Report on the results obtained in 2024 in the PN project 23 30 04 04: Developing an environmental monitoring methodology for potential CO2 storage sites in Romania

The **aim of the project** is to elaborate and develop an innovative environmental monitoring methodology (namely for CO_2 leakage) of potential geological CO_2 storage sites in Romania. This methodology, designed for potential land-based CO_2 geological storage projects, where the first storage projects in the country are already planned, it will be based both on the application of the methods already used in the field of CO_2 leak monitoring (geochemical methods - flow measurements, sol-gas surveys; shallow seismics), and also on methods less used for this purpose (electrometry, GPR, microgravimetry). We aim thus to demonstrate that the use of geophysical methods is also feasible in the environmental monitoring of CO_2 sites. The newly created methodology and the methods included will be tested on natural analogues of geological storage of CO_2, namely natural emission sites (analogue for CO_2 leaks) and natural CO_2 reservoirs. We also want to understand the underlying mechanisms of CO_2 leaks by making a comparative analysis between the geological and structural models of sites where CO_2 comes to the surface and those where CO_2 remains inside the reservoir, an essential analysis for the planning of the environmental monitoring and detection of the potential leaks.

For 2024, two phases were implemented, the first phase having the deadline 6.06.2024 and the second phase ending on 13.11.2024.

Phase 3, entitled **Selection and characterization of the test sites for the monitoring methodology**, had as main objective selection and preliminary characterization of the test sites for the preliminary environmental monitoring methodology for CO_2 geological storage.

This objective was fully achieved through the implementation of the following activities:

- Selection of test sites - analogues for geological storage
- Geological characterization of the selected sites
- Field reconnaissance campaign

The most important result of this phase was the final selection of test sites and the validation of the environmental monitoring methodology.

As a natural analogue for CO_2 leakage into the environment, we selected the Lăzărești site (Harghita County). Among all the others investigated and previously analysed, this site has a good location, features good infrastructure elements, especially access (paved roads), and also presents an area with lower emissions south of the touristically exploited mofetic alignment. Specifically, this area with lower emissions presents a good degree of analogy with a potential CO_2 leakage from an anthropogenic reservoir. Another factor that led to the selection of this site was the support provided by the Cozmeni town hall, which is extremely important for the realization of future campaigns.

As a natural analogue for storage integrity, we chose the Bodoc site (Covasna County), corresponding to the Talomir-Bodoc carbonated mineral water deposit, as a test site. From the analysis of the inventoried data, the CO_2 in the aquifer of the deposit is naturally retained in the reservoir. It can be considered a good analogue with a saline aquifer where CO_2 is injected and stored. The selection criteria, besides the degree of analogy with a saline aquifer, included the presence of infrastructure elements (access to the site via paved roads), the relatively shallow depth of the aquifer

(suitable for implementing non-invasive investigation methods), and also the support of local authorities.

Following the selection of the test sites, the analysis of available data, and the geological elements identified in the field campaign from the previous phase, we conducted a geological characterization for each area in this phase. This characterization was also based on a field reconnaissance campaign implemented from May 8-12, 2024, during which the main geological features, logistics, and infrastructure elements were identified. Additionally, a preliminary geochemical and geophysical characterization was carried out during the same campaign to prepare for future campaigns in the fall and spring of 2025. The data acquisition plans from the campaign are presented in Figure 1.

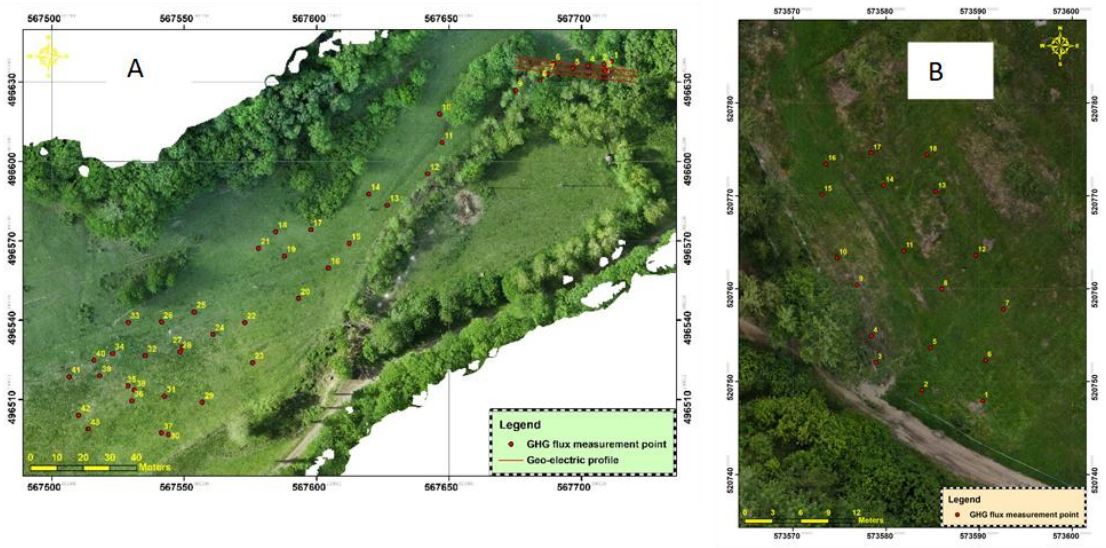

Figure 1. Plans showing the location of points and profiles measured within the field campaign at A. Bodoc. B. Lăzărești

Within the Bodoc perimeter, greenhouse gas flux measurements, three electrometry profiles, and aerial photogrammetry were conducted. Additionally, the modular seismic system SmartSolo, acquired in 2023 as part of the project, was put into operation in this perimeter. The final result of the aerial photogrammetric measurements was a digital terrain model.

Within the Lăzărești perimeter, only greenhouse gas flux measurements were conducted in the southern part of the site, where recent terracing has been done.

Following the field campaigns, two GIS projects were developed, one for each studied area, both created using ArcGIS software. These GIS projects contain all specific elements, namely: the coordinate grid, the project's graphical scale, orientation, and legend. Additionally, the topographic base on which the information from the thematic maps was rendered is an orthorectified image resulting from the processing of photogrammetric data.

As dissemination activities in this phase, the project's results were presented at a prestigious conference in the field of CO_2 storage, namely the CO_2GeoNet Open Forum, 17th edition, as well as at the AGROLIFE 2024 conference. Additionally, in this phase of the project, an abstract was submitted

and accepted for the GHGT 17 conference (17th International Conference on Greenhouse Gas Control Technologies).

Phase 4, titled **"Implementation of the Monitoring Methodology in Test Sites (Fall Campaign)"**, had the main objective of applying, testing, and validating the preliminary environmental monitoring methodology newly developed in the project on the selected test sites through the acquisition campaign of geophysical, geochemical, and biological data in the fall season.

This objective was fully achieved through the implementation of the following activities:

- Data acquisition planning
- Data acquisition campaign in selected areas
- Interpretation of acquired data

To test the preliminary monitoring methodology at the test sites selected in the previous phase, taking into account existing geological information and previously developed GIS projects, we developed data acquisition plans for the included methods. For the geophysical data acquisition plans, we conducted preliminary modelling, considering possible anomalous sources for the two areas.

To test the methodology, we designed and implemented two field data acquisition campaigns: one for geochemical and biological data acquisition from September 3-8, 2024, and one for geophysical data acquisition from October 3-8, 2024.

At the Bodoc site, measurements included flux, soil-gas surveys, vegetation surveys, sample collection, electrical measurements, GPR (Ground Penetrating Radar), and seismic surveys.

At the Lăzărești site, measurements included gas flux, soil-gas surveys, sample collection, vegetation surveys, GPR, seismic surveys, and aerial photogrammetry.

The gas flux measurements highlighted significant natural emissions at the Lăzărești site and very low emissions, likely related to biological activity, at the Bodoc site. This once again confirms the analogy of natural sites with a storage site where CO_2 leaks (Lăzărești) and a storage site where CO_2 is securely stored in the reservoir (Bodoc). The CO_2 flux variation maps are presented in Figure 2.

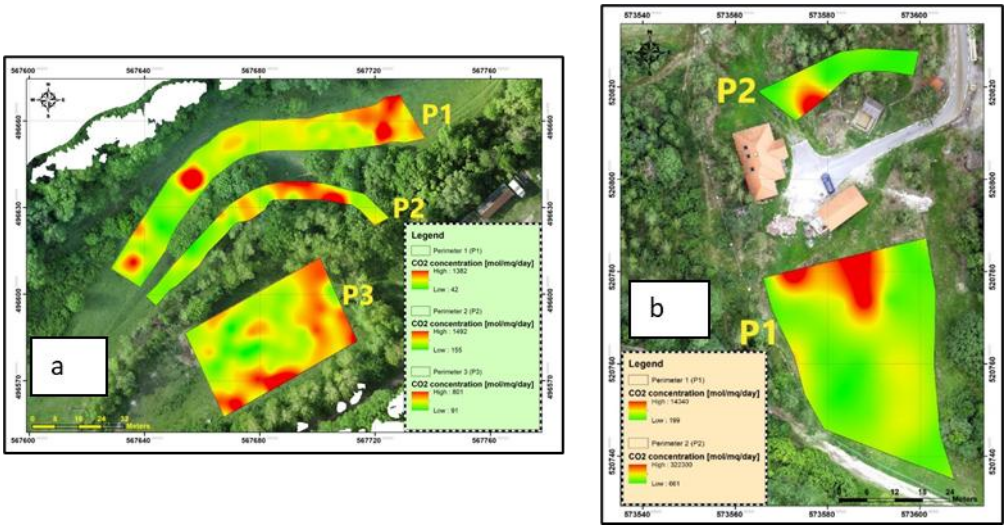

Figure 2. Maps showing the variation of CO_2 flux within a. Bodoc site. b. Lăzărești

Regarding the vegetation surveys, they did not reveal the presence of indicator species for increased CO_2 concentrations and fluxes during the fall season. Additionally, we are still unable to make a clear correlation between the variation in gas fluxes and the type and condition of the present vegetation.

The interpretation of geophysical data highlighted potential CO_2 migration pathways to the surface at the Lăzărești site, as well as the alternation of layers at the Bodoc site. The geophysical anomalies identified will need to be confirmed in the summer season to observe the influence of the hydrological regime, especially for electrometric and GPR measurements.

In addition to testing the monitoring methodology during the fall measurement campaign, we also conducted dissemination activities in this phase. Thus, the project's results were disseminated at the most important conference in the field of carbon capture and storage, namely the Greenhouse Gas Control Technology Conference (GHGT-17), held in Calgary, Canada. Furthermore, an article in MDPI is in the process of being published.

Additionally, as planned earlier, we managed to organize a second workshop with the project's end users, gathering representatives from the industry and relevant authorities. The ideas discussed during the workshop are extremely important for the continuation of the project and the finalization of the environmental methodology. We will maintain contact with the end users throughout the next year, with consultations taking place during individual consultation sessions.