-visit examination of each lake, with geo-location enabled, for photographic documentation of lake condition and associated infrastructure, particularly dams.

In the field, detailed information on the general condition of the lake, dam, outlet channels and other relevant technical elements was collected, updating the database used in the analysis and monitoring process. For a better understanding and presentation of the results of the inventory process, a digital map was realised, which formed the basis of the geo-information application. For this purpose, OpenSource GIS sources and tools and technologies were used [7], applied mainly on the Google Earth platform. Thus, layers with lakes from official sources are used to create a digital map with lake representation. Although it is possible to vectorise the lakes on orthophoto images, it is not recommended, because due to the fall and rise of the water level in the lakes, we will have an aliasing surface, depending on when the orthophotos are taken.

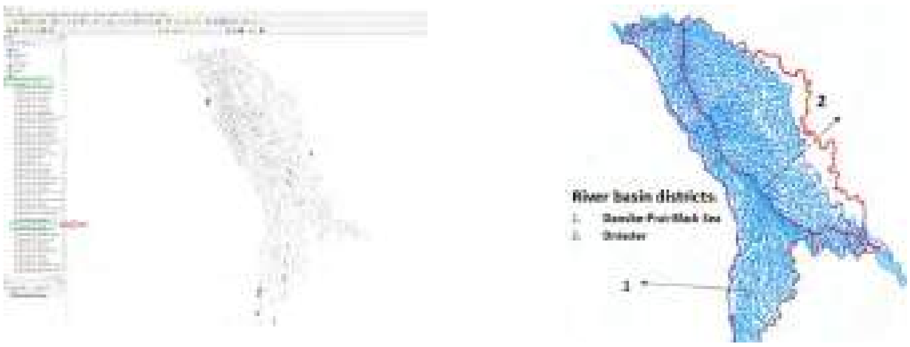

Figure 5. Lakes and rivers of the RM on the map

Thus, the vectorised lakes layer at the normal retention level (NNR) will be used. This "lake_area" lake layer will be imported from the database „Base map 2017” (figure 5), adding this layers in QGIS by connecting to WFS with the link: https://geodata.gov.md/geoserver/maps/wfs. After the list of lakes of interest, we searched on the map and exported each individual lake. This was due to the fact that some lakes were divided by different cadastral nr. in QGIS they were also divided into separate polygons, therefore only one polygon had to be created for each lake.

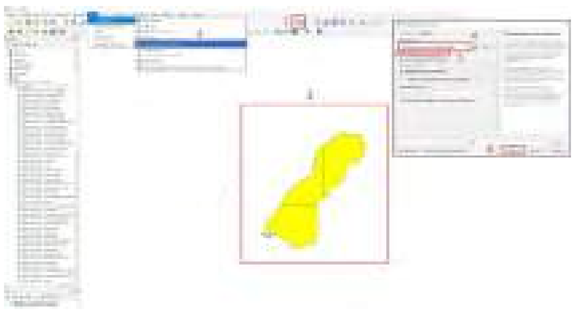

Figure 6. The process of merging vector layers in QGIS

Thus, the polygons were united. The "Merge on Attribute" function was used to combine multiple regions while preserving their original geometry (figure 6). This method helps integrate the data into a single "polygon". Thus, the polygons were merged. The "Merge on Attribute" function was used to combine multiple regions, preserving their original geometry, integrating the data into a single polygon. The standardised questionnaire for the assessment of the general and technical condition was completed for each pond/pond. The process included data collection through detailed visual on-site inspections, supplemented with information from official sources. The main steps of data collection included:

- General information (project documentation, location, surface area, lake volume and administrative details about the dam. Data such as the type of dam, the duration of operation and its purpose were included.
- General visual inspections - identify deformations, signs of corrosion and the general condition of structural components. Assess drainage systems and analyse the presence of vegetation.
- Structural integrity - inspecting the canopy, the integrity of the dam. Observation of possible seepage and analyse the need for rehabilitation of joints.
- Mechanical devices and equipment - the condition of the operating systems (water level regulators, water level regulating valves and outlets. Functionality of pumping equipment, if any, etc.).
- Safety and protection - presence of monitoring systems, warning signs and evacuation plans. Assessment of alarm systems for critical water levels.

- Documentation and reporting - verification of operational documentation and repair/restoration reports.

5. BlogSpot geoinformational product on Google Earth

Google Maps products are available on web "browsers", mobile devices (Android and iOS) and can be integrated into third-party applications via the Google Maps API. They have evolved significantly over the years, introducing technologies such as machine learning to provide more accurate arrival time estimates and improved local exploration functionality. One of the key innovations of Google Maps is the integration of "Live View" functionality, which uses augmented reality to provide real-time directional directions superimposed over images captured by a mobile device's camera. In addition to personal use, Google Maps plays a key role in areas such as transport, tourism, logistics and spatial data analysis. This platform continues to lead the way in real-time digital mapping solutions thanks to constant innovation and extensive functionality. The present study benefited from the integration of Blogspot and Google Maps platforms, which represent a modern solution for geospatial data management and presentation. Blogspot provides a flexible environment for documenting and publishing information in an accessible format, while Google Maps adds an interactive dimension by visualising data on digital maps. The combination of these tools is ideal for projects involving complex geographic data, as it facilitates public access to detailed information and allows intuitive navigation between content.

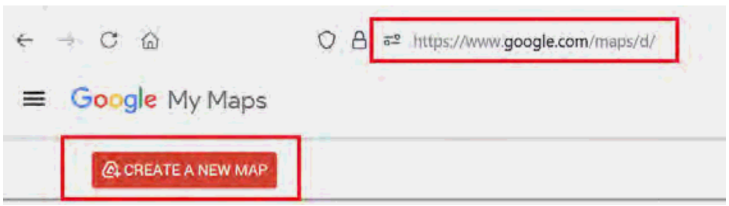

Figure 7. Initiating process of the map creation

Using the Blogspot platform, the information centralised in the digital map created on My Maps will be published and made available to interested parties. This approach allows for the organisation and presentation in an interactive way of data on reservoirs already integrated in My Maps. The main purposes of the application include:

- ✓ Data presentation - publishing information on lake status, dam characteristics and other relevant details in a clear, structured and easy-to-navigate format.
- ✓ Integration with My Maps - adding interactive links to the digital map, providing quick access to detailed information and multimedia.
- ✓ Information sharing - creating a dedicated public space where authorities, experts and other interested parties can consult information on the reservoirs.
- ✓ Simplifying access - transforming technical data and geospatial information in My Maps into a more accessible and understandable format for the general public.

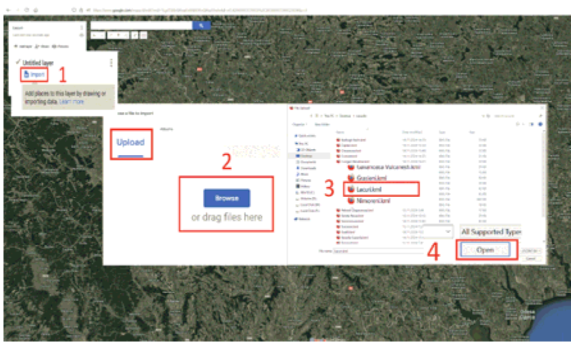

Figure 8. Import layer - lacks

To create the digital map, click on the link (figure 7) and activate the "CREATE A NEW MAP" button. Give a name, e.g. "Lakes" if needed it can be changed at any time. To import information, activate "Add Layer", then the "Import" button. The first step is importing the varnish layer (figure 8). Once the lakes have been imported, the next step is the creation of the attribute database, for ponds/lakes creating the attribute table based on the data collected and integrated in the questionnaire prepared by the authorities and filled in during the inventory process (figure 9).

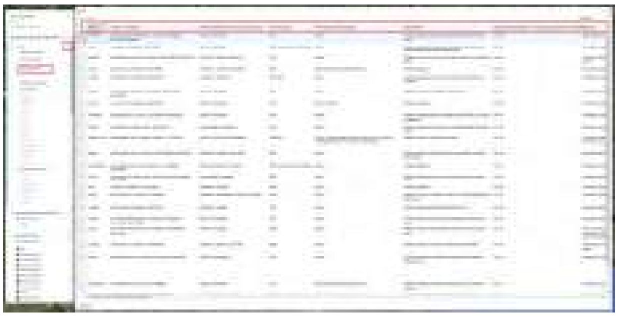

Figure 9. Attribute table generated based on the questionnaire

For convenience it was decided to classify the aquatic bodies into two groups: 1) satisfactory - coloured green and 2) unsatisfactory - coloured orange. The main attribute in this grouping was used "Overall assessment of dam condition" (figure 10).

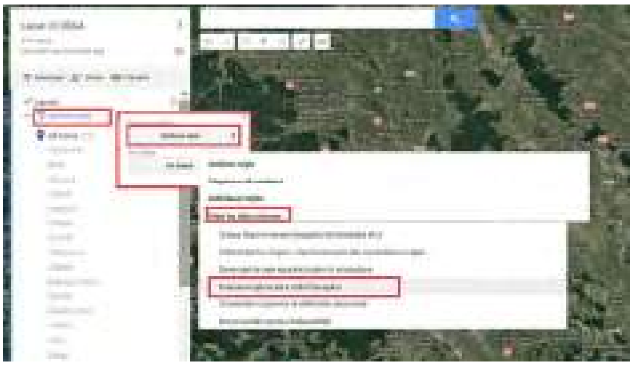

Figure 10 Classification by attribute

After these operations/manipulations the localisation of the lakes is performed, correspondingly on the left side of the application interface, we have the lakes grouped into satisfactory and unsatisfactory, including all the information about each one. The information about each lake appears when we select a particular lake in the list, at the same time it automatically zooms to the selected lake, or if we search for the lake manually on the map, we left-click directly on the map on the polygon of the vectorised lake and all the information about it appears, including the photographic images taken during the field visits.

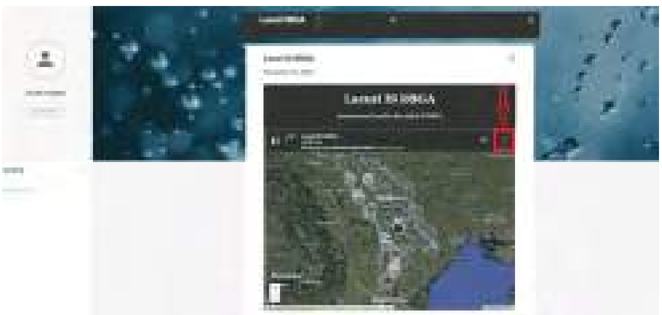

Figure 11. Application start interface https://lacuriisdbga.blogspot.com/2024/11/lacuri-dbga_19.html

The end result is the page published on BlogSpot that provides an accessible and well-organised space for presenting information about the IS DBGA reservoirs (Figure 11). The digital map is displayed in a compact window and the dedicated button allows it to be expanded to the full screen, providing a detailed and interactive visualisation. The application can be developed by filling in and updating the data of interest, being an object tool for assessing the state and evolution of geographic obiccations with spatial and descriptive features.

6. Conclusions

The WEB GIS application is an "open window" to the ponds/ reservoirs of interest, providing information on the actual situation on the ground regarding the state of the hydro-technical constructions (dams, regularisation systems). It is published with updated information in a blog format, this is a way of highlighting the real state of the actual status of the facilities of interest to stakeholders.

Monitoring the status of hydro-technical constructions, protection zones and drawing up action plans becomes much easier with the involvement of GIS technologies.

The study confirms the effectiveness of OpenSource GIS technologies in managing spatial objects, in this case lakes and ponds, characterised by shape, size, position and time. The possibility to continuously update data and information emphasises the importance and value of this product.

Remote sensing technologies have become increasingly accessible, in particular due to the possibility of using free data, simple methods of collecting and downloading information, and the calculation of specific parameters such as NDWI indices.

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THE NEED FOR THE CONSOLIDATION OF AGRICULTURAL LANDS

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Abstract: *The Republic of Moldova being an agrarian country, where about 80% of the country's soils are chernozems, would benefit from a significant increase in the productivity of agricultural crops. The agrarian reform implemented in the Republic of Moldova in the 1990s contributed to the excessive fragmentation of agricultural land into small plots, which considerably reduced the productivity of the land and its rational use. This problem was and is present in the field of agriculture. In order to solve it, it is necessary to apply modern methods of territorial organization, one of the most effective would be the further application of the land consolidation process. In this context, it is necessary to develop/update the legislation on territorial organization, based on the practice of European countries, which successfully implement these methodologies. The paper analyzes projects on the consolidation of agricultural land carried out both in the Republic of Moldova and in some countries of the European Union. As a result, it is worth mentioning the current need to consolidate agricultural lands in the Republic of Moldova as well as the development of solutions to speed up this process, which is very necessary for efficient agriculture. It will give farmers, the opportunity to apply innovative, sustainable and competitive land tillage practices, by applying rotation systems, by using advantageous irrigation technologies, by their rational processing, by combating erosion, etc.*

Keywords: *consolidation, agricultural land fragmentation, land consolidation project.*

1. Introduction

The Republic of Moldova, being an agrarian country, where about 80% of the country's soils are chernozems, would benefit from a significant increase in the productivity of agricultural crops and their sustainable and long-term development.

But unfortunately, the agrarian reform implemented in the republic in the 1990s contributed to the excessive fragmentation of agricultural land into small plots, which significantly reduced land productivity and their rational use. This problem was and is present in the field of agriculture.

A solution to the problem would be the consolidation of agricultural land, which, according to the Land Code approved in 1991, and starting from 07.03.2025 another Land Code will come into force in which the notion of consolidation of agricultural land is not provided, represents. The consolidation of agricultural land represents a complex of legal and technical actions, undertaken in order to optimize the size, location of land and organize the system of measures to combat soil erosion and increase its fertility, creating favorable conditions for the economic activity of peasant households (farmers), enterprises and agricultural production cooperatives, which cultivate privately owned land.

Analyzing the development related to land consolidation in the European Union, we can mention that it began in 1923 in Poland, where the Laws on Land Consolidation were first adopted. The terminology of land consolidation in various countries is different, for example in the Netherlands, it represents the exchange of land rights between land owners, through lease, sale-purchase, etc. and is applied for various purposes, which achieve the objectives of the 2030

Agenda, nature conservation, by expanding protected areas, resolving land fragmentation, water management, to combat drought/floods, land improvements, etc.

Therefore, it is worth mentioning the current need to consolidate agricultural lands in the Republic of Moldova as well as the development of solutions to accelerate this process, which is very necessary for efficient and sustainable agriculture. This will provide farmers with the opportunity to apply innovative, sustainable and competitive land cultivation practices, through the application of crop rotation systems.

2. Fragmentation of agricultural land

The agrarian reform implemented in the Republic of Moldova since the 1990s has contributed to the excessive fragmentation of agricultural land into small areas (some examples can be found in figures 1,2 [11]), which has considerably reduced land productivity and its rational use. This problem has been and is present in the field of agriculture. Some examples can be found in figures 1,2 [11]

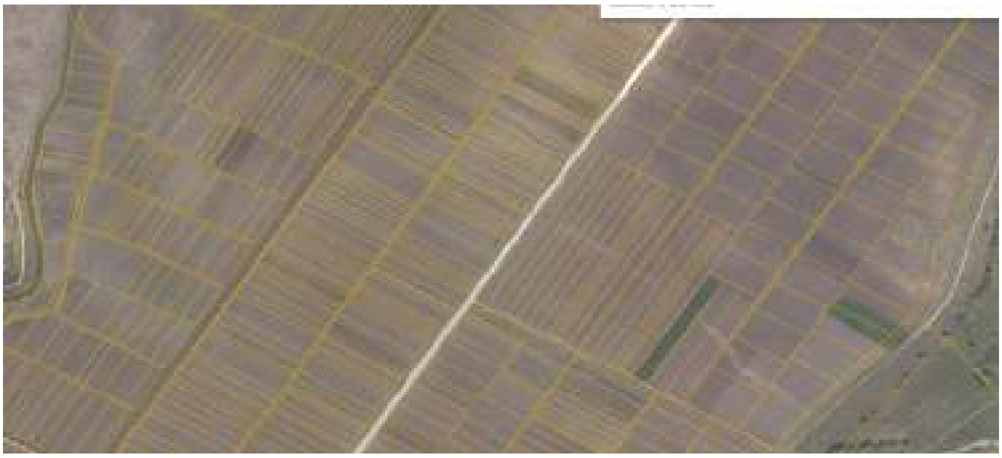

Figure 1. Examples of fragmented lands in Lăpușna commune, Hîncești district [11]

Small-scale land is difficult to cultivate and does not allow the use of modern technologies, which are essential for increasing productivity, and the use of large agricultural equipment is inefficient on fragmented land, and resources are distributed inefficiently.

Figure 2. Examples of fragmented lands, Onișcani commune, Călărași district [11]

Figure 3. Examples of fragmented lands in Hoginești village, Călărași district [11]

In Figure 3, it can be seen that an average plot has dimensions: length 300 m and width 5 m. Such land sectors, where the ratio between length and width is not respected, are found on about 60% of agricultural land located on the territory of the country.

The optimal ratio of length to width for rational processing of agricultural land is 2:1, but most peasant households in Moldova are small farmers, who do not have the capital to purchase modern equipment or to establish large and competitive farms. They face economic difficulties and are less able to cope with market demands.

Figure 4. Fragmentation of agricultural land in Sofia village, Drochia district [5]

3. Agricultural land consolidation project

In the Republic of Moldova, for the first time, the process (project) of agricultural land consolidation was implemented in 2004, with the support of the Land Privatization Support Project (PSPP), the initiators being investors in agriculture/buyers of small land areas, who later became owners of large land areas. Therefore, at the end of the agricultural land consolidation project, hundreds of plots involved in the project, which were purchased, exchanged or leased en masse, were transformed into large land areas owned by one or several owners.

State Enterprise Planning Institute of Land Management (S.E. IPOT) implemented, in 2005-2006, approximately nine land consolidation projects in the southern area of Moldova, by applying various land consolidation methods.

During the period 2007-2010, with the support of the Consortium formed by the National Rural Development Agency (ACSA); "Niras AB" from Sweden; "Terra Institute Inc." from the USA, and "Orbicon A/S" from Denmark, pilot projects for the consolidation of agricultural land were carried out in six localities in the republic.

During the years 2003-2017, 56 agricultural land consolidation projects were implemented in 53 localities.

Table 1: Implementation of agricultural land consolidation projects

Name	**number of projects**
Total projects	**56**
PLACES	**53**
small and medium-sized agricultural holdings	**50000**
total area of agricultural land, ha	**81776**
total number of plots	**175515**
COMPLETED	**50**
TAUs involved	**18**
completed in UAT	**16**

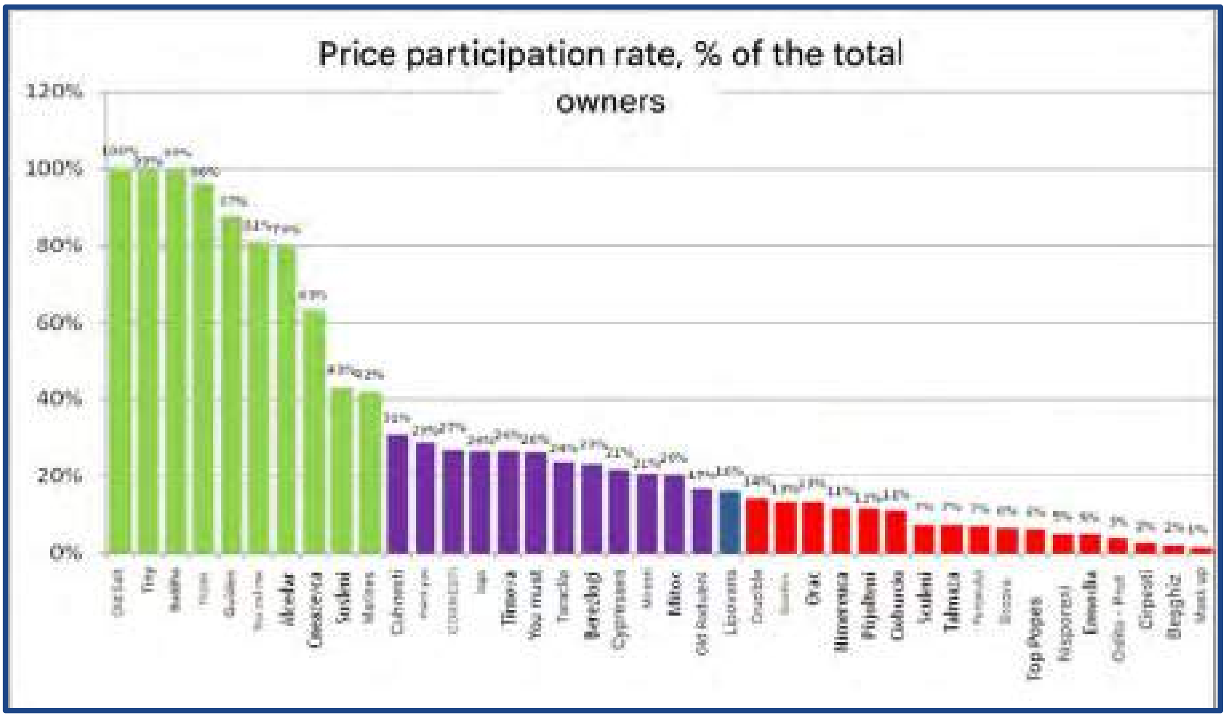

Figure 5. Participation rate of agricultural land owners in the consolidation project [6]

Analyzing the participation rate of agricultural land owners in the consolidation project, (figure 5, [6]) we deduce that:

1. all 100% of agricultural land owners participated in only one locality, Sărata Veche;
2. from 90% to 99% - 3 localities (Miciurin, Buda, Tirșiței);
3. from 70% to 89% - 3 localities (Ghiduleni, Călinești, Alcedar);
4. from 40% to 69% - 3 localities (Cneazevca, Susleni, Mărinici);
5. from other localities participated from 1% to 39%.

At the moment, no project is being implemented regarding the consolidation of agricultural land, and with the entry into force of the new Land Code, the regulation regarding land consolidation will also be repealed.

According to the legislation, which is still in force, consolidation can include agricultural land located within the boundaries of a single locality. The consolidation of agricultural land can be carried out in several ways:

➢ Based on the activity contract:

- by signing cooperation contracts: owners who own land in the same sector can agree jointly to use the territory compactly and rationally.

For example, if in a sector, the total area is 150 hectares, the owners reach a conclusion to jointly process
territory, by cultivating the same crop, therefore, they sign a cooperation contract and can organize agricultural activities: plowing, sowing, harvesting, etc., distributing expenses and harvest according to the areas owned. This allows to apply modern agrotechnical methods and increase productivity;

- by concluding sales and purchase contracts

For example, in a vineyard there are 200 plots of 10 acres. One of the owners purchases 150 plots, one next to the other, thus forming a single plot of land with an area of 15 hectares.

➢ By uniting (merging) the lands.

For example, an owner owns 50 plots of land with an area of 1.00 hectares, having common borders, he can initiate the merger process, in order to be register as a single plot of land with an area of 50.00 hectares.

➢ By voluntarily exchanging lands.

For example, the land sector, which after privatization was parceled into 100 parts, belonged to 100 owners, these properties were purchased by 3 landowners, located chaotically. In this case, they have the opportunity to exchange the lands, so that the plots belonging to one owner have common borders, then to come to an understanding, to conclude a collaboration contract for rational processing of the owned land

➢ By combining.

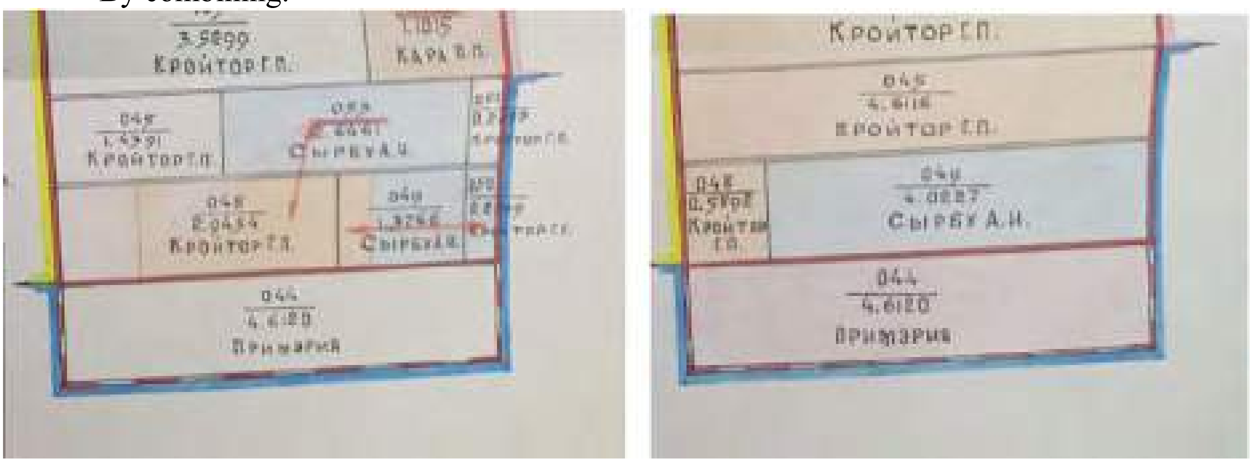

Figure 6. Example of combination within the agricultural land consolidation project [5]

4. Experiences in the application of Land Consolidation in European Union countries

Land consolidation has a very old tradition dating back over 200 years. In Europe, the first traces of land consolidation were discovered in Germany, by the 1900s, and the first legislative acts were approved in Poland in 1923, and in the Netherlands and Denmark in 1924.

There is no global consensus on the concept of land consolidation. For example, in the Netherlands, land consolidation is understood as the exchange of land rights between landowners with the aim of improving land use in the rural sector. In other European countries, rural development is often combined with nature restoration and environmental protection through infrastructure development.

Land consolidation has now become an increasingly global tool. Although its origins lie in Europe, it is now being applied in countries in most regions of the world, particularly in Asian countries, but increasingly in Africa. [1]

The implementation of land consolidation at the country level can contribute to achieving several SDG Targets, adopted by all member states of the United Nations, namely the 2030 Agenda for Sustainable Development.

A good example to follow would be the land consolidation applied in the Netherlands.

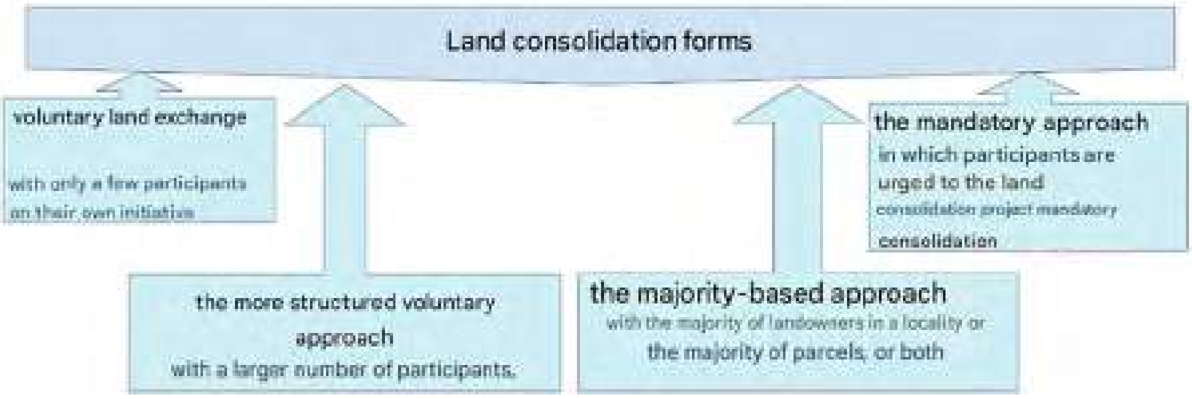

Figure 7. Forms of land consolidation in the Netherlands

The process of land consolidation in the Netherlands (figure 7 and 8) includes the analysis of land policy, determining the purpose of consolidation, followed by the study of landowners and land rights, location, configuration, area, fertility, etc.,

The next step is to develop a detailed activity plan for the implementation of the land consolidation project, such as the activity of the state, the activity of local public authorities, the activity of land holders (owners), the activity of specialists who will carry out the reparcelling, etc. And the land consolidation project is being finalized with the registration of real estate assets and the implementation of what has been achieved.

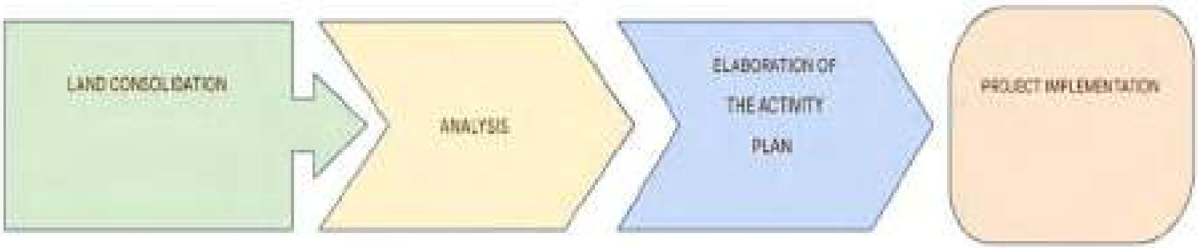

Figure 8. The land consolidation process in the Netherlands

Land consolidation has been proven to effectively reduce land fragmentation for agricultural holdings.

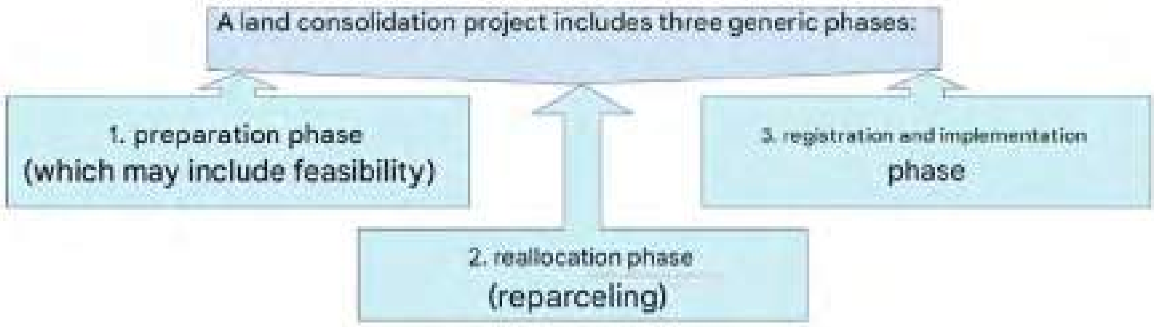

Figure 9. General phases of a land consolidation project in the Netherlands

The land consolidation process involves three phases of project implementation (figure 9).

The preparation phase, or in other words the planning phase, where the elements and stages for a single project or for several projects at the same time are reported, for example, a state program for land consolidation and includes the delimitation of the territory subject to the consolidation project, the establishment of organizational activities (the role, tasks of each participant in the consolidation, responsibilities).

The reallocation phase, the lands included in the consolidation project will be re-parceled. At this phase, topographic measurements are carried out, data is processed, then the lands are consolidated. This is followed by the registration and implementation phase, where the rights to the consolidated lands are registered, the consolidation project is transposed into nature.

5. Conclusions

Consolidating agricultural land is an important solution for the development of the agricultural sector in the Republic of Moldova.

By consolidating agricultural land, a number of important benefits are achieved, including:

- Increasing agricultural productivity, Peasant Households owning larger land areas will have the opportunity to implement modern technologies for processing, harvesting, maintaining or improving fertility, as well as protecting the environment;
- Reducing land processing costs while increasing agricultural productivity;
- Better access to internal and external markets, through large-scale production of agricultural food and to more efficiently value their products;
- Developing agricultural infrastructure, by investing in modern irrigation systems;
- Partial implementation of the 2030 Agenda for Sustainable Development.

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GIS APPLICATION FOR SPATIAL DATA ANALYSIS: MAPINFO VS QGIS

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Abstract: *In the context of the effective development of digital cadastral plans, the use of GIS software plays an essential role in the management and analysis of spatial data. The present study aims to compare two of the most popular software used in cadaster (older versions): MapInfo and QGIS. Both solutions have a variety of tools for creating, editing, analyzing, and viewing geographic data, but differ significantly in functionality, interface design, and associated costs. Exploring the interaction between these software, we will analyze their strengths and their use in other areas such as: urban planning, natural resource management, etc. Moreover, the study will evaluate their adaptability to modern challenges in geospatial technology, including data integration and visualization. Ultimately, the decision to use MapInfo or QGIS will depend on several factors, including available budget, project complexity, user experience level, and particular needs.*

Keywords: *MapInfo, QGIS, analysis, compare, software.*

1. Introduction

In an era characterized by rapid technological advancements, the use of Geographic Information Systems (GIS) has become indispensable for managing and analyzing spatial data. The development of digital cadastral plans, an essential component of territorial administration, requires the adoption of high-performing software solutions capable of ensuring precision and efficiency in processing geographic information.

Among the most widely used GIS solutions are MapInfo and QGIS, each offering distinct advantages and limitations. MapInfo, a well-established commercial software, is recognized for its intuitive interface and advanced functionalities tailored to users in fields such as urban planning and infrastructure development [1]. On the other hand, QGIS, an open-source solution, stands out for its flexibility, low costs, and an active global community that continuously contributes to enhancing its functionalities [2].

Analyzing and comparing these two programs is necessary to understand how they can meet the specific requirements of cadastral projects. Moreover, the applicability of these tools extends beyond cadaster, encompassing other fields such as natural resource management, urban planning, and environmental monitoring [3].

The increasing reliance on geospatial technologies underscores the importance of choosing the right tools for specific applications. While the development of cadastral plans is a key focus, the versatility of GIS software like MapInfo and QGIS positions them as pivotal in addressing contemporary challenges such as climate change monitoring, disaster management, and sustainable development. [4].

These applications demand not only precision in spatial data handling but also adaptability to diverse workflows, highlighting the necessity for comprehensive evaluations of software capabilities in alignment with emerging global needs.

In this context, the present study aims to explore the significant differences between MapInfo and QGIS, considering factors such as project complexity, user experience level, and financial constraints. The comparative analysis of these two solutions will contribute to identifying the most suitable tools for efficient use in cadaster and related fields.

2. Features and Functionality

MapInfo software

MapInfo is a complete set of GIS products developed by MapInfo Corporation, but now part of Pitney Bowes. MapInfo products are used in a wide range of endeavors, although usage appears to be concentrated in many business and municipal applications. This may be due to the ease with which MapInfo components are embedded in other applications. Data analysis and display components are supported through a number of higher-level language functions, allowing them to be easily embedded in other programs. In addition, MapInfo provides a flexible, stand-alone GIS product that can be used to solve many spatial analysis problems. [5]

The program's functionalities are supported by an integrated set of toolbars, menus and control panels, which ensure an intuitive and efficient workflow. Thus, MapInfo becomes an indispensable tool for spatial analysis and the creation of accurate cartographic products, applicable in a variety of fields, from urban planning and natural resource management, to environmental studies and economic development.[6]

Thanks to these tools, menus and control panels we have the following essential features and functionalities of the software:

- Visualization and analysis of geographic data where geographic data is structured on distinct layers which allows detailed visualization and complex analysis of different types of geographic information.
- Manipulation and editing of geographic objects are for precise measurements, in modifying the geometric shapes of objects and for performing spatial queries. Functionalities of this type are essential for advanced geospatial analytics and efficient data manipulation.
- Data and attribute tables facilitate the connection of data tables with geographic objects, in the result by analyzing the attributive information we have reports and graphic visualizations.
- Geoprocessing tools allow users to perform detailed spatial analysis and geospatial data management.
- Customization and automation that through the command line and macros, these features improve workflow efficiency and allow users to optimize complex processes.
- Import and export data in various standardized formats such as Shapefile, DXF and GeoTIFF. They enable interoperability with other GIS platforms and IT systems, facilitating information exchange and integration of external data.

QGIS software

QGIS is an open-source software project, an initiative within the Open-Source Geospatial Foundation. The software is a collaborative effort of a community of developers and users. QGIS is free, stable, changes smoothly over time, with source code available so it can be extended as needed for specific tasks. It provides a graphical user interface, supports a wide variety of data types and formats, and runs on Unix, MacOSX, and Microsoft Windows operating systems. As with most open-source software, the original offering had limited capabilities, but with an average of about two updates per year since 2002, QGIS offers a large number of basic GIS display and analysis functions. An interface was developed with GRASS, another open-source GIS with complementary analytical functions, but which lacks a simple graphical interface. [7]

QGIS present as a versatile and robust platform, offering a comprehensive set of tools for manipulating, analyzing, and visualizing geospatial data. This can be described in the following manner:

- *User-Friendly Interface and Support for Various Data Formats*: QGIS provides an intuitive interface that supports a wide range of data formats, including shapefiles, GeoTIFF, KML, CSV, and more. It handles both raster (images, maps) and vector (points, lines, polygons) data, offering increased flexibility for complex analyses.

- *Advanced Spatial Analysis and Geoprocessing*: The platform includes powerful geoprocessing tools that enable detailed spatial analysis, such as intersection, union, network analysis, and data geometry manipulation.
- *Customization, Automation, and Extensibility*: QGIS allows for customization and automation through the Python scripting language and macros, enabling users to extend the platform's functionality via plugins. This extensibility ensures that QGIS can meet the specific needs of various projects by adding new features and tools.
- *3D Visualization and Data Rendering*: QGIS supports advanced 3D visualization, facilitating more detailed data interpretation. This is particularly useful in complex analyses and when presenting data in a more accessible format.
- *Data Import and Export*: The platform supports the import and export of data in standardized formats, such as Shapefile, DXF, and GeoTIFF, making it easier to integrate external data and exchange information across different platforms.
- *Georeferencing and Geocoding Support*: QGIS offers strong capabilities for georeferencing and geocoding, enabling precise spatial referencing of data.

Figure 1. Data flow representation for a complex analysis

The organization and processing of geospatial data are fundamental steps in any geographic information management project. Various software tools, such as MS Office, are used to initially organize the data, facilitating the process of structuring and processing it in a format suitable for further analysis. Next, GIS applications such as MapInfo are used to georeference data and create detailed cadastral plans, essential in land and natural resource management. For more complex analysis and advanced data visualization, applications such as QGIS offer a robust set of tools that enable advanced geospatial analysis and the creation of accurate maps, supporting informed decision-making in areas such as urbanism, cadastre and environmental protection (figure 1).

3. Practical applications

In the cadastre discipline, the task was to vectorize lands and buildings in Trebisăuți village, followed by completing the attribute table corresponding to each geographic object. During this process, challenges arose, particularly with the orthogonality of buildings. It was later discovered that these issues could be rectified directly within MapInfo (figure 2). Additionally, difficulties were encountered with the orthophotoplane's loading speed and performance, which hindered workflow efficiency.

These obstacles prompted an exploration of the integration capabilities between MapInfo and QGIS. The interconnectivity of these two applications proved highly effective, streamlining the creation of the cadastral plan. This compatibility facilitated efficient data transfer and management, significantly reducing time and resources while producing accurate and comprehensive cadastral maps. This experience underscored the value of leveraging the interoperability of GIS software to overcome technical limitations and enhance performance in cadastral tasks. To address these challenges, the combined use of MapInfo and QGIS not only improved the accuracy of the cadastral data but also accelerated the overall workflow, ensuring a more efficient mapping process.

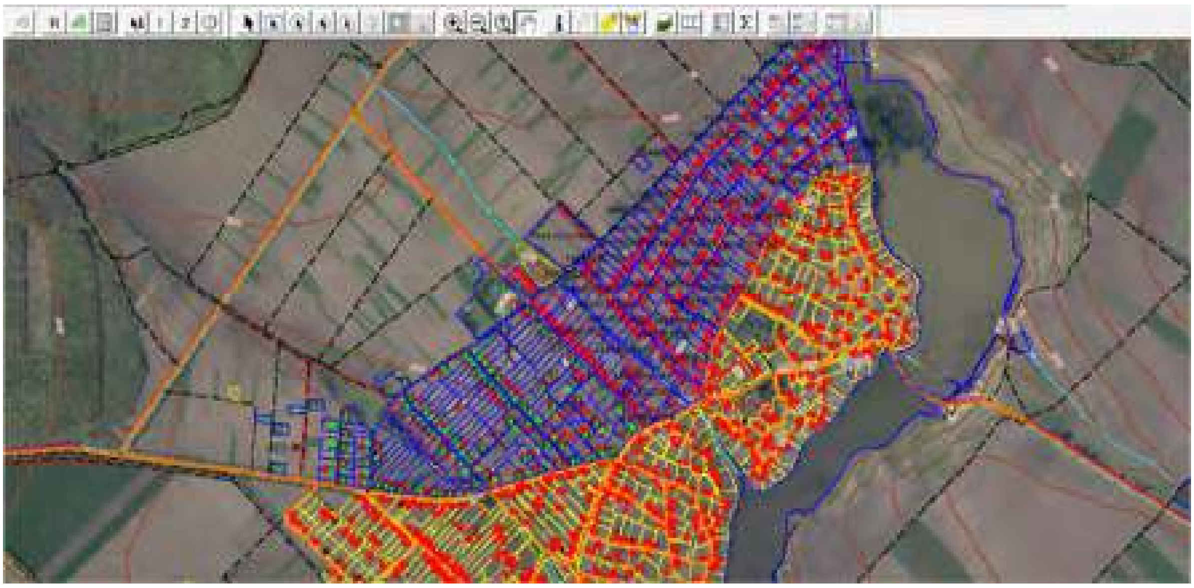

Figure 2. Vectorization of Trebisăuți village in MapInfo software

Upon utilizing QGIS software, the buildings appeared perfectly orthogonal, and the orthophotoplane's performance significantly improved, providing a smoother workflow. Additionally, completing the attribute table became more efficient and enjoyable. After making the necessary modifications in QGIS and closing the application, the changes were automatically synchronized with MapInfo, highlighting a seamless integration between the two platforms. This feature represents a considerable advantage, especially for students, by streamlining the process and enhancing usability (Figure 3).

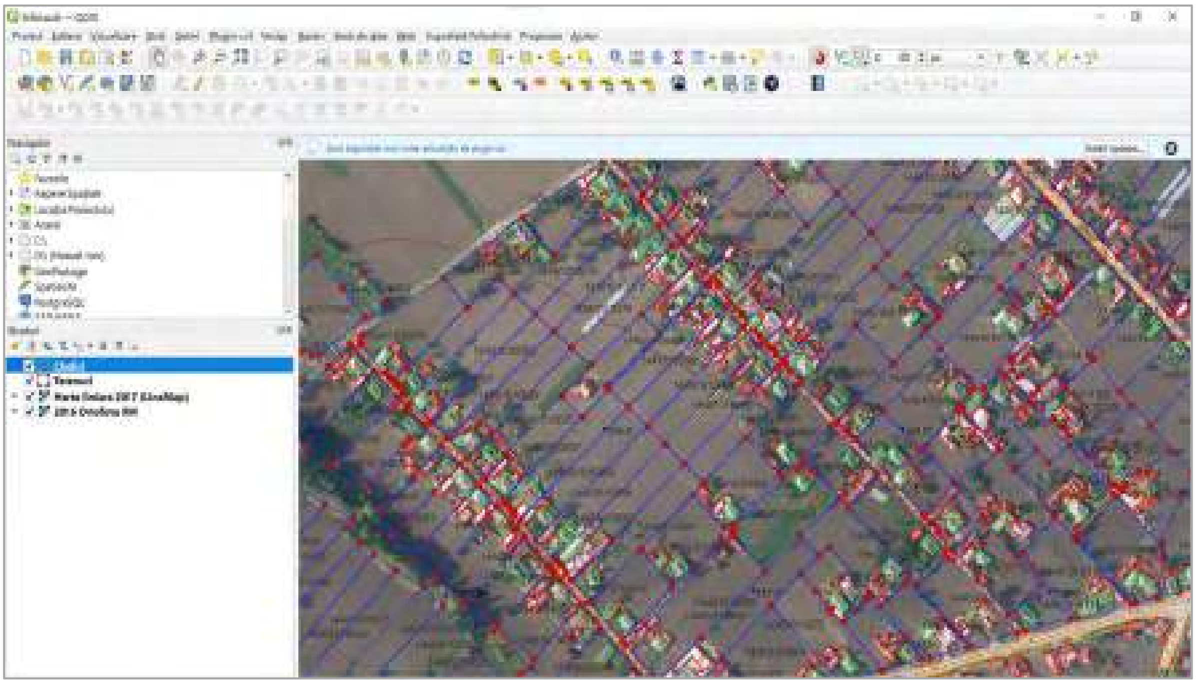

Figure 3. Representation of the vectorized village on the QGIS platform

In addition to improving the workflow, the integration of MapInfo and QGIS demonstrated remarkable versatility in handling complex datasets. For instance, QGIS's advanced geoprocessing tools allowed for the seamless merging of multiple data layers, enabling a more detailed analysis of spatial relationships. At the same time, MapInfo's robust data visualization capabilities facilitated the production of high-quality cartographic outputs that met professional standards. This synergy between the two software solutions proved particularly valuable for addressing tasks such as spatial querying, network analysis, and topological corrections, which are critical components of cadastral work. Overall, the combined use of these GIS tools not only enhanced technical efficiency but also provided a practical learning experience in applying geospatial technologies to real-world problems.

4. Comparative Analysis

The comparative use of QGIS and MapInfo in practical tasks, such as the cadastral mapping project in Trebisăuți village, highlights the strengths of both software platforms in geospatial data manipulation, visualization, and analysis. For instance, vector data was utilized to represent land plots and buildings, while raster data such as orthophotoplanes served as a base layer for accurate referencing. Both QGIS and MapInfo allowed for the creation of complex maps by layering these datasets, adding labels, and customizing symbols, ensuring that the resulting maps were both functional and visually informative [8].

The use of spatial analysis tools, such as object buffering and intersection, proved invaluable during the cadastral task. For example, these tools helped in accurately delineating property boundaries and identifying overlaps or gaps between parcels. The support for common geospatial data formats like shapefile and GeoJSON facilitated seamless data sharing and integration between the two platforms, streamlining the workflow.

The project also benefited from automation capabilities; QGIS's Python scripting was employed to automate repetitive tasks, such as batch editing of attribute tables, while MapInfo's MapBasic scripts were utilized for custom spatial queries. These functionalities not only reduced manual workload but also minimized errors, underscoring the efficiency of process automation in GIS software.

In this context, the choice of using both QGIS and MapInfo was strategic, as their complementary features addressed different challenges encountered during the project. For example, QGIS's advanced geoprocessing tools were used for orthophotoplane adjustments, while MapInfo's user-friendly interface facilitated the straightforward editing of cadastral data. Table 1, included in the analysis, further elaborates on the comparative strengths and features of both software solutions, providing a clear visual summary of their capabilities.

This practical example demonstrates how the integrated use of QGIS and MapInfo not only enhanced technical efficiency but also ensured the accuracy and completeness of the cadastral maps, making these tools indispensable for geospatial professionals.

Table 1. Comparison of MapInfo and QGIS

Category	MapInfo	QGIS
Platform and Cost	A commercial software requiring a license, which involves a considerable cost. This can be a challenge for institutions with limited budgets.	An open-source, free software available for download. It is compatible with multiple operating systems, including Windows, macOS, and Linux.
Features and Interface	Offers a user-friendly interface tailored for geography and cartography professionals. It includes intuitive tools for vectorization, attribute editing, and spatial data analysis. However, advanced functionality may require additional extensions.	Provides extensive functionality through plugins, with a strong community continuously adding new features. While the interface may appear complex for beginners, it offers great flexibility and customization options.

Table 1 continued

Spatial Analysis and Visualization	Supports basic spatial analysis and includes robust visualization tools sufficient for cadastral and cartographic applications. Advanced analysis, however, often requires dedicated extensions.	Covers a broad range of spatial analyses, from basic to advanced, integrating tools like GDAL and GRASS for advanced functionality, including network analysis, raster manipulation, and topological analysis.
Compatibility and Interoperability	Ensures compatibility with other GIS and CAD solutions, allowing the export and import of common formats like DXF, DWG, and SHP. However, conversions might occasionally be required for smooth data integration.	Highly flexible, supporting most GIS data formats. It integrates seamlessly with other GIS software and databases, such as PostgreSQL/PostGIS and MySQL, and handles SHP, GeoTIFF, and other geospatial formats without significant limitations.
Extensibility and Customization	Features a robust set of functions via commercial extensions. While Pitney Bowes offers tools for development and customization, creating extensions or scripts may be more complex compared to QGIS.	Offers high extensibility through plugins and Python scripting. It allows the creation and customization of complex analyses and integration with other open-source platforms, providing developers full control over tools.
Applicability in Cadastre and Cartography	Known for its reliability in cadastral data management, MapInfo is widely used by governmental and private institutions due to its accuracy and stability.	Equally used in cadastre and cartography, it is particularly preferred by smaller organizations and academic projects for its accessibility and flexibility. It is especially effective for collaborative tasks and projects involving the integration of multiple data sources.

A radar chart was created to compare MapInfo and QGIS based on the data provided in table 1. The chart illustrates the strengths of each software across six key categories (figure 4).

Despite its steeper learning curve, QGIS provided customization and extensibility unmatched by MapInfo, enabling the creation of detailed visualizations tailored to specific cadastral requirements. Meanwhile, MapInfo’s familiar and straightforward tools allowed efficient handling of essential cadastral tasks, making it a valuable asset for team members needing quick adaptability.

This integrated approach illustrates the practical advantages of leveraging multiple GIS tools in tandem. By utilizing the strengths of both MapInfo and QGIS, the team was able to produce precise, visually detailed cadastral maps, optimize workflow efficiency, and overcome technical limitations effectively. This collaboration highlights the importance of adaptability and interconnectivity in modern geospatial practices.

Additionally, the integration of both QGIS and MapInfo allowed for a more streamlined workflow by enabling data exchange between the two platforms. This interoperability was particularly beneficial when transferring geospatial data, ensuring consistency and reducing errors. The ability to seamlessly combine the advanced analysis capabilities of QGIS with the user-friendly interface of MapInfo created a versatile and efficient working environment, making it easier to address the diverse needs of the cadastral mapping project.

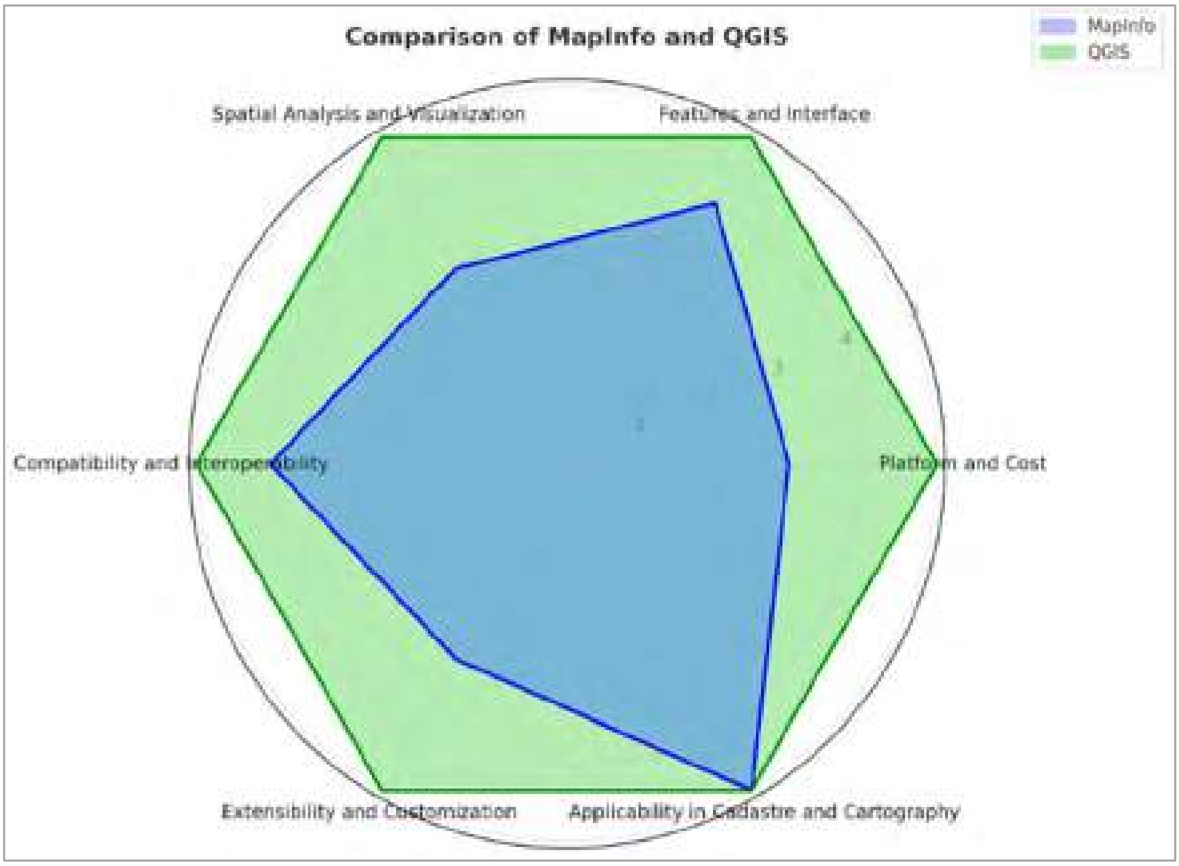

Figure 4. Radar chart comparing key features of MapInfo and QGIS

5. Conclusions

The comparative analysis of MapInfo and QGIS in the context of a cadastral mapping project highlights the strengths and complementary features of both GIS software platforms. While both MapInfo and QGIS are powerful tools for geospatial data manipulation, visualization, and analysis, they each have distinct advantages that make them suitable for different use cases.

MapInfo, with its user-friendly interface, commercial support, and reliable performance in cadastral applications, is particularly well-suited for professional and governmental institutions. Its ability to integrate with other GIS and CAD solutions makes it an effective tool for managing and visualizing geospatial data. However, its reliance on extensions for advanced functionalities and its cost may be limiting factors for some organizations, especially those with budget constraints.

On the other hand, QGIS, as an open-source and highly extensible platform, provides a broad range of advanced geospatial analysis tools and the flexibility to integrate with a variety of data formats. Its ability to support a wide array of spatial analyses, from basic tasks to more complex operations like network analysis and raster manipulation, makes it a robust solution for a wide range of users, including smaller organizations and academic projects. The automation and customization options available through Python scripting and plugins further enhance QGIS's utility, allowing users to tailor the software to specific project needs.

The integration of both software platforms, as demonstrated in the cadastral project in Trebisăuți village, reveals the potential for increased efficiency and accuracy in geospatial work. The seamless transfer of data between MapInfo and QGIS, coupled with the strengths of each platform in their respective areas, proves that leveraging the interoperability of GIS software can optimize workflows and overcome technical limitations.

In conclusion, both MapInfo and QGIS offer valuable features for geospatial professionals. The choice between them depends on project requirements, budget constraints, and the level of customization and analysis needed. By combining the capabilities of both platforms, users can maximize the efficiency, accuracy, and scope of their geospatial data management and analysis tasks.

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USE OF SPECIALTY SOFTWARE AND GEOPORTALS IN THE TEACHING PROCESS

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Abstract: *This article aims to briefly present the specialized software used in the specialized classes, namely in the Geodesy, Topography and Cartography training program, as well as the products made by the students. This article presents the application of GIS (Geographic Information System) technologies, namely the QGIS (Quantum GIS) application in the development of digital and analog maps for different fields studied within the College of Ecology. The stages and production of maps is a complex process that involves the collection, matching and selection of data from various sources, the design and layout of map representations, verification, updating and preparation for the final format. QGIS applications offer the possibility to option result safely and easily. These maps can be used to improve the current situation of various fields involved in the national economy in the Republic of Moldova.*

Keywords: *thematic map, QGIS, datasets, web platforms, specialized software, AutoCAD*

1. Introduction

We all know that the century we live in is the century of high information technologies. Modern pupils and students live in the world of electronic culture.

Our role as a teacher in the information culture is changing; we must be the coordinators of its information flow. A teacher who keeps up with the times is today psychologically and technically ready to use information technologies in teaching. Any stage of a lecture or practical lesson in specialized classes can be revived by introducing new technical means.

Online learning platforms qualitatively improve the content of education, leading to the improvement of the instructional-educational process by adopting active and autonomous learning processes, increasing students' interest in training, and creating new formal or non-formal, individual and group learning environments.[1]

Specialized software has gradually developed, increasingly supporting students and teachers. With their help, content and products of great importance are created within specialized classes.

QGIS (formerly known as Quantum GIS) is an open-source desktop geographic information systems (GIS) application that supports the visualization, editing, and analysis of geospatial data.

QGIS functions as a geographic information system (GIS) software, allowing users to analyze and edit spatial information, in addition to composing and exporting maps. QGIS consumes both raster and vector data. Vector data is stored as either point, line, or polygon features. Multiple raster images are supported, and the software can georeference maps.

QGIS is a professional GIS application based on free applications, and is also free and open source software (FOSS).

- under the GNU General Public License;
- official project of the Open Source Geospatial Foundation (OSGeo);
- volunteer-based project;
- loads numerous vectors, raster, database formats and functionalities.[2]

2. The role of GIS in various fields

Making decisions based on geography is essential to human thinking. By understanding geography and people's relationship to location, we can make decisions about how we live on our planet. A Geographic Information System (GIS) is a technological tool for understanding geography and making intelligent decisions. The system is used to create, store, analyze, and process spatially distributed information through a computerized process. GIS is software that links spatial information with descriptive information. Unlike a regular paper map, where what you see is what you get, a GIS can present many types of information.[5]

Some of the most common uses of GIS in various fields are:

- in solving problems such as: identifying suitable sites for planting trees, determining plants, and identifying regions suitable for planting in harsh environmental conditions of high temperature and low relative humidity;
- rendering the current situation about land both in the country and in certain regions of it or for certain producers in particular, which can also be monitored by local public authorities;
- representation and creation of various thematic maps.[4]

3. Specialized software used in specialized disciplines

QGIS software

GIS (Geographic Information System) is the framework that enables the collection, management, and analysis of data. With its roots in the science of geography, GIS integrates multiple types of data. It analyzes spatial locations and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals a deeper understanding of data, such as patterns, relationships, and situations, helping users make smarter decisions.

Hundreds of thousands of organizations in almost every field use GIS to create maps that communicate, analyze, share information, and solve complex problems that arise in the world. This is changing the way the world works.[6]

Cartographic production is the process of arranging map elements on a page in such a way that, even with a few words, the average person can understand what is being said. Maps are usually produced for presentations and reports, whose audience or group of readers is composed of politicians, citizens or students, without professional experience in the field of GIS. For this reason, a map must communicate spatial information effectively.

The usual elements of a map are: title, map body, legend, north direction, graphic scale, accreditation information and map frame.

The main components of QGIS. QGIS includes the main program QGIS Desktop, the QGIS Browser for QGIS Desktop is the main interface for collecting, analyzing, and presenting data from the client side and is similar to ArcMap.

Most of the menus and symbols are self-explanatory and should be easy to use for anyone with basic knowledge of GIS techniques, but the "Plugins" menu in particular is different from other programs. Projects (equivalent to map documents in ArcGIS) Saved in QGIS are stored using the XML (Extensible Markup Language, machine-readable) standard and with the extension * .qgs.[6]

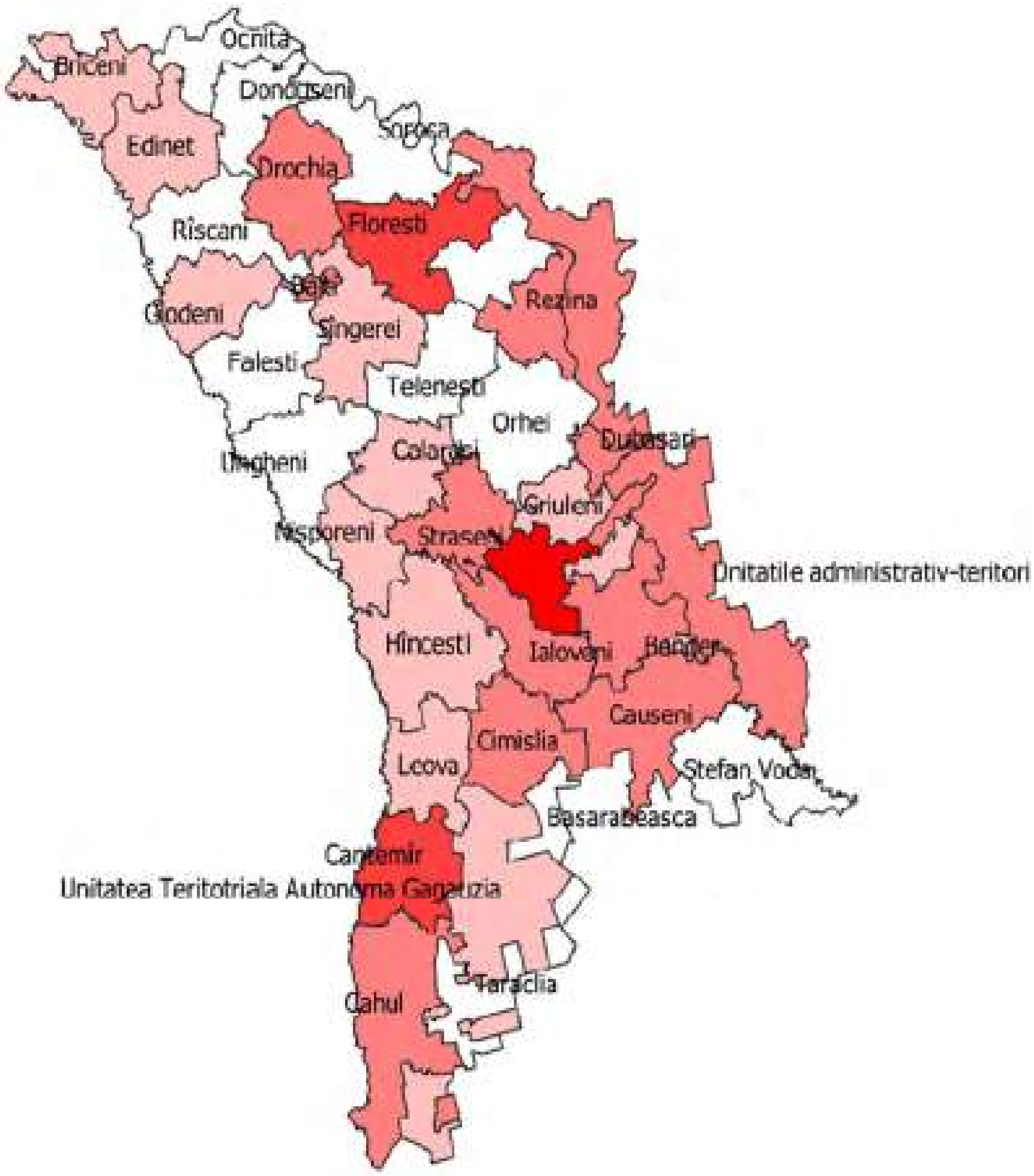

Figure 1. Thematic maps created by students in QGIS software

AutoCAD software

AutoCAD is a computer-aided design and drafting program that allows you to create detailed projects, both in 2D and 3D.

The new facilities related to the implementation of Geographic Location allow the expansion of design activity in the field of cartography and land use planning, making a direct connection with real geospatial coordinates and images obtained via satellite.

The main project of this software is its precision on drawings, models and any architectural, engineering, urban, mechanical and other projects that you need to carry out. You can use it on several fields of work due to its versatility and operability. Another thing that I like about this software is that you can work with archives of other software programs just by importing them and you can also export to other formats, in addition, you can select the year version of its native format, so that you can work with previous versions of this software, increasing productivity among colleagues.[5]

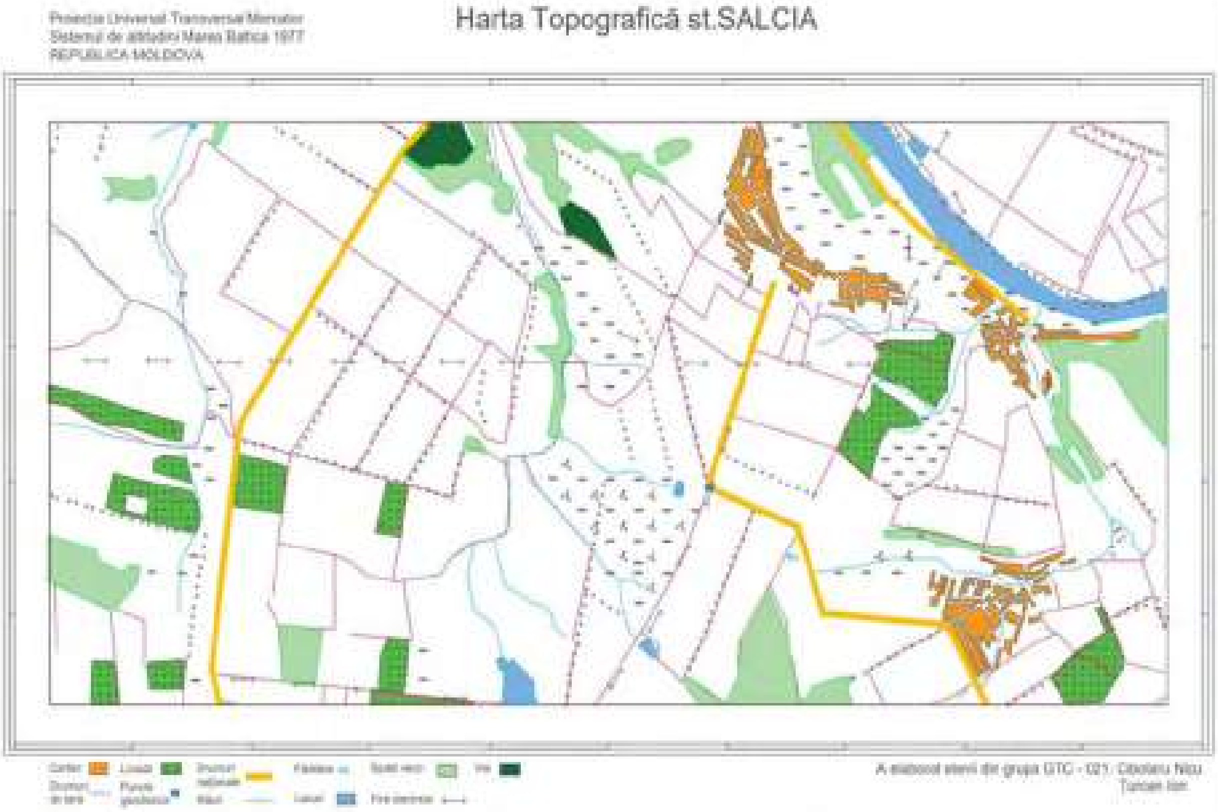

Figure 2. Fragment of the topographic map made in AutoCAD software, within the scope of the topographic drawing practice

INVENTORY software

Inventory is a multifunctional graphic editor created by an independent software manufacturer specifically for inventors, cadastral engineers and designers. The program is an indispensable tool for professionals who save their time and strive to automate, streamline and optimize the process of work on technical inventory, cadastral registration and state registration of real estate. Inventory is primarily focused on improving the quality of work of SCT employees.[3]

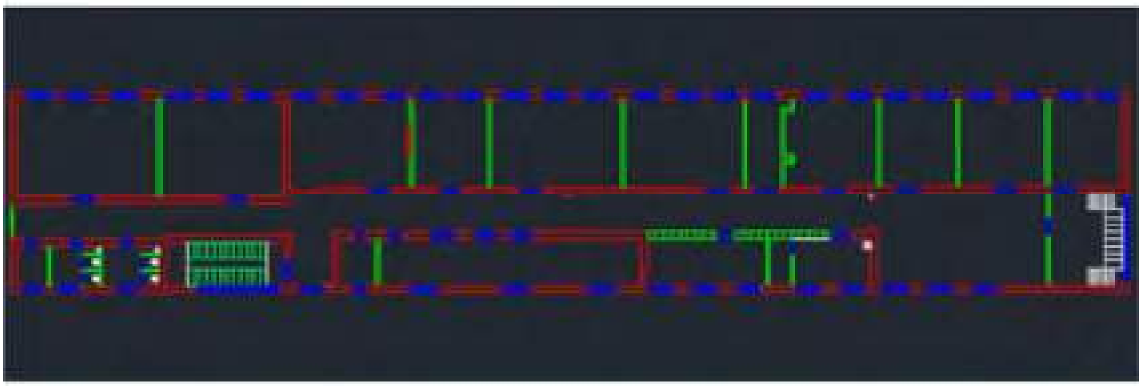

Figure 3. Fragment of floor plan made by students

MapInfo Professional software

MapInfo is a leading desktop location solution used for creating, editing, visualizing, and analyzing customer and business data in the context of location. MapInfo offers a wide range of dynamic new features, including a powerful yet extremely easy-to-use interface, improved data access, and robust map output capabilities.

With MapInfo Professional you can take full advantage of all the benefits of mapping geographic information. You can display data on a map as points, colored ranges, charts, etc. You can perform operations on geographic objects, ask questions of your own data, and query remote databases directly from MapInfo Professional.[2]

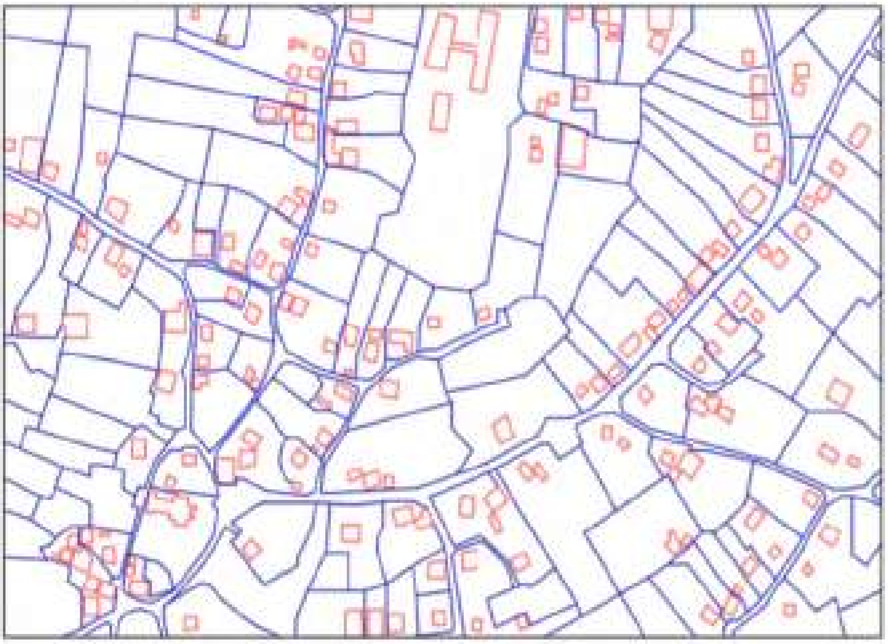

Figure 4. Fragment of cadastral plan made by students

Geoportal moldova-map.md

A geoportal can be defined as an entry point to the Internet with tools for retrieving metadata, searching, viewing, downloading, and in some cases providing analysis of geographic information. The core element of a geoportal is a mapping application that allows spatial data to be viewed through interactive maps. Web mapping applications can present spatial data in the form of general or thematic maps. [3

Figure 5. Performing various map queries on the moldova-map.md geoportal

4. Conclusions

This article presents the information technologies used in specialized subjects. The efficiency of using information technologies for the purpose of developing intellectual work skills in students is due to the fact that they mobilize the will of students and increase their interest in learning.

Educational platforms provide learning and training opportunities that are student-friendly. New technologies stimulate innovative learning capabilities, adaptable to conditions of rapid social change, which allows students to adapt to a constantly evolving society.

- The use of information technologies stimulates the creativity of teachers and students in the educational process.
- Software provides learning and training opportunities that students enjoy.
- New technologies stimulate innovative learning capacities, adaptable to conditions of rapid social change, which allows students to adapt to a constantly evolving society.
- The efficiency of using information technologies for the purpose of training intellectual work skills in students is due to the fact that they mobilize students' will and increase interest in learning.
- Geoinformation technologies can operate and analyze different data sets in relation to specific geographic locations and are beneficial to apply in the teaching process.

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THE BONNE PSEUDO-CONIC PROJECTION FOR THE TERRITORY OF THE REPUBLIC OF MOLDOVA

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Abstract: *The paper presents a study on the equivalent pseudo-conic Bonne map projection for the representation of the territory of the Republic of Moldova and the associated cartographic grid, providing a rigorous and efficient mathematical method for calculating point positions within this projection. The primary aim of the study is to ensure increased accuracy of cartographic data and to minimize specific deformation errors, such as linear and angular distortions, which may occur during the process of depicting the Earth's surface on maps. The article delves into the methodological details of the calculations involved in applying the Bonne projection, focusing on the analysis of geometric errors and identifying the most effective techniques for determining these errors. Additionally, it offers a comprehensive approach to the process of automating calculations by developing specialized algorithms implemented using modern programming languages. These algorithms are capable of generating precise results, which can subsequently be exported in formats compatible with CAD or GIS systems, facilitating their integration into professional cartographic workflows. Another aspect of the paper is the graphical analysis of the territory of the Republic of Moldova in the Bonne projection. The graphical representation was carried out using AutoCAD software, highlighting both the advantages and limitations of this projection, with a precise indication of the deformations encountered. The paper emphasizes the importance of algorithmizing the calculation process as part of modernizing the geospatial infrastructure, underlining the relevance of using an equivalent projection to achieve a faithful representation of the Earth's surface.*

Keywords: *Cartography, map projection, equivalent pseudo-conic Bonne projection, programming languages, algorithmizing.*

1. Introduction

Modern cartography is grounded in the use of map projections, which enable the transpositioning of the Earth’s three-dimensional surface onto a two-dimensional plane. The selection of an appropriate projection is not arbitrary but depends on numerous factors, such as the size and shape of the territory, the purpose of the map, and the requirements for geometric accuracy. In the process of creating maps for national or regional territories, projections must minimize distortions and allow for the most accurate representation of geographical features. [1,2]

The Bonne Pseudo-conical projection is renowned for its distinctive characteristics in this context. This projection is based on the depiction of parallels as arcs of concentric circles, perpendicular to a straight line representing the central (axial) meridian of longitude λ_0. Unlike other projections, the meridians in the Bonne projection are represented as curves symmetrical about the central meridian, facilitating a coherent representation of geographical space, particularly for territories with considerable latitudinal extent. [3]

The founder of this projection, Rigobert Bonne (1727-1795), was a French geographer. This projection has been employed for both large-scale and small-scale cartography over the past 450 years. During the 19th century and the early 20th century, the most notable use of the projection was in the creation of maps of continents for geographic atlases. The widespread application of the Bonne projection for topographic mapping was initially introduced by France. Currently, its use remains relevant primarily in certain regions of Portugal, France, Ireland, Morocco, and some countries in the Eastern Mediterranean. [4]

The Bonne Pseudo-Conical Projection was widely used in the present-day territory of The Republic of Moldova, when it was part of Romania (figure 1), being extensively applied between 1873 and 1972. Its application varied across the country, as different reference ellipsoids and also coordinate systems were used on different parts of the country. For the territory located to east of the Zimnicea Meridian, was used The Bessel 1841 Ellipsoid, with topographic mapping for regions of Moldova and Eastern Muntenia. For the territory to the west of Zimnicea Meridian was used The Clarke 1880 Ellipsoid, with topographic mapping for regions of Western Muntenia and Oltenia. [5]

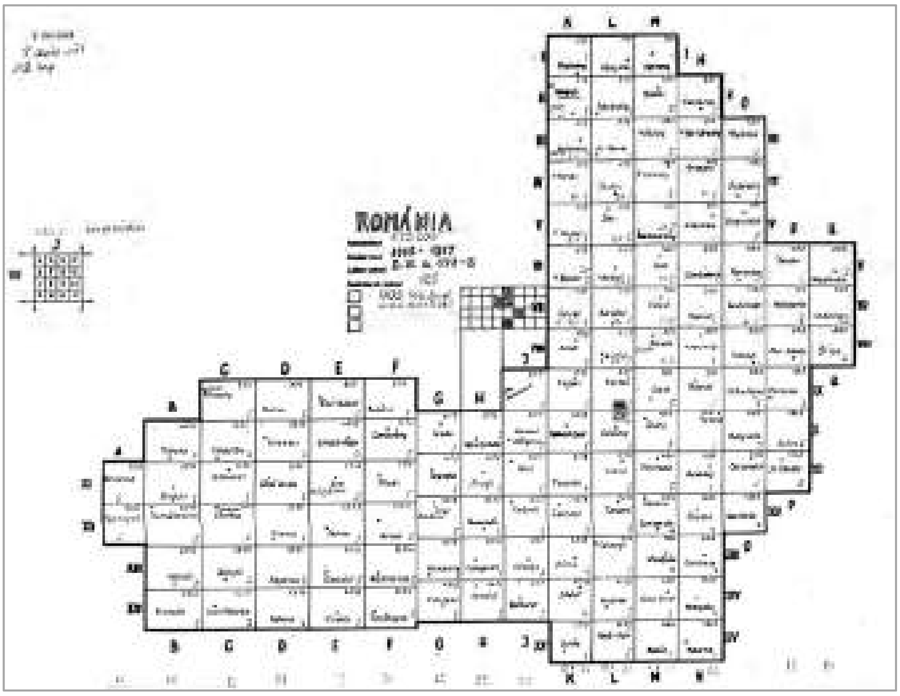

Figure 1. The index series topographic maps of 1:75 000 Romanian

For the Republic of Moldova, the use of The Bonne projection offers significant advantages, considering the relatively small size of the territory and the need for precise representation in administrative, economic and geographical contexts. This projection can minimise distortions in central areas and allows for detailed depiction of local features, such as the hydrographic network, relief and administrative boundaries. Furthermore, the application of The Bonne Projection is justified by its compatibility with modern cartographic systems, ensuring an efficient transition to the use of GIS tools in geographic data management.

2. Methodology

The determination of the plane rectangular coordinates for representation on the projection plane can be performed for both sphere and ellipsoid surfaces.

For the direct transformation (φ, λ → x, y) of the coordinates of points on the sphere of radius R the formulas and procedure are as follows: [3,4]

$$\rho = R(ctg\varphi_1 + \varphi_1 - \varphi) \tag{1}$$

$$\delta = R(\lambda - \lambda_0)cos\,{}^{\varphi}/_{\rho} \tag{2}$$
$$x = \rho sin\delta \tag{3}$$
$$y = Rctg\varphi_1 - \rho cos\delta \tag{4}$$

Where: φ_1 - standard parallel latitude, λ_0 - mean meridian longitude.

Formulas for reverse transformation (x, y → φ, λ) are as follows:

$$\rho = \pm[x^2 + R(ctg\varphi_1 - y)^2]^{\frac{1}{2}} \tag{5}$$
$$\varphi = ctg\varphi_1 + \varphi_1 - {}^{\rho}/_{R} \tag{6}$$
$$\lambda = \lambda_0 + \frac{\rho\left[arctg\left(\frac{x}{Rctg\varphi_1 - y}\right)\right]}{(Rcos\varphi)}. \tag{7}$$

For the direct transformation (φ, λ → x, y) of the coordinates of points on the rotative ellipsoid are as follows:

$$m = \frac{cos\varphi}{(1 - e^2sin^2\varphi)^{\frac{1}{2}}} \tag{8}$$
$$M = a\left[\begin{array}{c}\left(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{256} - \cdots\right)\varphi - \left(\frac{3e^2}{8} - \frac{3e^4}{32} - \frac{45e^6}{1024}\right)sin2\varphi + \\ \left(\frac{15e^4}{256} - \frac{45e^6}{1024} - \cdots\right)sin4\varphi - \left(\frac{35e^6}{3072} - \cdots\right)sin6\varphi + \cdots\end{array}\right] \tag{9}$$
$$\rho = am_1/sin\varphi_1 + M_1 - M \tag{10}$$
$$\delta = am(\lambda - \lambda_0)/\rho \tag{11}$$
$$x = \rho sin\delta \tag{12}$$
$$y = am_1/sin\varphi_1 - \rho cos\delta \tag{13}$$

Formulas for reverse transformation (x, y → φ, λ) formulas are as follows:

$$\rho = \pm[x^2 + (am_1/sin\varphi_1 - y)^2]^{\frac{1}{2}} \tag{14}$$
$$\mu = M/\left[a(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{25}\right] \tag{15}$$
$$e_1 = \left[1 - (1 - e^2)^{\frac{1}{2}}\right]/1 + (1 - e^2)^{\frac{1}{2}} \tag{16}$$
$$\varphi = \left[\begin{array}{c}\mu + \left(\frac{3e_1}{2} - \frac{27e_1}{32} + \cdots\right)sin2\mu + \left(\frac{21e_1^2}{16} - \frac{55e_1^4}{32} + \cdots\right)sin4\mu + \left(\frac{151e_1^3}{96} - \cdots\right)sin6\mu \\ + \left(\frac{1097e_1^4}{512} - \cdots\right)sin8\mu + \cdots\end{array}\right] \tag{17}$$

$$\lambda = \lambda_0 + \rho\left[arctg[x/am_1/sin\varphi_1 - y]\right]/(am) \tag{18}$$

The study of deformations shows the following:

- The Bonne Projection is an equivalent projection, so it does not deform the areas;
- An important property is that the scale remains constant along the direction of the parallels (k=1), including along the standard parallel (where distortions are zero);
- Along the central meridian, distortions are absent, but in the direction of the other meridians, linear distortions occur. These can be calculated using the deformation modulus relationship:

$$h = \frac{1}{cos\varepsilon};\ Where: tg\varepsilon = (\lambda - \lambda_0)\left(sin\varphi - \frac{Ncos\varphi}{\rho}\right); \tag{19}$$

- In the direction of the meridians, there are positive distortions;
- Angular deformations can be calculated using the following relationship:

$$tg\frac{\omega}{2} = \frac{1}{2}tg\varepsilon; \tag{20}$$

- Consequently, it follows that along any parallel, angular distortions increase as the difference in longitude from the central meridian increases.

3. Automation of Calculations

The calculation methodology presented above, highlights the complexity and large volume of mathematical operations required in order to transform coordinates into the projection plane. This process involves numerous steps which, if performed manually, would demand significant effort and could introduce errors in the results.

To streamline the process and ensure accuracy, a dedicated program was developed in C++ as part of the study. C++ is a first-level programming language created by Bjarne Stroustrup in 1979 as an extension to the base language C. C++ was chosen due to its exceptional characteristics, making it suitable for applications requiring high performance an efficiency. As a compiled language, it offers superior execution speed compared to interpreted languages like Python. Furthermore, it provides detailed control over hardware resources, such as memory management, which makes it ideal for intensive computations and complex data manipulation. [6,7]

The application is an executable file (.exe) compatible with any version of the Windows operating system. Using the application involves placing the program in a directory alongside a TXT or CSV file containing the initial data for transformation. This file must include columns for point names, latitude, and longitude. After launching the application, a new folder is automatically created in the original directory, containing three output files. The first file provides the transformed coordinates for each point, the second file presents deformation analysis results for each point, and the third file contains transformed coordinates arranged for import into computer-aided design applications, such as Autodesk AutoCAD.

The program's functionality, also illustrated in the UML diagram (figure 2), consists of three main stages.

Figure 2. UML scheme by Druguș Daniil

The first block defines the input data, which includes the file with initial coordinates. The program incorporates predefined geodetic constants, such as the parameters of the GRS80 ellipsoid (ETRS89), the axial meridian and standard parallel values (in radians) for the territory of the Republic of Moldova, and the false northing and easting offsets to ensure positive transformation results. Variable data is extracted from the input file using the “function”. In the second block, the program performs the necessary calculations to determine the transformed coordinates and deformation parameters. The final stage corresponds to the output data block, generating three result files. Each file serves a specific purpose in the analysis and subsequent use of the data.

4. Final Results

The final outcome of the study consists of the creation of a map of the Republic of Moldova, developed using the Bonne pseudo-conic projection at a scale of 1:2,000,000. To generate this map, calculations were performed using the developed application for both the points of the cartographic network and the contour of the entire territory of the Republic of Moldova, as well as for the positions of the main city centres (figure 3).

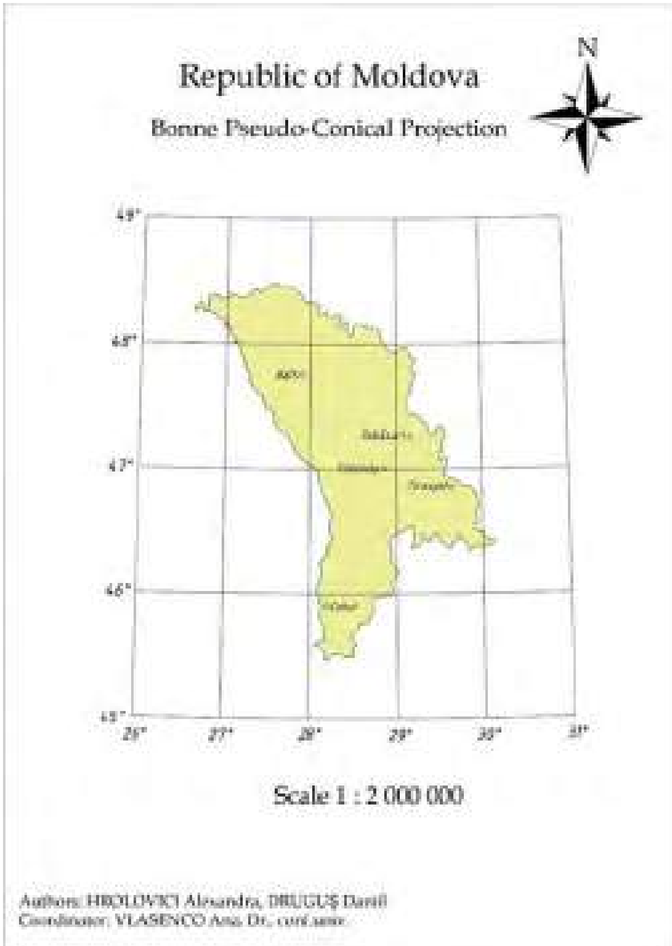

Figure 3. Map of The Republic of Moldova, Bonne Pseudo-Conical Projection

Due to the fact that the deformations are minor, the deformation ellipses are also very small and are nearly equivalent to the reference circles for the points of the cartographic grid. Consequently, a diagram has been developed to illustrate the values of three types of deformation (figure 4): the linear deformation modulus along the parallels k, the linear deformation modulus along the meridians h, the areal deformation modulus p, and the relative linear deformations D.

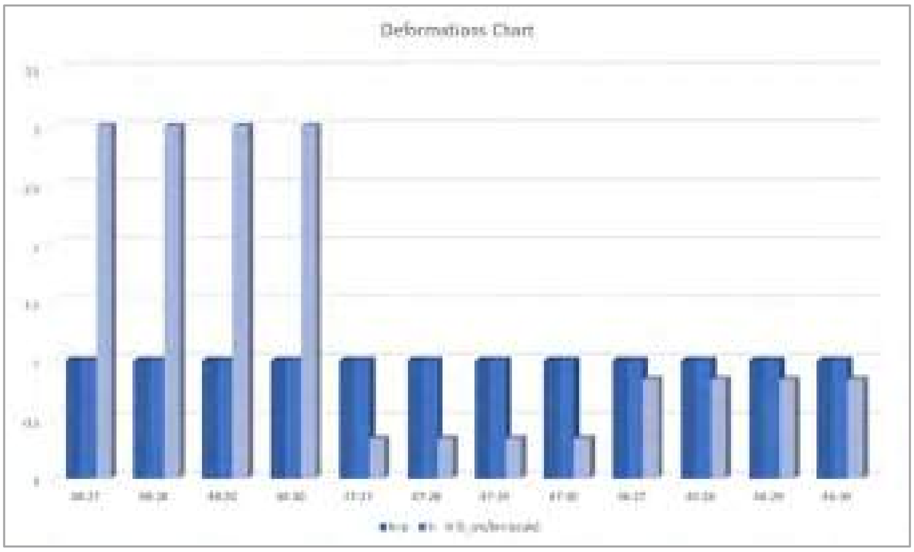

Figure 4. Deformations Chart

5. Conclusions

The automation of cartographic calculations has had a significant impact on this study. The developed application has considerably reduced the time required to perform coordinate transformation calculations and those related to the study of deformations, enabling the processing of a substantial dataset—approximately 700 points—in just a few seconds. The implementation of automation through the development of algorithms and applications equipped with graphical interfaces represents an innovative step in addressing cartographic computations, with potential applicability at both national and global levels.

The Pseudo-Conical Equivalent Bonne Projection has a longstanding tradition of use within the territory of the Republic of Moldova and offers promising prospects for the future of cartographic representation. It is particularly valuable in cadastral representations due to its essential properties: zero area deformations, minimal deformations in the highly urbanised central zone of the country, and reduced deformations across the entire territory. These characteristics make the Bonne projection an efficient solution for various cartographic and cadastral applications.

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CREATING AN INTERACTIVE GIS-BASED MAP FOR THE TECHNICAL UNIVERSITY OF MOLDOVA CAMPUS USING QGIS AND WEB TECHNOLOGIES

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Abstract: *This study details the process of developing an interactive map of the Technical University of Moldova campus using QGIS, an open-source GIS tool and the QGIS2Web plugin also some coding lines. This study involved gathering and structuring spatial data for campus buildings and other essential facilities, which were then visualized on an interactive map offering a clear and user-friendly representation of campus building locations. Pop-up windows were set up for each point of interest to show information such as building identifiers, available dormitories, working hours, contact information, and links to faculty webpages, ensuring users can easily retrieve relevant details. To make the map accessible online, the research utilized the Leaflet JavaScript library, which facilitated adding interactive features and integrating the map on a local server. The final map presents a simple and intuitive interface, allowing users to explore the campus, find specific locations, and access necessary information quickly. This project highlights the potential of open-source GIS tools as an effective and accessible method for mapping university campuses, aiding in spatial orientation and streamlining information access. The interactive map created can serve as a reference for other universities wishing to develop similar systems, showcasing how GIS and web technologies can enhance the user experience in academic environments.*

Keywords: *interactive map, GIS, QGIS, QGIS2Web, Leaflet, Technical University of Moldova, university campus, spatial data, web accessibility, open-source solutions.*

1. Introduction

Universities play a vital role in society, providing education studies and services to the community. Every prospective student, professor or even visitor is faced with the problem of finding the desired university campus. In order to facilitate access to their positions and applicable information about them, a contemporary cartographic answer is needed. Computer software frequently aims to replace specific jobs or get past barriers. Spatial data is a natural part of any task or situation involving Geographic Information Systems (GIS) [1]. One kind of GIS that has significantly improved is Internet GIS, or Web GIS, often referred to as web mapping or geo web, and it is particularly relevant in the context of public involvement [2].

So, information is now a part of the infrastructure, which has led to a significant phenomenon: gaining broad information literacy is becoming more and more necessary to maintain social control over society [3]. In this context, an interactive map proves to be an essential tool, providing not only spatial exposure but also quick access to up-to-date data and details.

This project intends to create an interactive map of the Technical University of Moldova's campus utilizing advanced geospatial processing and visualization tools such as QGIS software and the JavaScript Leaflet library. The locations of university buildings and dorms will be depicted in a comprehensive and interactive manner on the map, together with pertinent metadata like contact information, opening hours, and links to official websites.

The goal is to enhance the orientation and information accessibility experience for visitors, staff, and students on campus. The project offers a digital platform that encourages user interaction with the university infrastructure and makes campus navigation more effective by fusing geographical data with contemporary technology.

2. Creating the interactive map

The following technologies will be needed to create an interactive map: GitHub, Leaflet.JS, Visual Studio Code, QGIS, and QGIS2Web plugin. The data has been organized into vector layers (figure 1), each of which represents a distinct aspect of the data, to facilitate processing and analysis. In order to ensure that the information is clear and beneficial to those who will review it, each location has been updated with precise and well-defined attributes.

- GitHub is an example of the most recent software forging generation. Many of GitHub's features, such as issue-tracker, pull request support, monitoring and following systems, etc., are specifically designed to make project collaboration and social interactions easier. The platform also gives users access to the metadata of the projects it hosts, making it the ideal source of the raw data needed to examine and comprehend the dynamics of development communities [4].
- Leaflet is the top open-source JavaScript library for interactive maps that work on mobile devices. Most developers will find it to have all the mapping features they require. The design of the leaflet prioritizes use, performance, and simplicity [5].
- The Microsoft source code editor Visual Studio Code (VS Code) is used to write, edit, and debug source code in a variety of programming languages. [6]
- The Open-Source Geographic Foundation is the agency behind the open-source software project QGIS. A community of developers and users worked together to create the program. In addition to being free and stable, QGIS also evolves seamlessly over time and has source code that may be expanded for certain purposes as needed [7].
- The QGIS2Web plugin was used to export the project, creating the files required to allow for further interactive map updating.

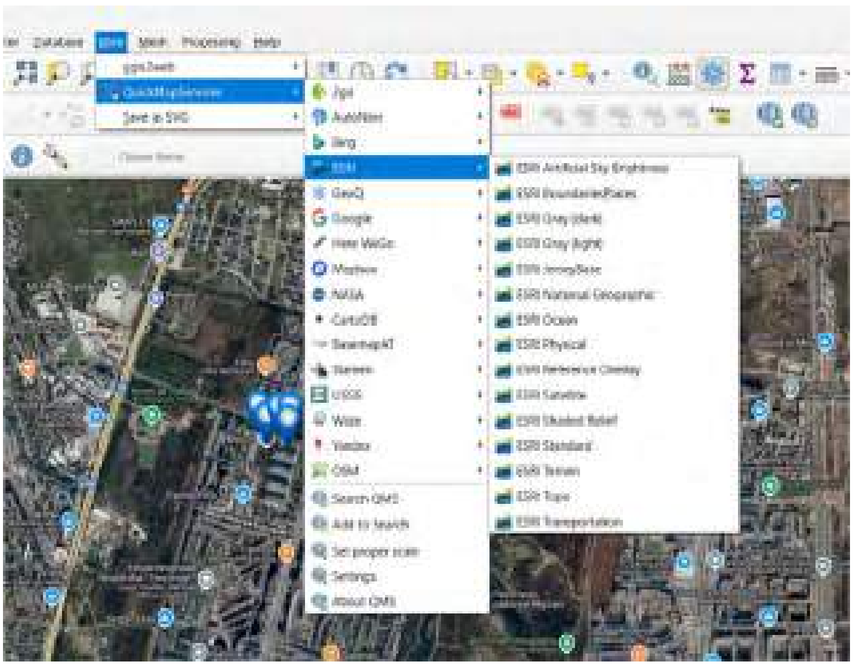

Figure 1. QGIS interface for map viewing using ESRI web services

For online viewing to be seamless and performance-efficient, files must be integrated into an ordered structure. In the process of creating web applications, HTML, CSS, and JavaScript all have distinct purpose. The page's structural basis is provided by the HTML file, the visual styles required for an aesthetically pleasing and accessible interface are defined by CSS, and the interactive functionality which enables user interaction with the map or other page elements- is provided by JavaScript (figure 2). An efficient user experience is created by integrating the problems of various files, which ensures not only a logical and aesthetically beautiful display but also optimal performance without delays.

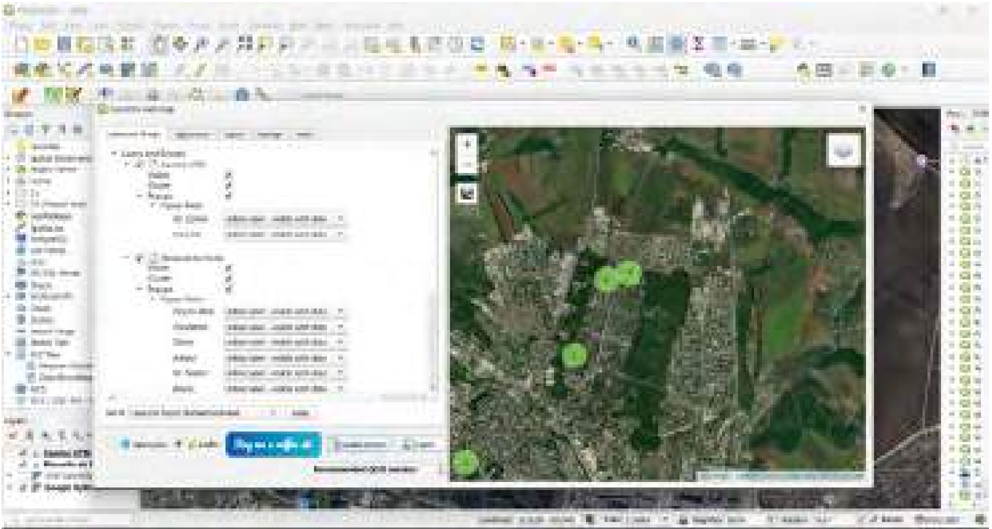

Figure 2. Convert to a web map

Modern geographic visualization relies heavily on interactive maps, which include features that improve accessibility and user experience. An essential element of these maps are the interactive labels, which are placed at key locations throughout the plotted region. But just clicking on these labels, users can access contextual information. On an academic building, for example, a marker might display the building's name, contact information, hours of operation, and a link to its official website. These features are implemented using web technologies using web technologies like HTML, CSS, and JavaScript, guaranteeing an informative and visually appealing portrayal.

The navigation experience is enhanced by interactive elements like zooming and panning, which allow users to explore particular details or obtain a macroscopic picture of the mapped region. Dedicated interface features, such as scroll-wheel capability and zoom buttons, which enable dynamic scale modifications, further enhance navigation. Users may also move between different areas of the map with ease, making interactive fluid and simple.

A legend, which is intended to act as a visual reference for understanding various map features, is incorporated into the map to improve comprehension and usage. Symbols for parking lots, pedestrian walkways, and academic buildings are among them. The design of the legend is simple and user-focused, and it is positioned discretely inside the interface to prevent getting in the way of navigation. More complex systems could have a dynamic legend that changes in real time to show the layers that are now visible on the map, guaranteeing contextual relevance and clarity.

The map meets the many demands of its users while preserving an effective and rigorously scientific design by combining these complex components, which strikes a balance between use and attractiveness.

Figure 3. Faculty details on an interactive campus map

3. Editing data in visual studio code

This step entails buildings the application's functionality and design using web technologies like JavaScript and CSS in conjunction with the Leaflet.js package. Changes performed during this phase contribute to a contemporary, tidy, and cross-device compatible user interface.

Optimizing CSS designs.

The design was made simple and easy to use with CSS (Cascading Style Sheets). Adjustments have been made to the visual components to create a visually appealing and useful experience. Fonts and color scheme has been chosen to make navigating easier, steering clear of combinations that could be visually off-putting. Also employed are loose and clear typefaces that work well on mobile devices and big displays (figure 3).

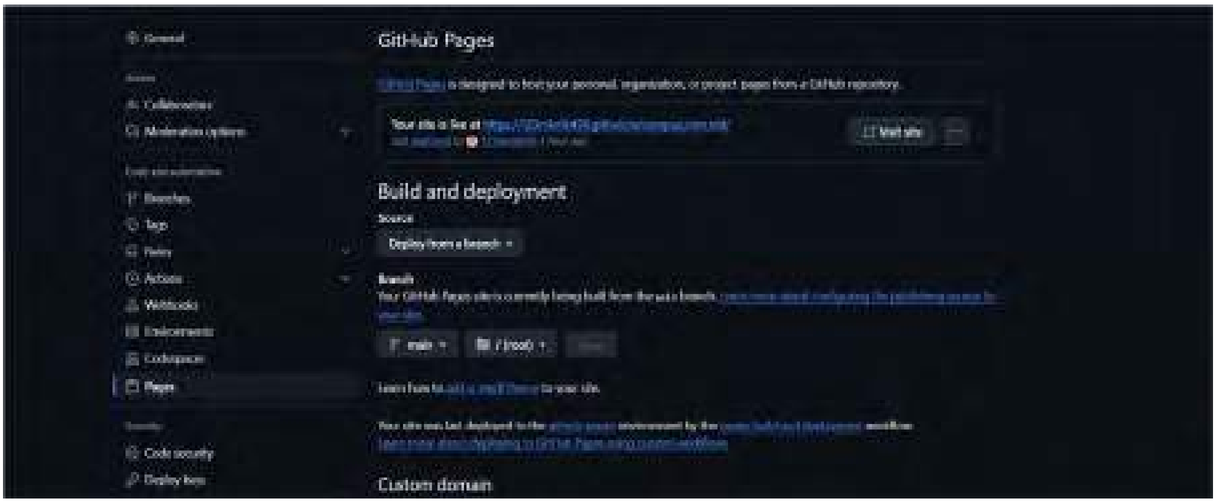

Figure 4. GitHub Page Setup

The direct incorporation of real-time local information into the platform, GitHub was a major turning point in its growth (figure 4). This feature guarantees that customers may obtain up-to-date information, including exact building addresses, business hours, contact numbers, and other pertinent facts. The platform ensures that users receive the most up-to-date and correct data by syncing this data on a regular basis.

In order to keep the map useful and relevant for a wide range of users, this integration is essential. Students can find courses, libraries, and dorms more quickly because to its effective campus navigation. By giving university employees consolidated, easily accessible information, the system facilitates operational planning and coordination. Intuitive navigation and a clear grasp of campus layout improve the overall experience of external visitors, such as potential students or conference participants.

4. Final Results

Users were able to quickly and easily obtain important thanks to the interactive campus map’s sophisticated features. Both students and visitors expressed tremendous appreciation for the consolidated data structure and its intuitive interface, which greatly improved their capacity to precisely and easily plan itineraries and move around the campus. The map is now an official navigation tool for the organization thanks to this endeavor, which has been transformative (figure 5). Because of its broad use, it has shown to be successful and is positioned as a model that might be modified for use at other educational institutions or at major events. In addition to expanding its usefulness, its scalability highlights its potential to set the standard for improving community involvement and geographical accessibility in academic settings.

Figure 5. Final Interactive Map

5. Conclusions

Stated differently, the integration of open-source GIS with web technologies provides us with a contemporary, effective, and economical approach to creating interactive maps that are customized to meet the requirements of scholars and educational establishments. When compared to exclusive commercial solutions, this method not only offers unmatched flexibility but also drastically lowers costs, enabling projects to be expanded and customized to fit unique needs. Researchers or administrators may easily incorporate information on events, transit timetables, or other pertinent features that improve the map’s usefulness, for example.

Putting such systems in place at universities has several advantages, including improving information accessibility and making the orientation process easier for guests and students. Making campus travel easier by offering accurate and current information, including the specific location of lecture rooms, library hours, or internal transit routes and schedules, is a concrete example. Beyond these practical benefits, interactive maps are a calculated instrument for enhancing the university's reputation as a progressive, cutting-edge, and technologically sophisticated establishment.

The creation of such a project creates a framework that is flexible and scalable, ready to change to meet the institution's future needs. The systems may be adapted for larger corporate or educational contexts, and new functional modules can be effortlessly added. These solutions are more than just technical aids; they are essential instruments for creating a more integrated, effective, and fulfilling social and academic environment. Universities may establish themselves as leaders in digital transformation and foster inclusion and operational excellence in the academic setting by adopting such technologies.

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THE USE OF ORTHOPHOTOS FOR CADASTRAL WORKS IN THE REPUBLIC OF MOLDOVA

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Abstract: *The use of orthophotos in cadastral work is an important aspect of modern technology and geographic information systems used in the context of cadastral work. An orthophotomap can be used in a wide range of cadastral activities, including mapping and updating cadastral maps, determining property boundaries, land valuation, underlining their importance in modernizing and streamlining the processes of property registration and delimitation*

Keywords: *Orthophotoplan, cadastre, cartography, maps, terrain.*

1. Introduction

The orthophoto, the product of aerial photogrammetry, is a geometrically corrected (orthorectified) aerial image, creating a representation of the terrain at a uniform scale, which allows true measurements of distances. The Earth's surface and objects on it are represented by precise georeferencing to a specified coordinate system.

The creation of orthophotos allows to quickly obtain accurate maps of the terrain and settlements at high resolution and complete information about the state of objects and their dynamics. The integration of the Republic of Moldova into the European Spatial Data Infrastructure started in 1999 when it became an active member of EUREF and the National Geodetic Network points of order 0 were integrated into the European Geodetic Network. The Republic of Moldova transposed the EU INSPIRE Directives into national legislation with the adoption of Law No. 254/2016 on the National Spatial Data Infrastructure. According to GD no. 458 /2017 for the approval of the responsibilities of public entities for spatial data sets [1] (Law No. 254/2016 on the National Spatial Data Infrastructure), the Land Relations and Cadastre Agency is currently the Geodesy, Cartography and Cadastre Agency is responsible for spatial reference datasets, including Orthophoto and Digital Relief Model images. The project Orthophoto Image Production 2007 for the territory of the Republic of Moldova was a technical support project received from the Government of the Kingdom of Norway. The major importance of the work is to provide all branches of the national economy with an up-to-date cartographic base corresponding to the current situation for various geodetic, cadastral, construction, agricultural, forestry, territorial planning, scientific research in the field of geodynamics, communications, mining production, water supply, military authorities, private sector, educational and scientific research institutions, and for inclusion in European programs for spatial data infrastructure [2].

2. Ortophotoplan, Republic of Moldova

Ortophotoplan 2007

A progressive step for the Republic of Moldova was the realization of the project "Moldova- Orthophoto" 2007 (figure 1), in collaboration with the Norwegian Cartographic and Cadastre Authority "Statens Kartverk" a grant in the form of technical assistance provided by the Ministry of Foreign Affairs of Norway, through the Norwegian government: orthophoto 40 on the whole territory of the Republic of Moldova and orthophoto 20 on 38 localities

Aerial photography from airplanes was carried out in 2007 for the whole country at 40 cm resolution and for 45 settlements at 20 cm resolution. The imagery was used to produce orthophoto images with the same geographical accuracy as conventional maps, and a digital terrain model representing the elevation of the landscape was developed. It was a revolutionary step for Moldova, which at the time had no up-to-date maps. The project has provided Moldovan authorities at all levels, as well as the private sector, academia and the general public with up-to-date photo maps supporting property registration as well as a wide range of other uses, notably geodesy, mapping, cadastral, construction, agriculture, forestry, land use, utilities, etc., to ensure Moldova's integration into the European Spatial Data Infrastructure. The products are now publicly available at the Geodesy, Cartography and Cadastre Agency.

Figure 1. Ortophoto 2007
*[**Source:**Instituția Publică Cadastrul Bunurilor Imobile]*

Ortophotoplan 2011

In the following years in collaboration with the Norwegian mapping authority - Kartverket (SK) and the Land Relations and Cadastre Agency, the Geodetic, Cartographic and Cadastre Agency is currently managing and implementing a project of linear maps for flood risk areas in the Republic of Moldova (figure 2).

Figure 2. Line map for flood risk areas
*[**Source:**Agenția Geodezie, Cartografie și Cadastru]*

To ensure the sustainability of the project and knowledge transfer, it was also agreed to engage the state enterprise INGEOCAD [3] to execute the production of linear maps for an area of 425 km² - 10% of the project area, as well as to perform quality control of aerial photographs, aerial oriented imagery, linear map data, LIDAR scan data, digital terrain model data and contour line data provided by the consortium [4].

The total area of orthophoto production is 6275 km² (figure 3). This territory is located in the central part of Moldova. In order to strengthen the local expertise, the ALRC requested SK to engage the state enterprise INGEOCAD to produce orthophotos for the project area based on aerial photographs and other related data provided by the consortium.

Figure 3. Ortophoto 2011

*[**Source:**Instituția Publică Cadastrul Bunurilor Imobile]*

Production of 20 cm orthophotos for the total area of the project - 6275 km², executed according to the technical specifications for 20cm orthophotos developed for the Moldova Orthophoto project. [5]

Ortophotoplan 2016

Project "Moldova: Aerialphotography, production of digital terrain model and digital orthophotos" - MOLDPHOTO 2016 (figure 4) was carried out between 01.02.2016-31.12.2016. The works executed within the project were the following: acquisition of aerial images with a resolution of 20 cm/pixel for the entire territory of the Republic of Moldova, approximately 33,000 km2, production of digital terrain model for the entire territory of the Republic of Moldova and production of color orthophoto for the entire territory of the Republic of Moldova, approximately 33,000 km2 [6].

Figure 4 Ortophoto 2016

*[**Source:**Instituția Publică Cadastrul Bunurilor Imobile]*

Ortophotoplan 2020, 2021

In 2020 it is planned to cover the central sector of the territory of the Republic of Moldova with air flights (figure 5). The major importance of the works is to provide all branches of the national economy with current orthoimages, reflecting the current situation, for solving various problems of the national economy, state security and defense [7].

Figure 5. Ortophoto 2020,2021
*[**Source:**Instituția Publică Cadastrul Bunurilor Imobile]*

3. Cadastral work using orthophotos

When representing features on the map, visualizing the map using graphic layers is essential for perceiving information (figure 6). Orthophotos are useful for analyzing and managing the objects displayed on the map.

Figure 6. Orthophoto representation of Horodiște
*[**Source**:* National geospatial data fund (geoportal.md)*]*

They provide detailed information about land area, buildings, roads, green areas and other features of the area. The use of orthophotos within a region provides the benefits of creating an information base that can be more easily analyzed, edited and visualized.

Vectorization using orthophotos refers to the process of transforming information from an orthophoto image into a vector data set, such as lines, polygons and points. This process can be performed using specialized GIS (Geographic Information Systems) editing software[8].

Use the QGIS program (figure 7, figure 8), the Line Map layer, which includes the subtractions:
- Maps: lm17_area_roof_area;
- Maps: lm17_line_fence;
- Maps: lm17_line unspecified limits.

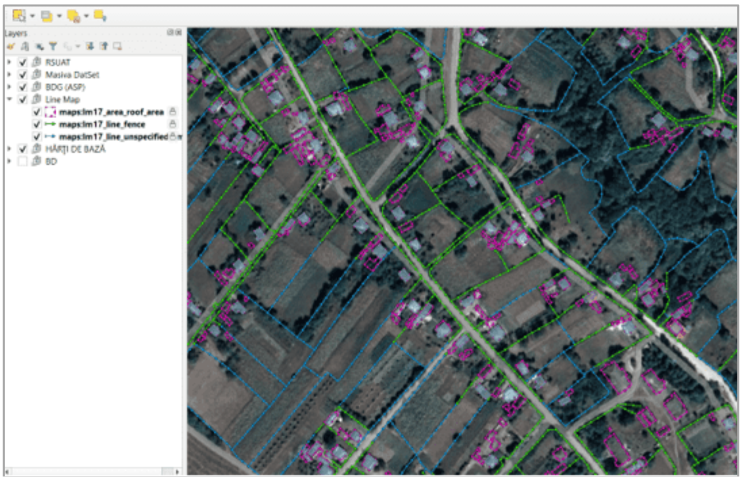

Figure 7. Layer representation in Qgis
*[**Source**: Image by the author]*

Each layer contains unique and precise information, Maps layer: lm17_area_roof_area, is rendered on the map as a pink polygon. It symbolizes real estate, constructions, buildings.

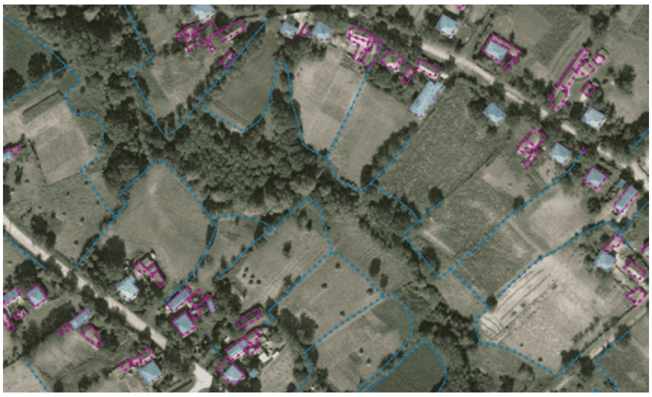

Figure 8. Vectorized real estate representation
*[**Source**: Image by the author]*

State maps: lm17_line unspecified limits are undetermined and unfinalized boundaries due to environmental conditions such as trees which are an obstacle in capturing details (figure 9). For this reason, geodetic teams will be requested to travel to measure the actual land surface situation.

Figure 9. Representation of undetermined boundaries
*[**Source**: Image by the author]*

Another layer is maps: lm17_line_fence it displays the terrain vectorization depending on the location of the corresponding terrain fence, also in this case in some parts the fence is covered by trees which makes the vectorization more complicated or even impossible.

In the case of changes in the composition of the real estate, as well as the division of land or the merging of land, in addition to the identification works, other necessary cadastral works shall be carried out. If the general boundary of the land represented in the cadastral or geometric plan does not correspond to the actual possession of the land and the deed establishing the boundaries is missing, the local public administration authority, at the request of the owner and on his behalf, shall establish the boundaries of the land on the spot. The keeping of the register of lease contracts shall be coordinated with the keeping of the land cadaster, the tax information system and other systems, in the manner prescribed by law.

The maps: lm17_line_fence and maps: lm17_line unspecified limits layers define the boundary of land and real estate according to the orthophoto plan (figure 10).

Figure 10. Representation of boundaries by fence location and undetermined boundaries
*[**Source**: Image by the author]*

The Land layer is vectorized by the cadastral engineer and measured by the geodetic engineer (figure 11). Here it is necessary to carry out measurements with a GPS device. These topographic measurements use satellite signals for positioning. The measured points determine the exact position (point) of the boundary of each plot of land. According to Law No. 1543 of 25-02-1998, if according to the existing documents the boundary established at the time of land allocation cannot be determined, then the general boundary is established after the de facto possession of the neighboring plots, provided that the deviation in the land area does not exceed 10% of the size of the area in the documents confirming the right. [17] The deviations in the land area from the size of the land area shall be determined by the central specialized cadastral body.

Figure 11. Land representation
*[**Source**: Image by the author]*

By activating the Land and maps: lm17_line unspecified limits layer, the changes and corrections made after the measurements are noted (figure 12, figure 13). The surface area of the land and the conditions of its use for the above-mentioned purposes shall be determined in accordance with the rules and technical design documentation. It is forbidden to start construction works on the allocated land until permission has been granted by the architectural and urban planning authorities.

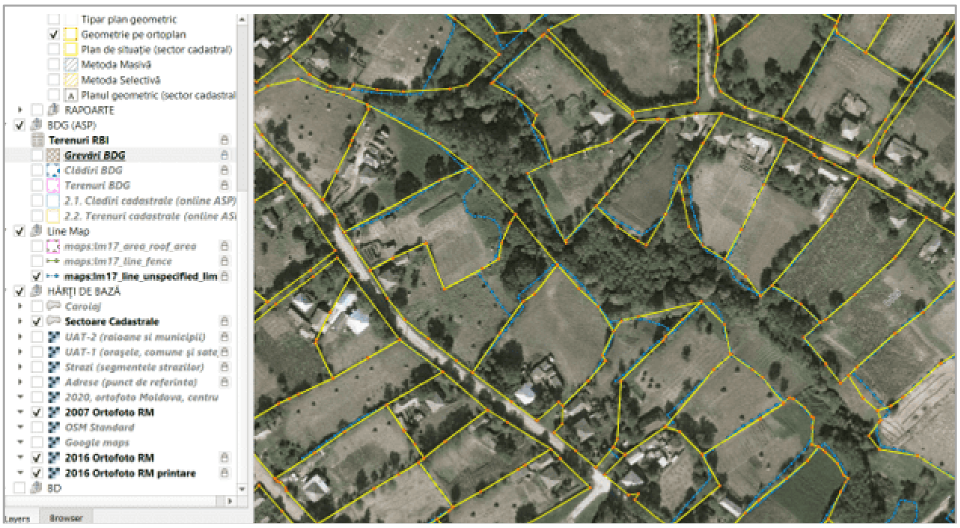

Figure 12. Changes after measurements

*[**Source**: Image by the author]*

It also shows the changes by activating the Land, maps: lm17_line_fence and Maps: lm17_area_roof_area layers. These changes have been made following field data collection, i.e. measurements by geodetic engineers and then processing by cadastral engineers. The identification of the real estate is done by comparing the cadastre data with the data found in the field.

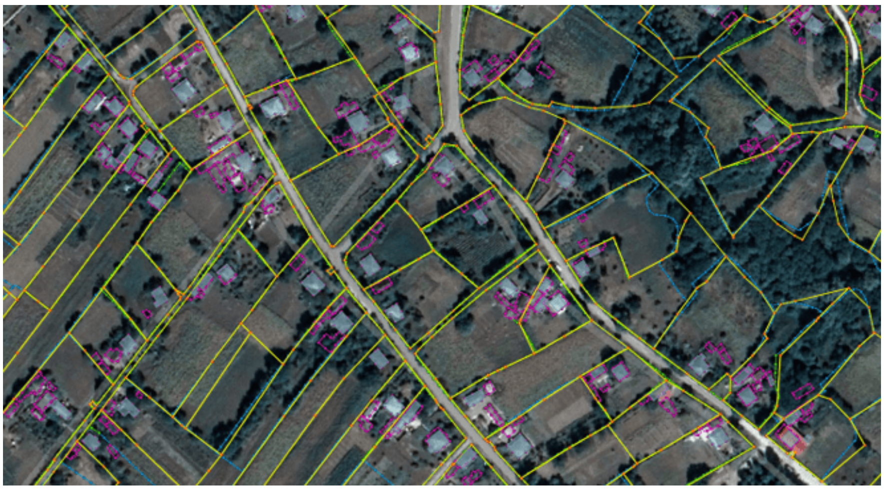

Figure 13. Changes after measurements

*[**Source**: Image by the author]*

The process of vectorization work using orthophotoplan is a complex one. Data processing requires specialized software such as QGIS, AutoCAD, MapInfo and dozens of other useful programs. The end result of the work process is to obtain the exact accuracy and precision of points located on the earth's crust and to obtain qualitative information.

4. Conclusions

The use of orthophotos in cadastral work, especially in the vectorization process, is an essential tool for increasing accuracy and efficiency in geospatial data management. They provide geometrically corrected aerial images that can be used as precise reference bases, facilitating the delineation and digitization of property boundaries, infrastructure or other relevant terrain features.

Vectorization based on orthoimagery allows reducing errors, saving time in the field and easier integration with other geospatial data sources, thus contributing to a more accurate and up-to-date cadastral framework. Orthophotos are a valuable support in the cadastral process, improving the quality and speed of vectorization work, with a direct impact on the efficiency and accuracy of cadastral information management. In cadastral works a major aspect is the definition of cadastral parcels, buildings and property boundaries in which they must be according to the bad location and dimensions. Quality control following terrestrial measurements with existing boundaries and to ensure that they are accurately reflected in cadastral records, they can be compared with existing orthophotos.

Orthophotos provide a detailed image of the land that can be used for property valuation purposes. This helps to determine the value of the land, which is essential for taxation and compensation in land acquisition or expropriation processes.

Authorities can visually inspect properties for unauthorized construction, land use discrepancies or zoning violations by comparing actual orthophotos with cadastral records.

Urban planners use orthophoto maps to analyze existing land use patterns, plan new developments and assess infrastructure needs. This helps to ensure that new projects align with cadastral data and that zoning and land policies are implemented effectively. Without orthophotos, cadastral and spatial planning processes would be much more difficult.

Orthophotos are of particular value in various fields, being an essential tool in land analysis and management and in any geographic information system.

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THE STRUVE GEODETIC ARC – WORLD HERITAGE MONUMENT

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Abstract: *The Struve Geodetic Arc is a series of triangulation survey points along the 26°E meridian, spanning approximately 2,820 km from Hammerfest in northern Norway to Izmail in Ukraine. Established and measured between 1816 and 1855, the Arc was instrumental in determining the Earth's size and shape by measuring triangulation arcs and astronomical coordinates. The survey was a model of international cooperation, involving both scientific and administrative collaboration [7]. The Struve Geodetic Arc include 258 main triangles with 265 main and over 60 subsidiary station points that passes through ten countries, i.e. Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Belarus, Moldova and Ukraine. Each of the ten countries possesses some sites with reliable signs, which mark on the ground the positions of the geographical points where the measurements were performed [1][2][3]. The ten countries concerned have contributed to the preparation of the documentation with a view to nominating the Arc for inscription on the World Heritage List. The World Heritage Committee inscribed the Struve Geodetic Arc on World Heritage List in July 2005 [8]. The World Heritage site includes 34 commemorative plaques or built obelisks out of the original 265 main station points. According to the common procedures and guidelines based on the World Heritage Convention, each State Party is responsible to take care of the preservation and other management of the sites within its territory. The Struve Geodetic Arc is one of the foremost scientific and technical achievements of its time, and it has a truly universal significance. For almost 200 years the Arc has connected from the Black Sea to the Arctic Ocean and will continue connected also in the future. The paper describes the status of Struve Geodetic Arc and procedure of the national legislation, preservation and Management Mechanism and joint international responsibility of the countries possessing the Struve Geodetic Arc sites [4][5][7][9].*

Keywords: *Struve Geodetic Arc, triangulation survey, geodetic measurements.*

1. Introduction

The Struve Geodetic Arc is a geodetic network linking the Black Sea to the Arctic Ocean, spanning 10 modern-day countries and covering a distance of 2,880 km. This network consists of 258 triangulation points and 265 geodetic stations, with 13 points precisely determined using astronomical methods. The Arc was measured from 1816 to 1865 under the supervision of Friedrich Georg Wilhelm Struve (1793-1864) to refine the calculation of the Earth's shape.

In July 2005, UNESCO recognized the Arc as a cultural heritage site of "exceptional and universal value," adding it to the World Heritage List. The designated sites include 34 of the original station points, distributed as follows: Norway (4), Sweden (4), Finland (6), Russia (2), Estonia (3), Latvia (2), Lithuania (3), Belarus (5), Moldova (1), and Ukraine (4). Other preserved points are protected at the national level [1] [2] [3].

One of these 34 World Heritage points “RUDY” is located in the north part of the territory of the Republic of Moldova.

Figura 1. Struve Meridian Arc

Figura 2. Struve Meridian Arc in Moldova

Markers used for the Arc range from simple drilled holes in rock surfaces to engraved crosses, stone or brick markers, and larger commemorative monuments. While modern GNSS technologies have replaced triangulation as the primary geodetic method, the Struve Geodetic Arc remains a cornerstone in the history of geodesy and cartography, having significantly contributed to determining the Earth's dimensions and mapping techniques.

Numerous influential figures were involved in the Arc's development, including European emperors, military geodesists, astronomers such as Struve, Bessel, and Gauss, and precision instrument manufacturers like Fortin and Repsold. Their collaborative efforts made this project a landmark in European scientific advancement.

2. Measurements of The Struve Geodetic Arc

Initially, measurements were carried out in the Vilnius and Baltic Sea regions before expanding further. The project aimed to cover these territories with a triangulation network for mapping purposes. Karl Tenner proposed using part of this network for a broader geodetic arc measurement [9].

Struve and Tenner worked independently to advance the project, and upon securing funding, two geodetic arcs were measured, eventually forming the Struve Geodetic Arc. Struve divided the work into four main phases:

1. **Preliminary Phase (before 1831)**: Initial measurements in Lithuania and the Baltic region
2. **Expansion (1830-1844)**: Extension northward to Tornio, Finland, and preparation for southern measurements
3. **Further Expansion (1844-1851)**: Surveying continued south to the Danube and into Scandinavia
4. **Final Adjustments (post-1851)**: Connecting segments and refining Earth's ellipsoid calculations

Results were reviewed by esteemed scientists, including Friedrich Wilhelm Bessel, and confirmed the precision of the measurements. Today, the Arc represents a significant milestone in geodesy, astronomy, and cartography.

According to the performance order of technological geodetic work, the measurements of the Struve Geodetic Arc (Struve, 1861a) can be divided into stages, provided in the Table 1.

Table 1. Stage of measurements of the Struve Geodetic Arc

No.	Names of geodetic arcs	Latitudes		Supervisors of the measurements	Measurements	
		from	to		from	to
1	Arc of Lithuania	52°03′	56°30′	Karl Tenner	1816	1828
2	Arc of Ostzeja[a]	56°30′	60°05′	Wilhelm Struve	1816[b]	1831
3	Arc of Finland	60°05′	65°50′	Wilhelm Struve	1830	1851
4	Arc of Podil and Valyn	48°45′	52°03′	Karl Tenner	1835	1840
5	Arc of Bessarabia	45°20′	48°45′	Karl Tenner	1844	1852
6	Arc of Finmarketsk	68°54′	70°40′	Christopher Hansteen	1845	1850
7	Arc of Lapland	65°50′	68°54′	Nils Haqvin Selander	1845	1852

3. The Struve Geodetic Arc in the Republic of Moldova

Measurements in present-day Moldova began in August 1846 as part of a broader triangulation project in Bessarabia. General Tenner oversaw the project, with operational management by Lieutenant Colonel Hildenband. The measurements concluded in 1848, using key stations in Ukraine and Moldova [9].

Of the 27 original geodetic points in Moldova, only two remain. The **RUDY station**, rediscovered in 2003 near Rudi village, was confirmed as an authentic Struve point and inscribed in the UNESCO World Heritage List in 2005.

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Figure 3. Open Ceremony of Struve Geodetic Arc Point in Moldova „RUDY“, 2005

Another point, **GEAMĂNĂ**, was later identified through research conducted between 2006-2007. This site, near Geamănă village, features a stone marker with precise geodetic coordinates [9].

Figure 4. The Struve Geodetic Arc point GEAMĂNĂ

4. Protection and managements requirements

To achieve UNESCO inscription, the ten involved countries collaborated in locating and verifying historical measurement sites through geodetic surveys and satellite-based methods. Each country has enacted legal protections for the sites, either under geodetic laws or cultural heritage regulations.

At the national level, the primary responsibility for conservation lies with mapping authorities and local administrations. Internationally, a Coordinating Committee oversees the Arc's management, meeting biennially to discuss preservation efforts. Promotional activities include postage stamps, educational materials, exhibitions, and commemorative coins issued by countries.

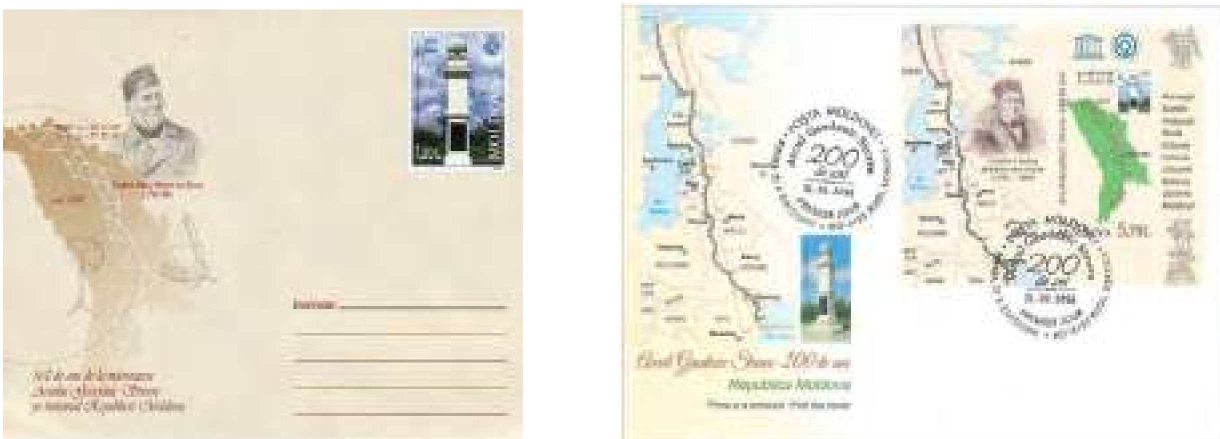

Figure 5. Editions of postal stamps in honor of the Struve Geodetic Arc in Moldova

Figure 6. Commemorative coins for the Struve Geodetic Arc in Moldova

5. Conclusions

In July 2005, the UNESCO World Heritage Committee officially inscribed the Struve Geodetic Arc as a site of "outstanding universal significance." It remains the only geodetic monument recognized on the World Heritage List, spanning ten countries and 34 station points [8] [11].

Since the initiation of the Struve Arc Project in 1994, participating countries have demonstrated strong commitment to its preservation and recognition. The Arc's inclusion in the World Heritage List highlights its crucial role in the history of geodesy, astronomy, and mapping, ensuring that its scientific and historical importance endures for future generations.

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