SOIL CO_2 EMISSION MONITORING

Summary

Soil processes are often invisible, making it difficult for farmers to assess whether sustainable practices are improving soil health. Within the trans4num project, soil CO_2 emission monitoring was tested as a practical tool to evaluate the impact of Nature-based Solutions (NBS) on soil biological activity, nutrient cycling, and carbon efficiency. By combining CO_2 measurements with soil, plant, and drone monitoring, farmers can make more informed decisions and better understand how their management practices influence long-term soil resilience.

The need

Many soil degradation processes remain unnoticed until crop performance has already declined. Declining biological activity, poor soil structure, reduced water retention, and inefficient nutrient cycling often develop gradually and are difficult to detect with visual observations alone. Farmers need practical monitoring tools that provide early information on soil functioning and help them evaluate whether Nature-based Solutions are delivering environmental benefits.

In the Szigetköz region of Hungary, these challenges are particularly relevant because agricultural production is exposed to changing groundwater conditions, drought risks, and strong natural soil variability.

The benefits

Soil CO_2 monitoring provides several practical benefits:

- Makes below-ground biological activity visible and easier to understand
- Helps assess whether NBS improve soil functioning
- Supports more precise nutrient management decisions
- Links climate mitigation objectives with everyday farm management
- Helps farmers identify spatial and temporal variability within fields
- Strengthens advisory services, demonstration activities, and farmer learning
- Supports long-term monitoring of regenerative agricultural practices

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trans4num solution

The trans4num project integrated soil CO_2 emission monitoring into a broader Nature-based farming system tested in Kimle, Hungary. The trial compared NBS with conventional intensive farming across a three-year rotation of durum wheat, sorghum, and soybean.

The Nature-based system combined: crop rotation, no-tillage farming, reduced herbicide and pesticide use, poultry manure pellets as bio-based fertiliser, biostimulants, winter cover crops and continuous crop and soil monitoring

CO_2 emissions were measured using a portable instrument and a closed-chamber method, alongside soil sampling, plant nutrient analysis, soil profile observations, drone monitoring, satellite imagery. The measurements were interpreted together, as a single CO_2 value cannot determine whether a system is improving or losing carbon.

Across all three crops, Nature-based systems consistently produced equal or lower CO_2 emissions per unit of harvested yield than conventional systems.

Key findings include:

- Lower CO_2 emissions were observed under Nature-based management for soybean, sorghum, and durum wheat
- Significant reductions were recorded for sorghum and durum wheat
- Nature-based systems improved carbon efficiency while maintaining comparable yields
- The results demonstrate the climate mitigation potential of Nature-based agriculture

The project also found that soil biological improvements become visible gradually. Positive trends were observed in:

- Organic carbon
- Organic matter
- Nitrogen cycling
- Soil biological activity

The strongest effects occurred in the top 0–30 cm soil layer.

What were the challenges / limitations in the implementation process?

- Soil CO_2 emissions vary greatly throughout the season
- Results are strongly influenced by temperature, moisture, and recent field operations
- Natural field heterogeneity can sometimes mask treatment effects
- A single measurement cannot provide reliable conclusions
- Long-term monitoring is needed because soil changes occur slowly

What kind of resources do you need to implement the proposed solution?

- **Equipment**: portable CO_2 sensors, closed-chamber measurement systems, soil moisture and temperature measurements, drone and satellite monitoring tools
- **Knowledge and advisory support**: farmer training on interpreting CO_2 measurements, advisory services combining multiple monitoring tools, data-driven nutrient management approaches
- **Long-term monitoring**: repeated measurements throughout the season, consistent protocols, multi-year datasets to identify trends

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More information

Practical recommendations:

- Measure several times during the growing season.
- Record soil moisture, temperature, crop stage, and recent field operations.
- Compare treatments under similar weather conditions.
- Use CO_2 measurements together with soil, plant, and remote sensing data rather than as a stand-alone indicator.

Soil CO_2 monitoring transforms invisible soil processes into measurable information, helping farmers understand whether Nature-based Solutions are improving soil health, increasing resilience, and reducing agriculture's climate footprint.

Find out more about the trans4num Hungarian NBS site: https://trans4num.eu/en/sites/eu/hungary/

Explore more Practice Abstracts: https://trans4num.eu/library/?type=ABS






Learn more about the project at https://trans4num.eu/en/

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