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GEOTECHNICAL ENGINEERING AND SOIL MANAGEMENT: LEGAL GAPS AND ENVIRONMENTAL CONSIDERATIONS

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Abstract

This study analyses the interaction between geotechnical risk, GIS-based territorial analysis, soil management, and the Romanian legal framework governing earthworks and environmental protection. The Borhanci area of Cluj-Napoca was selected as a case study due to recent large-scale grading operations associated with urban development. The methodology combined GIS analysis, urban planning documentation, field observations, photographic surveys, and legislative review. Field observations identified longitudinal and transversal fissures with depths ranging from 0.20 m to 1.30 m. Landslide susceptibility maps classified neighbouring slopes as medium, high and very high risk. The results indicate that extensive grading works may influence slope stability and drainage conditions in adjacent undeveloped terrain. The study highlights the need for integrated geotechnical assessment, territorial planning, and regulatory clarity regarding grading and levelling works.

Key words*: geotechnical engineering, GIS, landslide susceptibility, soil management, urban planning.*

INTRODUCTION

Geotechnical and civil engineering activities, which involve interventions on the soil and subsoil, are governed by a complex legal framework in Romania. Ensuring the stability and quality of construction requires strict adherence to regulations pertaining to construction quality (Law No. 10/1995, republished; Order No. 27/2023), authorization procedures (Law No. 50/1991, republished), land improvement works (Law No. 138/2004, republished), and environmental protection measures (OUG No. 92/2021 and OUG No. 195/2005). The objectives pursued in this paper involve identifying legislative problems with geotechnical implications and examining the specific normative regulations regarding the authorization of earthworks, particularly land improvements and site grading and levelling works.

A major challenge constantly analysed is legislative insufficiency regarding the regulation of site grading and levelling works. While technical documentation requires geotechnical investigations and the inclusion of descriptions of external works, site grading and levelling works, the legislation governing building permits does not explicitly classify or regulate standalone works involving modifications to land elevation.

The significance of this issue is particularly evident in rapidly developing urban areas such as Cluj-Napoca, where hillside development frequently requires extensive terrain modification and grading operations. Previous studies conducted in the region have shown that urban expansion on sloping terrain requires careful consideration of slope stability, groundwater management and landslide risk assessment in order to ensure sustainable development and reduce geotechnical hazards (Mureșan, 2011; Farcaș et al., 2021).

Geotechnical engineering increasingly relies on Geographic Information Systems (GIS) for the integration, visualization and interpretation of spatially referenced data. GIS supports the assessment of geotechnical hazards, territorial planning and risk management by enabling the analysis of complex interactions between geological, geomorphological, environmental and anthropogenic factors (Player, 2006; Singh et al., 2018).

The emerging field of Urban Geosciences highlights the importance of combining geotechnical engineering, geology,

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hydrogeology and land-use planning in order to support sustainable urban development. Within this framework, GIS-based analysis provides local authorities with an effective instrument for identifying landslide-prone areas, evaluating territorial constraints and supporting informed planning decisions (Azougay et al., 2020; Campagna and Deplano, 2002).

Modern geotechnical practice should integrate not only analytical knowledge but also information-based approaches, interdisciplinary decision-support tools and risk management strategies. Such an approach is increasingly considered necessary for addressing complex environmental and territorial challenges (Arciszewski, 2006; Chowdhury & Flentje, 2007).

The objective of this study is to analyse the interaction between geotechnical risk, GIS-based territorial analysis, soil management and the Romanian legal framework governing earthworks and environmental protection.

MATERIALS AND METHODS

The present study focuses on the Borhanci district of Cluj-Napoca, Romania, an area that has undergone significant land-use changes through urban planning procedures enabling the development of educational, healthcare, sports and public infrastructure facilities. Borhanci was selected as a case study due to the presence of extensive grading works, slope modification activities and documented landslide susceptibility conditions.

The analysis was based on multiple data sources, including the Cluj-Napoca GIS platform, the General Urban Plan (PUG), the Local Urban Planning Regulation (RLU), PUZ documentation, landslide susceptibility maps, field observations, photographic documentation and Romanian legislation regarding construction, environmental protection and land improvement works.

GIS analysis was used to evaluate the spatial relationship between planned urban development areas and landslide susceptibility zones. Official GIS layers and planning documentation were analysed in order to identify territorial constraints and risk-prone sectors. Previous studies have demonstrated that GIS represents an efficient framework for integrating geotechnical, geological and environmental information into a common decision-support system, supporting hazard identification, risk evaluation and territorial planning processes (Chowdhury & Flentje, 2007; Singh et al., 2018). The GIS platform of Cluj-Napoca provides valuable spatial information supporting urban planning and geotechnical risk assessment and is increasingly regarded as an essential component of digital governance and smart city initiatives (Campagna & Deplano, 2002). The integration of GIS-based spatial analysis, planning documentation and field observations provides an effective framework for identifying areas exposed to geotechnical hazards. Similar multidisciplinary approaches have been successfully applied in studies addressing slope instability and urban development in the hilly areas surrounding Cluj-Napoca (Ilieș et al., 2016; Farcaș et al., 2021). Figure 1 illustrates the planning framework applicable to the study area through the General Urban Plan (PUG).



Figure 1. Studied area highlighting zones delineated through GIS analysis in accordance with the General Urban Plan (PUG) of Cluj-Napoca

Figure 2 presents the planned urban development and land-use changes within the Borhanci area. Figure 3 illustrates the landslide susceptibility classes identified within the study area and provides a spatial representation of geotechnical constraints relevant to future development.

Field investigations focused on identifying visible instability indicators, including fissures, rupture surfaces, drainage conditions and vegetation associated with excessive moisture. Measured fissure depths ranged from 0.20 m to 1.30 m. Observations also identified longitudinal and transversal fissures, suggesting ongoing deformation processes in adjacent undeveloped terrain.

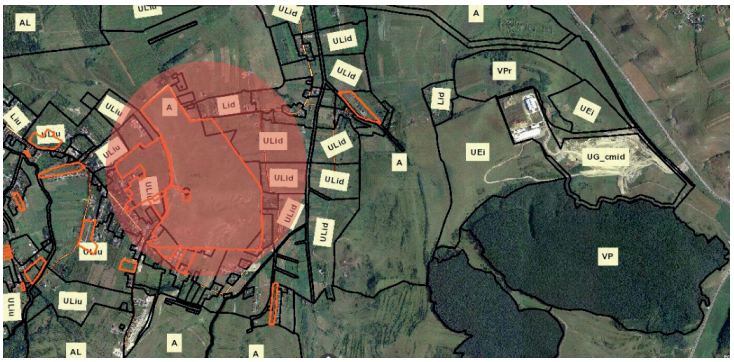


Figure 2. Studied area highlighting zones delineated through GIS analysis, in accordance with the General Urban Plan (PUG) of Cluj-Napoca, with the PUZ-regulated area highlighted in red

Figure 4 presents fissures and instability indicators identified during field observations within the Borhanci study area.

A legislative review was conducted in order to analyse the legal framework governing construction activities, land improvement works, environmental protection and waste management. The analysis included Law No. 50/1991, Law No. 138/2004, Government Emergency Ordinance No. 92/2021, Government Emergency Ordinance No. 195/2005, as well as relevant urban planning regulations applicable to the study area. The legislative review was performed in parallel with the GIS analysis and field investigations in order to evaluate the interaction between geotechnical risk, territorial planning and environmental governance.

RESULTS AND DISCUSSION

1. Legal Framework of Land Improvements

The regulation of land improvements is governed by Law No. 138/2004, with methodological norms approved by Government Decision No. 1.872/2005. Land improvement works are indispensable for the sustainability of agricultural land and soil quality, as well as for overall territorial protection.

Land improvements have several crucial objectives:

- Territorial Protection: Providing protection for lands of any kind and any categories of structures against floods, landslides, and erosion. This goal also includes regulating water courses and protecting accumulation lakes against silting.
- Soil Management: Ensuring an adequate level of soil moisture and the improvement of acidic, saline, and sandy soils (soil improvement), as well as providing protection against pollution.

These activities must be performed in compliance with environmental protection standards (Law No. 138/2004).

Land improvements consist of complex hydrotechnical, and soil improvement works that require a construction permit according to Law No. 50/1991. These works include:

- Irrigation and Rice Paddies: Including water catchment, pumping, transport, distribution, and evacuation works, and, where appropriate, site grading works.
- Desiccation and Drainage: Networks of structures, pumps, canals, and pipes used to prevent and remove excess water. The infrastructure includes components like canals and pumping stations.
- Erosion Control and Landslide Mitigation: Works aimed at preventing, reducing, or halting land degradation processes. These include soil protection measures, regulation of surface runoff on slopes, torrent control, and stabilization of loose sandy soils. Land improvement organizations may be established specifically for erosion control purposes.
- Soil improvement works: Works on saline, acidic, or sandy soils, including land levelling and modelling, scarification, deep loosening, and water drainage channels.

– Embankments and regulation of water courses.

The scope of these works clearly indicates that they involve significant earth moving and geotechnical interventions (Law No. 138/2004).

The infrastructure assets of land improvements, such as the secondary irrigation network in the private domain of the state, are administered by the National Agency for Land Improvements (ANIF) and can be transferred to legally constituted Land Improvement Organizations (OIFs) (Law No. 138/2004).

Law No. 138/2004 prescribes sanctions for unauthorized activities in these areas:

– Executing constructions, or modifying or extending constructions within land improvement facilities, without the prior authorization of the ANIF, organizations, or federations.
– Carrying out excavations, borrow pits, or trenches in embankments or their protection zones, or extracting materials from defence works, without the Agency's prior consent.

2. Soil Management and Environmental Considerations

The management of soil and excavated materials represents a key component of geotechnical risk prevention and environmental protection. Modern approaches increasingly emphasize the integration of geotechnical engineering, territorial planning and environmental governance in order to minimize the impact of earthworks on slope stability and land-use sustainability (Chowdhury & Flentje, 2007; Azougay et al., 2020).

The regulation of waste is critical in geotechnical projects involving earth movement. The framework aims to ensure a high level of protection for the environment and public health.

OUG No. 92/2021 excludes certain soil categories from the waste regime:

– Soils (in situ), including uncontaminated excavated soils and buildings permanently attached to the ground.
– Uncontaminated soils and other natural geological materials excavated during construction activities, provided there is certainty that the material will be used for construction in its natural state and on the site from which it was excavated.

If soil is moved off-site or utilized for uncontrolled filling (site grading works), its status can change, potentially classifying it as waste.

From a geotechnical perspective, the management of excavated materials is directly linked to slope stability, drainage conditions and the prevention of environmental degradation. GIS-based territorial analysis can support the identification of risk-prone sectors and contribute to more sustainable land management practices (Player, 2006; Singh et al., 2018).

Backfilling is explicitly defined as a recovery operation (R5 or R12 in the recovery operations list - OUG No. 92/2021), which is one of the preferred options in the waste hierarchy, above elimination. Backfilling involves the use of adequate non-hazardous materials for site restoration or landscaping purposes. The waste used for backfilling must replace non-waste materials and be limited to the strictly necessary quantity.

However, materials that no longer hold waste status and are used for backfilling are not considered towards meeting recycling objectives. Furthermore, placing waste (D1) in or on the ground (e.g., landfills) or burying any kind of waste is an offense (OUG No. 92/2021).

The environmental framework establishes principles such as the preventive action principle and the "polluter pays" principle. Holders of activities have the obligation to manage waste without endangering public health or damaging the environment, particularly without generating risks of contamination of air, water, soil, fauna, or flora (OUG No. 92/2021).

The lack of explicit authorization for site grading and levelling works in Law 50/1991 is particularly critical because unauthorized or uncontrolled deposits of soil, especially if classified as waste, violate fundamental environmental obligations and pose a direct threat of geotechnical stability. This directly contradicts the objective of land improvements to provide territorial protection against landslides. Failure to implement proper technical solutions for backfilling or slope

alterations results in a significant risk of landslides, a specific natural risk addressed in urban planning regulations.

The findings presented above demonstrate that soil management cannot be analysed solely from a legal perspective. The geotechnical consequences of uncontrolled filling activities include changes in drainage patterns, increased loading on slopes, and the potential activation of instability processes. Therefore, the integration of environmental legislation, geotechnical assessment and GIS-based territorial analysis is essential for sustainable land management and risk prevention (Chowdhury & Flentje, 2007; Singh et al., 2018).

3. Legislative Gaps and Proposed Solutions

Based on practical experience and the findings presented in this study, one of the most debated issues concerns the insufficient regulation of site grading works.

Although Law No. 50/1991 requires permits for "land improvement works" (which implicitly cover land levelling and modelling), it fails to explicitly include or sanction "site grading and levelling works involving changes in land elevations". This omission in the construction law framework creates disparate applications across local authorities and inconsistencies in permitting practices.

From a geotechnical perspective, insufficient regulation of grading and levelling works may lead to inconsistent implementation practices and difficulties in evaluating long-term impacts on slope stability. Similar concerns have been highlighted in studies addressing the integration of engineering practice, risk management and territorial planning (Arciszewski, 2006; Player, 2006).

In the case of general construction, the technical documentation must show the measures taken for the protection of neighbouring buildings' foundations, demonstrating that changes in site conditions (including site grading and levelling works) inherently impact structural stability.

The draft Code of Spatial Planning, Urbanism, and Construction aims to address this regulatory shortfall. This proposed legislation (which would eventually repeal Law No. 50/1991 and Law No. 10/1995) explicitly classifies land development works, including earthworks and external works, as requiring authorization. Under the proposed code, land arrangement operations, including demolitions, deforestation, site grading and levelling works, access roads, retaining walls, and drainage, are clearly listed as works that must be authorized.

In the light of the above analysis, the adoption of the new Code of Spatial Planning, Urbanism, and Construction may be considered necessary, particularly in view of its explicit regulation of external works and land development operations. Furthermore, the provision of clear and consistent solutions to divergent interpretations in practice is essential to ensure a coherent understanding and effective enforcement of the legal framework. Such clarification would contribute to addressing existing regulatory gaps concerning the aforementioned works and would facilitate both the proper application of the law by inspectors and local authorities, as well as its consistent interpretation and implementation by architects, engineers, and construction professionals.

4. Case Study: Implementation of Local Urban Planning Regulations in the Municipality of Cluj-Napoca (General Urban Plan (PUG) analysis)

Within the context of national legislative deficiencies regarding the explicit authorization of site grading and levelling works, the Local Urban Planning Regulation (RLU) related to the Cluj-Napoca General Urban Plan (PUG), Figure 1, institutes a set of strict constraints for specific intra-urban and extra-urban zones, aimed at territorial protection and slope stability.

The analysis of functional sub-zones highlights a systematic concern for the preservation of natural soil conditions and the mitigation of geotechnical risks, having selected all functional zones within the extra-urban area (Agricultural land - arable land, pastures, hayfields, tree nurseries, etc. (TDA), Agricultural land - orchards (TDA_L), Forested land (TDF)), while specifically focusing on agricultural lands, green spaces, and forests for the intra-urban area (Non-urbanized agricultural land (A), Non-urbanized and non-developable agricultural land - orchards (AL), Area designated for recreational activities

carried out in a natural setting, in proximity to forests located within or outside the intra-urban area (Aapp), The area includes sections of the corridors of the Someșul Mic River and the Morii Channel, comprising minor riverbeds, hydrotechnical works, riverbank arrangements, green strips or spaces, pedestrian and bicycle circulation routes, urban furniture, as well as protection strips along secondary watercourses (streams) located on the slopes (Ve), The area includes - green spaces with a protective function in relation to major infrastructure; main electricity and natural gas transmission networks, railway and road corridors; green spaces with a sanitary protection role for active or closed landfills and wastewater treatment plants; green areas designated for the ecological restoration of degraded land; plantations intended to stabilize steep slopes resulting from anthropogenic interventions or affected by natural landslide risks (VPr), Forested land located within the intra-urban area, introduced through urban planning documentation prior to the revision of the Romanian Forestry Code (2008). Subzone of forests designated for recreational use and subzone of pastures / hayfields within forested areas (VP)).

GIS-based territorial analysis provides an effective framework for integrating urban planning restrictions with geotechnical risk assessment. Such approaches enable the identification of environmentally sensitive sectors and support sustainable land-use management (Campagna & Deplano, 2002; Singh et al., 2018).

The analysis of intra-urban functional zones highlights a systematic concern for the preservation of natural soil conditions and the mitigation of geotechnical risks:

- A, AL: The preservation of the existing land-use structure is mandatory to maintain ground stability. Permitted uses include crops and land improvement works, while conditional works allow for greenhouses (>1 ha) and agricultural annexes (max. 10% Land Occupancy Percentage (P.O.T.) for A; 5% for AL). The discharge of wastewater and rainwater into natural watercourses is strictly prohibited, requiring on-site management solutions to prevent erosion processes. Additionally, all categories of waste must be managed in accordance with applicable regulations, to avoid the formation of uncontrolled deposits of excavated material.
- Aapp: Earthworks and, site grading and levelling works interventions that may affect public infrastructure or adjacent parcels are explicitly prohibited. Furthermore, a significant proportion of green space on natural soil (60–80%) is required, thereby limiting anthropogenic intervention.
- Ve, VPr: Permitted works include plantations and hydrotechnical works. The VPr zone is designated for afforestation and vegetation-based interventions aimed at stabilizing slopes with inherent landslide risk, as well as for the ecological restoration of degraded land. Within these areas, the P.O.T. is set at 0%, effectively prohibiting any construction activities involving alterations to ground morphology.
- VP: The RLU explicitly prohibits all forms of earthworks and site grading and levelling works interventions within forested areas. Only forestry exploitation and essential infrastructure are permitted, maintaining the P.O.T. at 0%.

In the extra-urban territory, the PUG focuses on maintaining ecological balance and preventing land degradation:

- TDA, TDA_L: Like intra-urban rules, it is forbidden to discharge water into slope watercourses, mandating on-site management to avoid soil transport. Permitted annexes are strictly limited to a maximum P.O.T. of 10% of the designated area (5% for orchards), while the remainder of the land must retain its natural state.
- TDF: To ensure "land stabilization" near the city, the PUG imposes severe restrictions, prohibiting all earthworks and site grading and levelling works, as well as any permanent constructions.
- The P.O.T. is strictly maintained at 0%.

A compelling example of how land-use modifications and large-scale site grading works can influence the morphological stability of adjacent terrains is provided by the Borhanci

area, located in the south-eastern part of the Cluj-Napoca municipality, near the Apahida-Vâlcele bypass road. This case study illustrates the geotechnical challenges encountered in rapidly developing urban areas where significant interventions occur on sensitive slopes.

The Borhanci development area represents a relevant example of the interaction between urban expansion, terrain modification and geotechnical risk. GIS-based analysis facilitates the assessment of territorial constraints and provides decision-makers with spatial information regarding landslide susceptibility and environmental vulnerability (Azougay et al., 2020).

According to the analysed documentation, this sector was initially classified under the General Urban Plan (PUG) of Cluj-Napoca as non-urbanized agricultural land incorporated into the intra-urban area (A). This status was subsequently modified through a Zonal Urban Plan (PUZ), Figure 2, approved by Local Council Decision (HCL) No. 510/2022 (later amended by HCL No. 645/2025), redesignating the area as Institutional and Public Interest Services Zone (Is Borhanci). This legal transition facilitated the development of a major infrastructure project, including an educational hub, healthcare and sports facilities, and a forest park.

The comparison between the planning documentation and the GIS-based territorial analysis indicates that significant grading operations were implemented in an area surrounded by sectors presenting varying degrees of landslide susceptibility.

While the construction platforms for the educational hub are being executed based on rigorous geotechnical investigations field observations indicate increased vulnerability in the adjacent terrains. GIS analyses and official risk maps classify the slopes in this area as having medium, high, and very high landslide susceptibility, Figure 3.

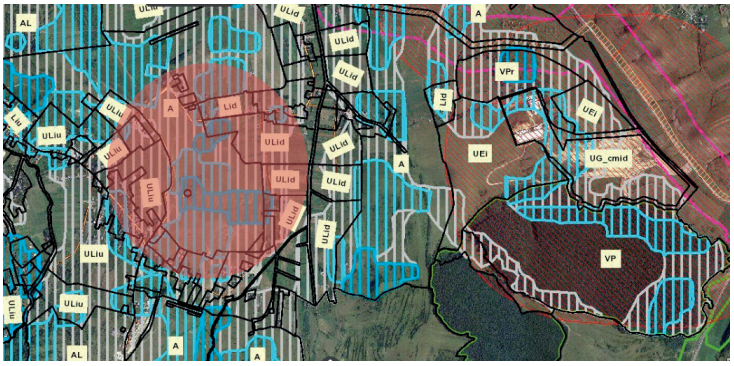


Figure 3. Studied area showing landslide susceptibility zones identified through GIS analysis: medium to high risk (grey), high risk (light blue), and very high risk (dark blue)

The GIS results demonstrate the importance of integrating landslide susceptibility information into urban planning decisions. Previous studies have shown that GIS-based risk mapping represents one of the most efficient tools for identifying sectors requiring enhanced monitoring and geotechnical investigation prior to the implementation of major earthworks (Bezerra et al., 2020; Singh et al., 2018).

At present, on the southern slope directly bordering the sites, where extensive site grading works have been carried out, active soil instability is evident. As this adjacent land has remained undeveloped (retaining the characteristics of the former agricultural Zone A), it serves as a natural indicator of the geotechnical stresses affecting the area (Table 1):

– Structural soil manifestations: Transversal and longitudinal fissures have developed within the non-homogeneous and uncompacted soil mass, with significant depths ranging from 0.20m to 1.30m, indicating structural failure within the soil mass, Figure 4.

- Morphological deformations: Multiple rupture zones and so-called *"slip surfaces"* (natural step-like terraces) have been observed, indicating that the shear strength of the soil has been exceeded under the influence of natural and anthropogenic factors.
- Hydrological indicators: The presence of hygrophilous vegetation confirms water stagnation or inadequate drainage, with excess moisture acting as a primary trigger for landslide processes.



Figure 4. Field photograph highlighting longitudinal and transversal soil fissures, suggesting active deformation processes

Table 1. Main geotechnical observations identified in the Borhanci study area

Indicator	Observation
Minimum fissure depth	0.20 m
Maximum fissure depth	1.30 m
Fissure orientation	Longitudinal and transversal
Landslide susceptibility classes	Medium, High, Very High
Hydrological indicators	Hygrophilous vegetation
Morphological indicators	Rupture surfaces and local deformation

The field observations indicate active deformation processes affecting adjacent undeveloped terrain. The identified fissures, rupture surfaces and hydrological indicators are consistent with instability phenomena commonly reported in areas affected by slope modification and inadequate drainage conditions. The integration of field observations with GIS-based analysis provides a more comprehensive understanding of local geotechnical risk conditions (Player, 2006; Azougay et al., 2020).

The Borhanci case highlights the critical importance of water management and controlled drainage, as well as the continuous monitoring of adjacent areas, in accordance with the principles set out in Land Improvement Law No. 138/2004. Although the authorized works benefit from dedicated geotechnical studies, the current lack of a unified national regulation under Law No. 50/1991 regarding the explicit authorization of ground elevation changes (site grading) makes it difficult to enforce preventive measures across the entire Territorial Reference Unit (UTR).

CONCLUSIONS

The legal framework governing geotechnical engineering requires a coherent correlation between construction authorization (Law No. 50/1991), land improvement regulations (Law No. 138/2004), and environmental protection legislation (OUG No. 195/2005 and OUG No. 92/2021).

Land improvement works, such as irrigation systems and erosion control measures, constitute essential infrastructure and are explicitly subject to construction permit requirements. Their primary role is territorial protection, particularly in mitigating landslide risks.

A major practical challenge lies in the omission of site grading and levelling works, specifically those involving changes in land elevation, as a distinct category requiring authorization under the current Law No. 50/1991. The uncontrolled execution of such works generates significant geotechnical risks and may lead to illegal waste management practices, as deposited materials can be classified as waste. In this context, the law strictly prohibits the embedment of any type of waste in the ground.

The findings of this study further demonstrate that major earthworks, even when technically adequate at the site level, can alter the overall equilibrium of slopes and generate indirect geotechnical effects in adjacent areas. The Borhanci case study provides clear evidence of such impacts, highlighting the vulnerability of neighbouring terrains in the absence of coordinated measures at the territorial scale.

The analysis of the General Urban Plan of Cluj-Napoca shows that local authorities partially compensate for this legislative gap through Local Urban Planning Regulations. By restricting site grading and levelling works and earthworks in sensitive zones (VPr, VP, TDF, Aapp) and imposing a 0% P.O.T. in high-risk areas, the local framework actively contributes to preventing geotechnical instability and the improper management of excavated soil as waste.

In this context, the adoption of a consolidated Code of Spatial Planning, Urbanism, and Construction, explicitly including site grading and levelling works among the categories subject to authorization is both necessary and justified. Such a framework would ensure a consistent legal basis for the application of sanctions, improve the protection of neighbouring properties, and reinforce the fundamental environmental principle of preserving soil and subsoil quality.

The Borhanci case study demonstrates the importance of integrating geotechnical assessment, GIS analysis, environmental protection and territorial planning. The identified fissures, rupture surfaces and landslide susceptibility zones highlight the need for continuous monitoring and risk-informed decision making in areas affected by extensive grading operations.

The GIS-based territorial analysis performed in this study complements the legal and geotechnical assessment by providing spatial information regarding environmental constraints and landslide susceptibility. Such interdisciplinary approaches are increasingly recognised as essential tools for sustainable urban development and territorial risk management.

The results support the integration of geotechnical engineering, GIS technologies, environmental governance and urban planning in order to improve the management of earthworks and reduce long-term geotechnical risks.

Future research should include detailed geotechnical monitoring, GIS-based temporal analysis and quantitative assessment of slope stability in rapidly developing urban areas.

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