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MaStER_G – tracing environmental resilience to geohazards

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Abstract

The MaStER_G project aims to establish international Master Study Program (MSP) in environmental geotechnics and geohazards, fully aligned with the Strategic Framework for European Cooperation in Education and Training. Through the joint effort of partner institutions with diverse backgrounds, the project reinforces the European Higher Education Area. The MaStER_G consortium brings together six institutions from five universities. They form a comprehensive academic network that bridges EU and non-EU regions, ensuring exchange of knowledge, mobility of students and staff, and cooperation in environmental geotechnics and geohazard risk reduction. The proposed MSP focuses on the geotechnical implications, including slope instability and infrastructure vulnerability, under extreme climatic events and seismicity. Students will benefit from cutting-edge research, international study environments, and multi-disciplinary problem-solving, significantly improving their readiness for market and careers. Thus, the MSP not only responds to regional needs, but also establishes a scalable model for interdisciplinary and transnational education in emerging risk-driven engineering domains.

Keywords

Education, Environmental resilience, Geohazards, Market.

1 Introduction

Many regions worldwide face numerous and different environmental challenges, characterized by an increase in the frequency of geohazards due to various influences, most often climate change. Considering the priorities of the European Union developed within the Erasmus+ program, higher education institutions from Croatia, Serbia, North Macedonia, Brazil and Iran (temporarily inactive member of the consortium), which deal with these problems, proposed a joint international project, i.e. master study program (MSP) that will focus on environmental geotechnics and geohazard management (Fig. 1). Through a detailed analysis of the Erasmus Mundus Joint Masters (EMJM) catalogue, it was concluded that currently there are 213 joint study programs financed through the Erasmus+ program, but by searching the study programs it was determined that none of them covers the field of geohazards and environmental geotechnics. For these reasons, the proposed international project „Environmental Resilience and Geohazards - MaStER_G“ represents a new educational initiative that deals with the critical needs. This joint MSP will cover the escalating geological challenges and risks related to the environment and climate change that require sophisticated cross-border expertise.



Fig. 1Part of the members of the project’s institutional partners.

2 General information about environment and geohazards

The technological and industrial progress of modern society has led to significant changes in the way of life and increasing needs of people, and thus to significant negative impacts on the environment, primarily due to the large consumption of natural resources, creation of a large amount of waste etc. On the other hand, climate change and geohazards are emphasized almost daily, which are defined as potentially harmful geological, geomorphological, hydrological or ecological processes and events that can cause loss of life, injuries or other health consequences, damage to property and infrastructure, social and economic disturbances or environmental problems. Typical geohazards include earthquakes, landslides, volcanic eruptions, tsunamis, land subsidence etc. (Fig. 2), which pose a very serious threat. A geohazard event is typically characterized by its location, magnitude or intensity, duration, frequency, and likelihood of occurrence. When such an event causes a serious disruption of the normal functioning of a society, exceeding the local capacity to cope with available resources, it can escalate into a disaster, resulting in widespread human, economic and environmental losses. In many cases, anthropogenic activities such as: urbanization, deforestation, mining, unsafe waste disposal, inadequate conversion of land use, poor design of infrastructure facilities etc., significantly contribute to triggering or intensifying the impact of geohazards. On the top of that, climate change increases the frequency and intensity of extreme weather events, such as heavy rainfall and long-term droughts, which further exacerbate certain geohazards, interact and combine, forming scenarios with multiple hazards that require interdisciplinary and transnational approaches.



Fig. 2 Official poster (left) and logo (right) of the proposed master study program.

3 About the study program

This project aims to create a new international MSP in environmental geotechnics and geohazards (MaStER_G, https://masterg.gfv.hr/), which will be fully aligned with the strategic framework for European cooperation in education and training, bringing together complementary academic excellence across Europe and selected non-EU regions. It defines a program that combines traditional engineering education through consistent use of advanced digital and other tools: data-driven, including numerical and physical modelling, GIS and remote sensing, monitoring technologies, and AI-supported learning environments, emphasizing critical thinking and practical skills in solving a variety of geohazard-related problems. Namely, past practice has shown that state universities are mostly focused on „acquiring knowledge“, so it is left to students to apply „acquired knowledge“ and supplement certain „abilities“ only after studying, which is what the market is now mostly looking for. Traditional study programs of civil engineering, geology, ecology and other disciplines, which are aligned with the Bologna process, do not, as a rule, provide teachers with the opportunity to elaborate on certain thematic areas within a certain course. For these reasons, in a conventional way, students are given the necessary information that can be used to solve only idealized problems. However, as a

rule, this approach is insufficient for students to develop a sense of critical thinking. Right for these reasons, MaStER_G will represent an additional experience, because through carefully designed courses and research work of students, topics related to real problems will be dealt with, which they will encounter in practice after completing their studies. Therefore, MaStER_G will partly enable students to „acquire skills“ through finding, analysing and interpreting processes and phenomena that affect the environment and geohazards, which will be supplemented with information from professional literature, web-based indexes of scientific works, etc.

The duration of this MSP is four semesters with a total of 120 ECTS. Teaching will be conducted through structured mobility of students between partner institutions, by semester. The 1st semester (30 ECTS) is organized by the coordinating institution, i.e. University of Zagreb, Faculty of Geotechnical Engineering in Varaždin, and the 2nd and 3rd semesters (60 ECTS) are hosted by partner institutions from North Macedonia (Ss. Cyril and Methodius Universityin Skopje – Institute of Earthquake Engineering and Engineering Seismology & Faculty of Civil Engineering), Serbia (University of Belgrade, Faculty of Mining and Geology) and Brazil (Federal University of Bahia). A summer school will be organized between the 2nd and 3rd semester. In the final semester (30 ECTS), the Master’s thesis (25 ECTS) is jointly supervised by academic staff from at least two partner institutions and, where appropriate, external stakeholders. The thesis represents a research- and practice-oriented capstone, integrating knowledge and skills acquired throughout the program and directly addressing learning outcomes related to independent research, innovation capacity and professional readiness. The remaining 5 ECTS credits will be earned through an internship.

Given that the teams from the countries participating in the project are made up of experts from different disciplines (civil engineers, geological engineers and geotechnical engineers), the MSP will be related to current topics in society when it comes to modern geodynamic processes (e.g., slow response in emergency situations caused by natural disasters), pollution caused by municipal waste disposal, as well as challenges with underground space. Through its innovative „learning by sharing experience“ methodology, students will learn at real geohazard locations, while simultaneously engaging in cross-border knowledge sharing through an interconnected network of laboratories. Based on strategic partnerships between higher education institutions and stakeholders in the economy, MaStER_G aims to develop experts capable of dealing with complex geological and environmental challenges, while fostering long-term regional resilience to geological hazards.

4 Expected results and benefits

The learning outcomes of the proposed joint MSPare harmonized with European qualification standards, which enables the possession of internationally recognized competencies in the field of „Environmental Geotechnics and Geohazards“. In addition, strengthened institutional cooperation is expected through the networking of young researchers from different countries and the transfer of knowledge between different institutions.

MaStER_G positions environmental geotechnics as a key enabler of resilience by focusing on the behaviour of soils, rocks, and ground–structure systems under changing environmental and hazard conditions. By integrating environmental geotechnics with geohazard risk assessment, digital tools, and international case studies, this study programme translates the broad concept of environmental resilience into measurable engineering actions and decision-making tools. Such approach ensures that graduates are equipped not only to analyse geotechnical processes, but also to contribute effectively to multi-disciplinary strategies for sustainable development, disaster risk reduction, and long-term environmental adaptation. Geohazards represent a naturally transversal and interdisciplinary theme, requiring integration of environmental geotechnical engineering, environmental science, geophysics, data, and risk management. For this reason, geohazards are placed at the core of the MaStER_G study programme.

The labour-market gap analysis highlights a clear and growing demand for young people in the field of environmental geotechnics and related geohazards. However, this interest is not reflected in enrolment figures. Over the past 15–20 years, many countries worldwide have experienced a continuous decline in the number of pupils completing primary and secondary education. As a result, despite increasing societal and labour-market needs, the number of students enrolling in geology, geotechnical engineering, environmental engineering, and civil engineering programmes—and subsequently specialising in the field of environmental geotechnics—remains critically low. These demographic and educational trends have led to significant structural challenges, including a reduced number of

graduates entering the labour market and a declining pool of young professionals interested in pursuing scientific and research careers. This situation negatively affects the capacity of both academia and industry to respond to emerging challenges related to climate change, environmental risks, and geohazards. To address these needs, the MaStER_G program aims to:

- increase the number of highly motivated students enrolling in geohazard-related fields;
- educate students on contemporary and challenging topics on environmental geotechnics;
- attract and retain talented young people with an interest in scientific and research careers;
- produce highly qualified graduates equipped with the competences required for professional careers in an international and interdisciplinary working environment.

Through its integrated design, international consortium, and alignment with labour-market and societal needs, the MaStER_G study program directly contributes to strengthening human capital in strategically important fields.

The geotechnical engineering market sector is undergoing a period of sustained financial expansion and structural transformation, driven by increased public and private investment in infrastructure development, climate adaptation, environmental protection and risk mitigation. At both national and European levels, significant financial resources are being mobilized to address ageing infrastructure, growing exposure to natural hazards and the transition towards a low-carbon and climate-resilient economy. Public investment programs, supported by EU Cohesion Policy funds, the Recovery and Resilience Facility, the Green Deal and climate adaptation strategies, are generating strong demand for civil engineering services. These investments increasingly prioritize resilient infrastructure, environmental sustainability, hazard mitigation and risk-informed planning, directly affecting the skills profile required in the labour market. From a market perspective, the demand is shifting from conventional construction activities towards high-value engineering services, including:

- geohazards assessment and risk management:
    - what's being bought: hazard/risk studies, slope stability & rockfall design, early-warning systems, deformation monitoring (InSAR, GNSS, ground-based radar), asset risk management for transport, dams, mining and energy.
    - market signal: the global geohazard market is commonly sized at ~US$0.77B in 2024, with forecasts to ~US$1.19B by 2032.
    - why it's growing now: climate-amplified extremes (intense rainfall → landslides/debris flows; coastal erosion), plus aging infrastructure; big owners shifting from "reactive geotech" to continuous monitoring + risk-based maintenance (especially rail/roads, pipelines, hydropower, mines); Europe-specific tailwind: Copernicus EGMS makes wide-area ground motion (InSAR) data accessible across borders, accelerating adoption of deformation screening and monitoring workflows.
- environmental geotechnics:
    - what's being bought: site investigation & risk assessment for contaminated land, landfill/waste containment (liners, covers, leachate control), brownfield redevelopment support, remediation design oversight, groundwater–soil interaction work, geosynthetics and barrier systems.
    - market signal (adjacent markets that drive environmental geotechnics): environmental remediation is often estimated at ~US$123.9B in 2025 with strong growth through 2029.
    - why it's growing: urban infill + brownfield redevelopment (ports, rail yards, industrial land); stricter compliance/environmental, social and governance (ESG) expectations and lender due diligence; growth in energy transition projects with heavy ground risk: grid upgrades, offshore/onshore, hydrogen, carbon storage sites (site characterization).
- monitoring and data-driven decision support,
- sustainable ground solutions and remediation.

These segments are characterized by higher knowledge intensity, greater added value and stronger growth potential, but they also require advanced and specialized competences that are currently in short supply. As a result, employers face increasing difficulties in recruiting engineers capable of operating at the interface of engineering, environmental science, geosciences and digital technologies. Financial constraints further amplify these challenges. While investment volumes are increasing, companies must optimize costs, comply with stricter regulatory frameworks and meet ESG requirements. This creates a clear market need for highly skilled professionals who can deliver efficient, resilient and sustainable solutions, reducing long-term risks and life-cycle costs. In this context, investment in advanced education and skills development represents a strategic response to both financial and market pressures.

The MaStER_G study program addresses these needs by equipping graduates with specialized, interdisciplinary and internationally recognized competences aligned with emerging market segments in geohazards and environmental geotechnics. By doing so, the program supports the efficient use of public and private investment, enhances employability and contributes to the competitiveness and resilience of the civil engineering sector.

5 Conclusion

The study programme has been developed within the framework of the Erasmus Mundus Design Measures (EMDM) MaStER_G project, implemented under the EMDM action of the Erasmus+ Programme of the European Union. The EMDM action supports the design and development of new, high-quality and integrated international master's program that aim to enhance academic excellence (ensured through common learning outcomes, harmonized assessment criteria and joint quality assurance, guaranteeing consistency and comparability of academic standards across all partner institutions), innovation in higher education, and cooperation between higher education institutions across different countries. The project brings together partner institutions with the objective of designing a modern curriculum aligned with European Higher Education Area standards, strengthening interdisciplinary education, and addressing current environmental and geotechnical challenges and needs of the geohazards and environmental geotechnics market sector. Each course and mobility phase contributes explicitly to the achievement of these learning outcomes. Innovative learning elements are embedded progressively across the MSP and are closely linked to the mobility structure.

The aim of the proposed MSP is to promote excellence in higher education through international cooperation with European universities and universities from Brazil (and Iran), as well as with eminent lecturers from other universities. The partner higher education institutions are from different regions of the world, facing different geohazard challenges, and hence apply different expertise, methodologies and technologies. This diversity provides a common basis for knowledge exchange, innovation and strengthening of the area of higher education in civil, geological and environmental engineering, while increasing global relevance and impact. In this regard, MaStER_G will directly contribute to improvement of transparency and recognition of qualifications, development of multilingualism, internationalization of education, as well as promotion of open access to educational resources and knowledge. Through its integrated approach, which connects resilience and risk assessment, the joint MSPMaStER_G will enable acquisition of certain qualifications for easier recognition and better understanding of environmental geotechnics and geohazards and beyond national borders, developing experts capable of dealing with complex geological and environmental challenges, while fostering long-term regional resilience to geological hazards.

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