Kmetijski inštitut Slovenije

European Climate Initiative EUKI

EUKI seminar

Enhancing Soil Health and Carbon Sequestration with Cover Crops: Principles and Practice

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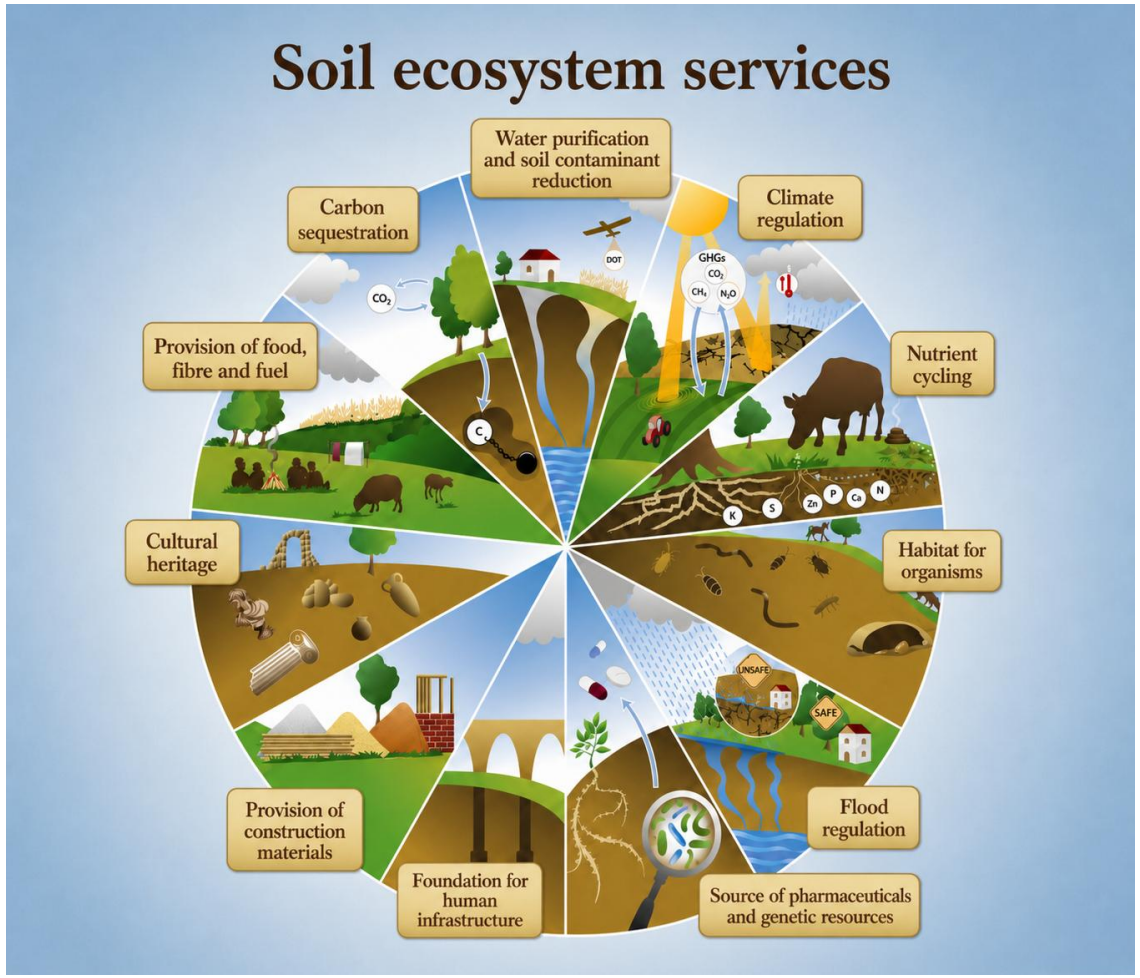
Soils under pressure: Essential services and global degradation



Adapted from: http://www.fao.org/resources/infographics/infographics-details/en/c/284478/).

- **Around one-third of the world's soils are already degraded.**
- **If current practices continue, most soils could be at risk by 2050 (FAO, 2015).**

Source: FAO & ITPS (2015). *Status of the World's Soil Resources (SWSR) – Main Report*. Rome: Food and Agriculture Organization of the United Nations.

Main causes of soil degradation

Simplified and intensive farming practices can reduce soil biodiversity, organic matter content and soil structure, thereby weakening the natural capacity of soils to support food production.

Photo: Tomaž Poje, Robert Leskovšek, 2025

What exactly are cover crops?

Cover Crop

German: Zwischenfrucht

French: cultures de couverture

Spanish/Portugese: cultivos de cobertura/culturas de cobertura

- A crop that is generally not intended for harvest, but is grown to improve soil quality and fertility, prevent soil erosion, nutrient losses and weed growth, reduce pests, and maintain biodiversity
- They are usually planted between main crops, after harvest, or during periods when the soil would otherwise remain bare.

Cover cropping is an old practice

- In traditional agricultural systems, cover crops were widely used before the broad adoption of synthetic fertilisers, heavy machinery and pesticides.

- Cover cropping appeared in many forms that supported soil health and productivity.

Graphic generated with assistance from ChatGPT/OpenAI; scientific content reviewed and edited by the author.

Why use cover crops?

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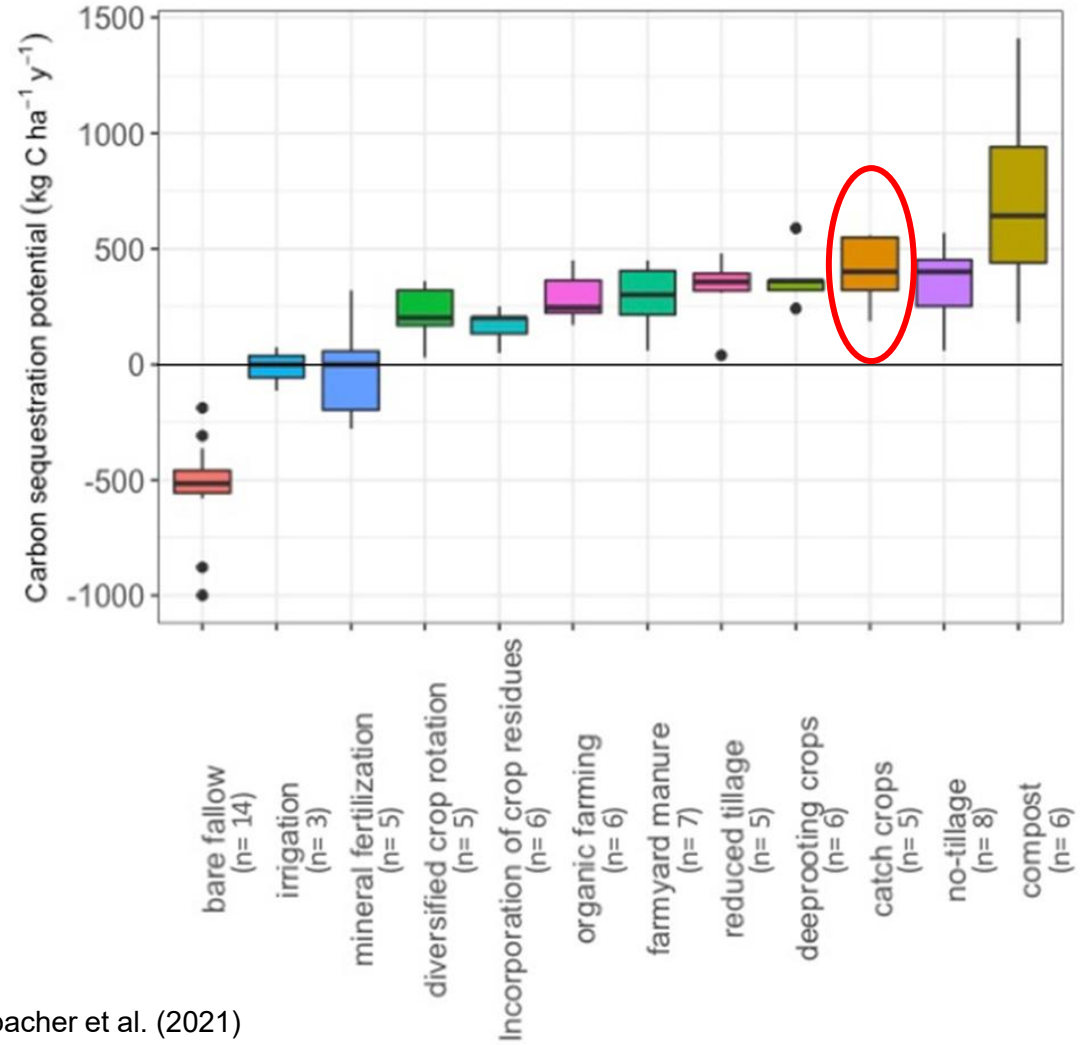
Why use cover crops for carbon sequestration?



Tiefenbacher et al. (2021)

Besides contributing to carbon sequestration, cover cropping is also:

- cost-effective
- feasible in many farming systems

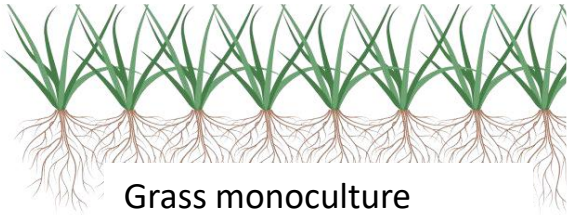
How do cover crops fit into the rotation?



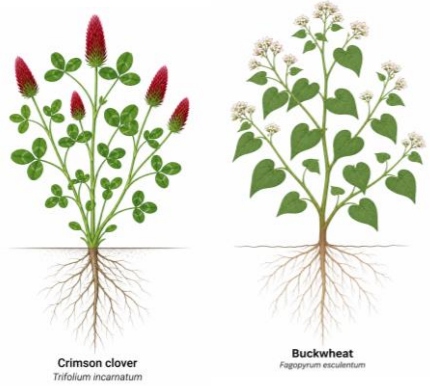



October — Winter cereal — June - July — May — Maize

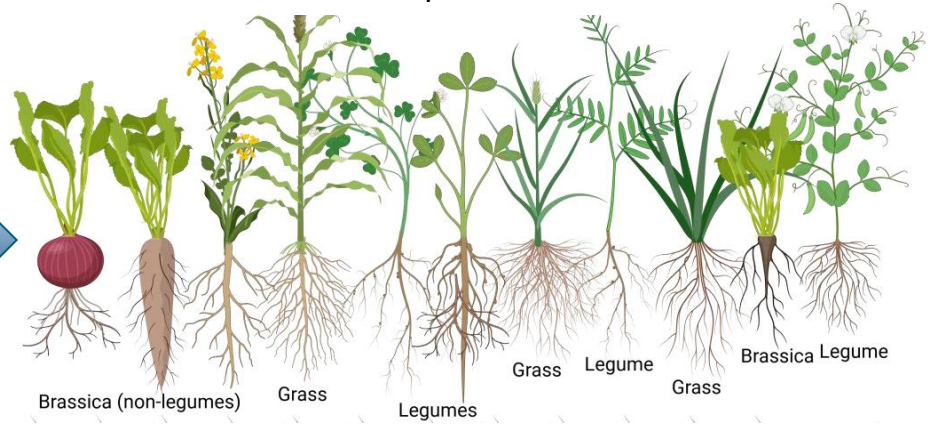
Common simple 2-year rotation cereal-maize


Grass monoculture

Diversification



Cover crop mixture



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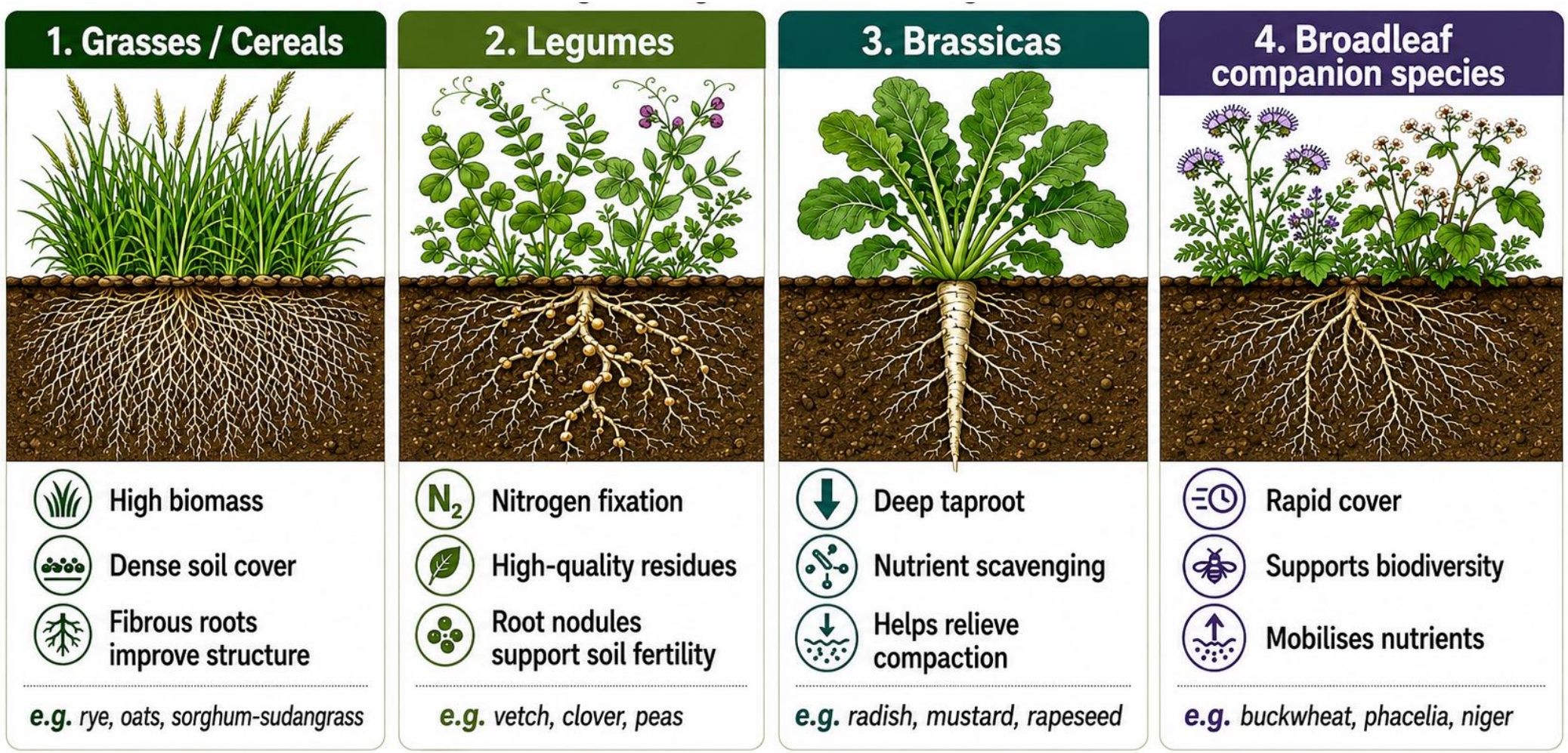
Main functional groups of cover crops



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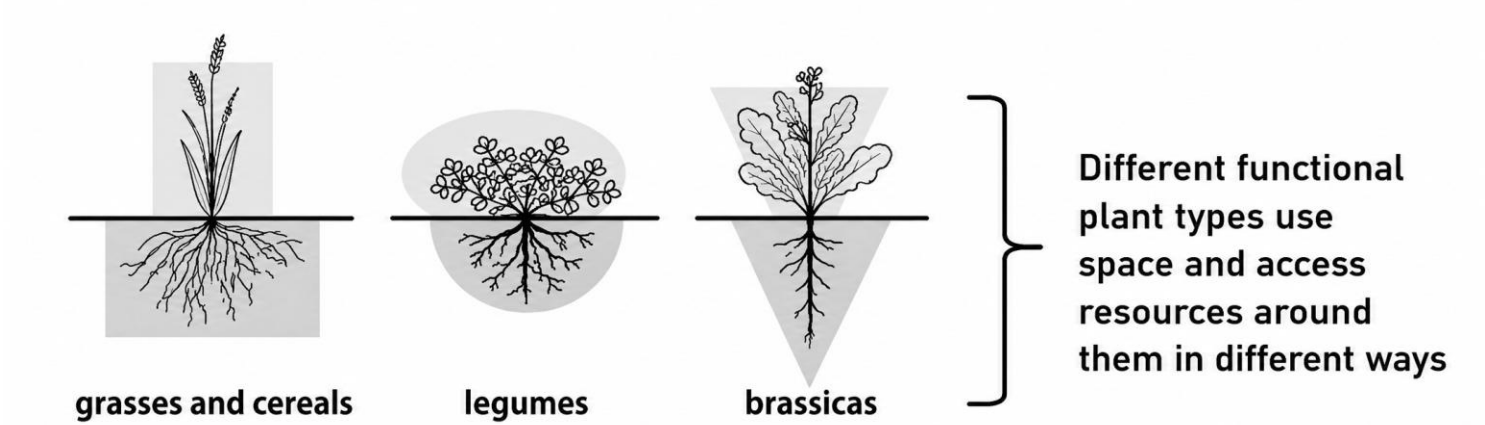
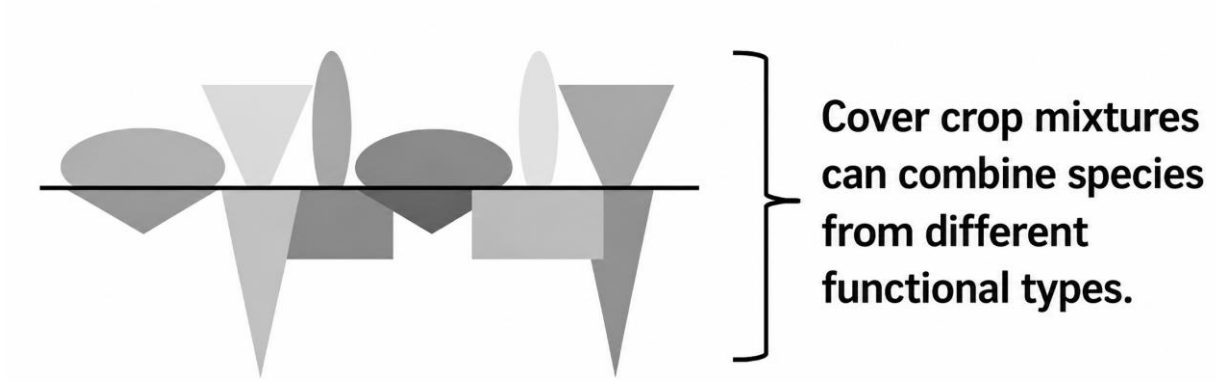
Cover crop mixtures





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Soil Organic Carbon (SOC) — A key indicator of soil fertility

Soil organic carbon (SOC) is the carbon component of soil organic matter. It plays a central role in soil health and fertility.

SOC improves **soil structure**, supports **nutrient cycling**, increases **water retention** and stimulates **biological activity**, making soils **more fertile, resilient and productive**.

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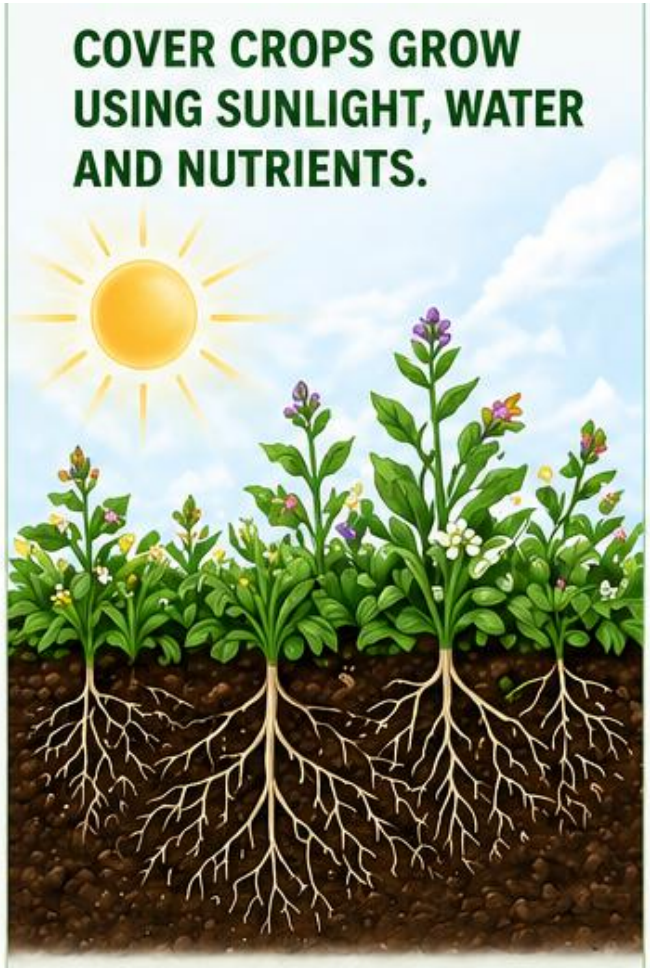
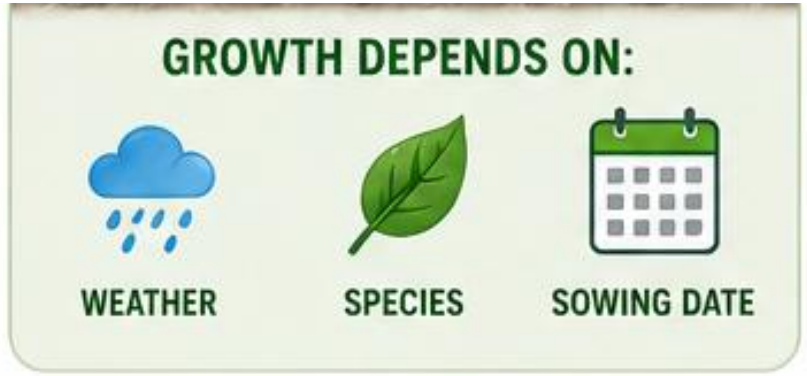
Carbon is stored in plant biomass

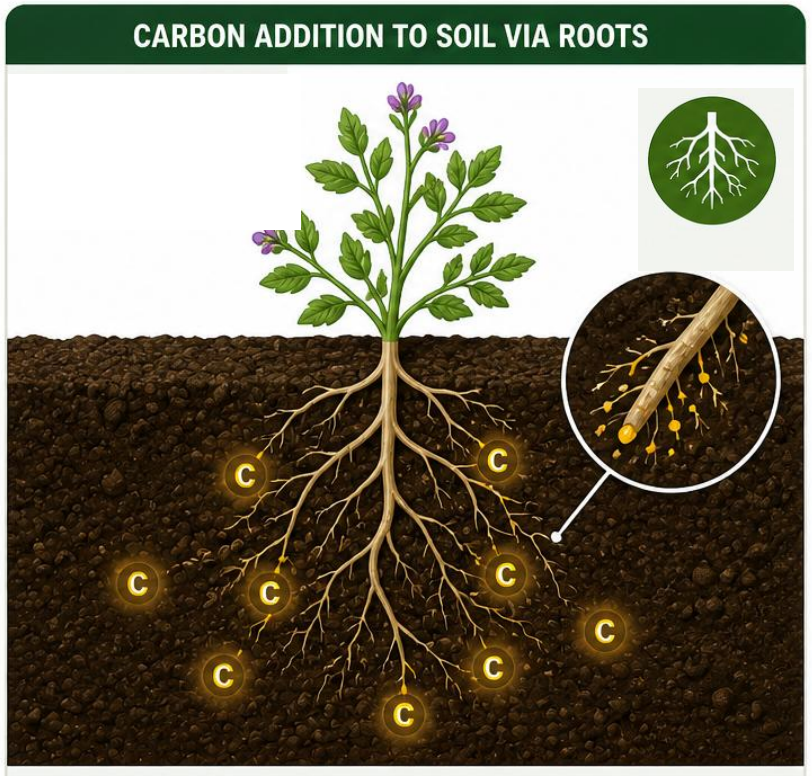




- Cover crops can produce 2–10 t of aboveground dry matter per hectare within 3–4 months.
- Total carbon content is approximately 30–40%.
- This corresponds to about 0.6–3 t C ha^{-1} temporarily stored in plant biomass

Graphic generated with assistance from ChatGPT/OpenAI; scientific content reviewed and edited by the author.

Cover crop roots release carbon into the soil



- Roots release carbon-rich exudates (sugars, amino acids) into the soil through rhizodeposition.
- Rhizodeposition represents 10-25 % of the total cover crop carbon input (Hansen et al., 2025).
- These carbon compounds feed soil microbes directly and can contribute to the formation of soil organic matter.

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Cover crop aboveground biomass is terminated

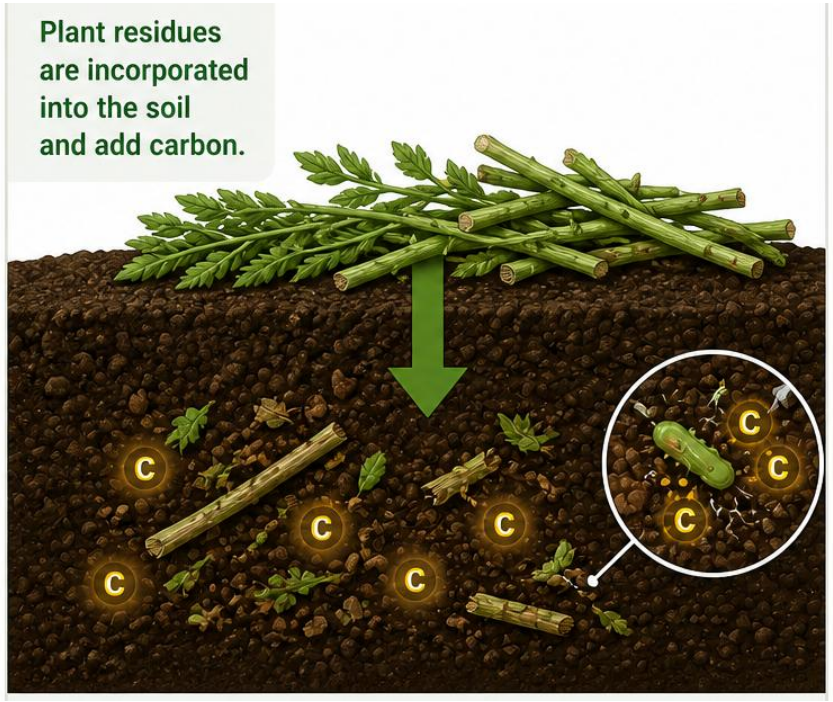



Photo: R. Leskovšek, 2020

- Aboveground biomass is left on the soil surface or incorporated into the soil.
- Plant residues decompose over time.

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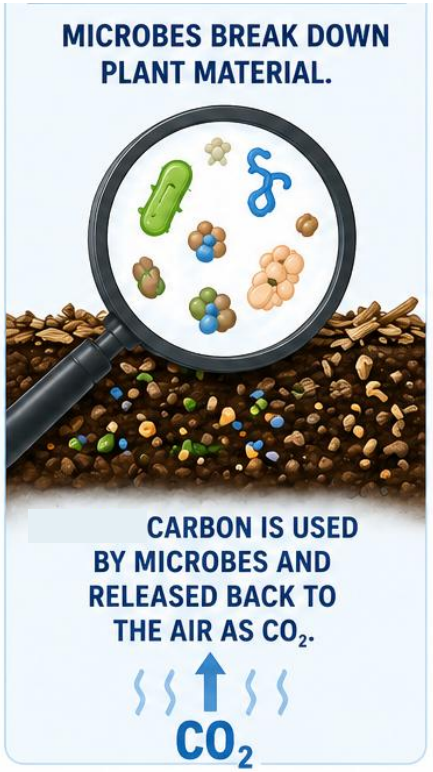
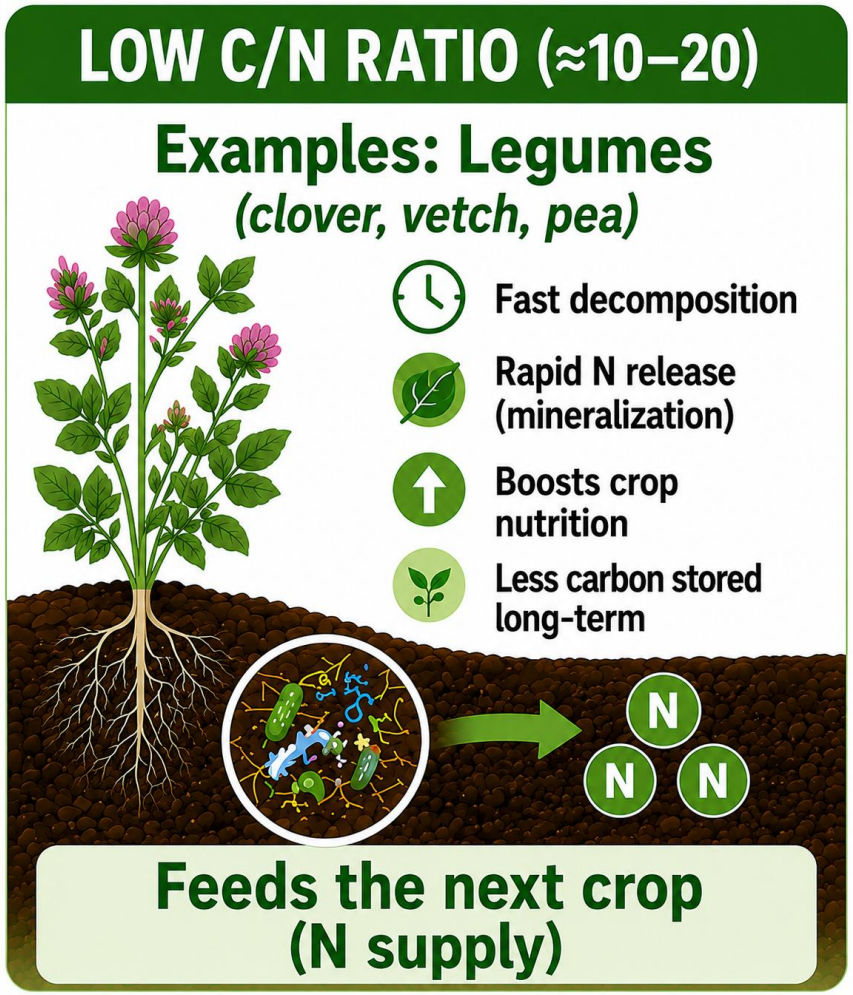
Low C/N residues decompose rapidly





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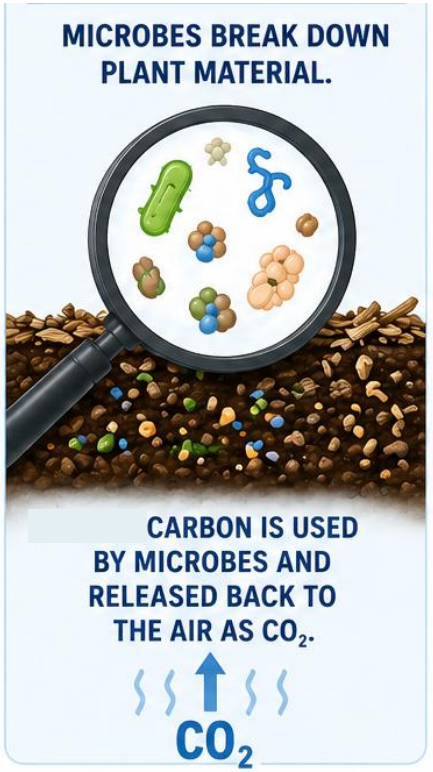
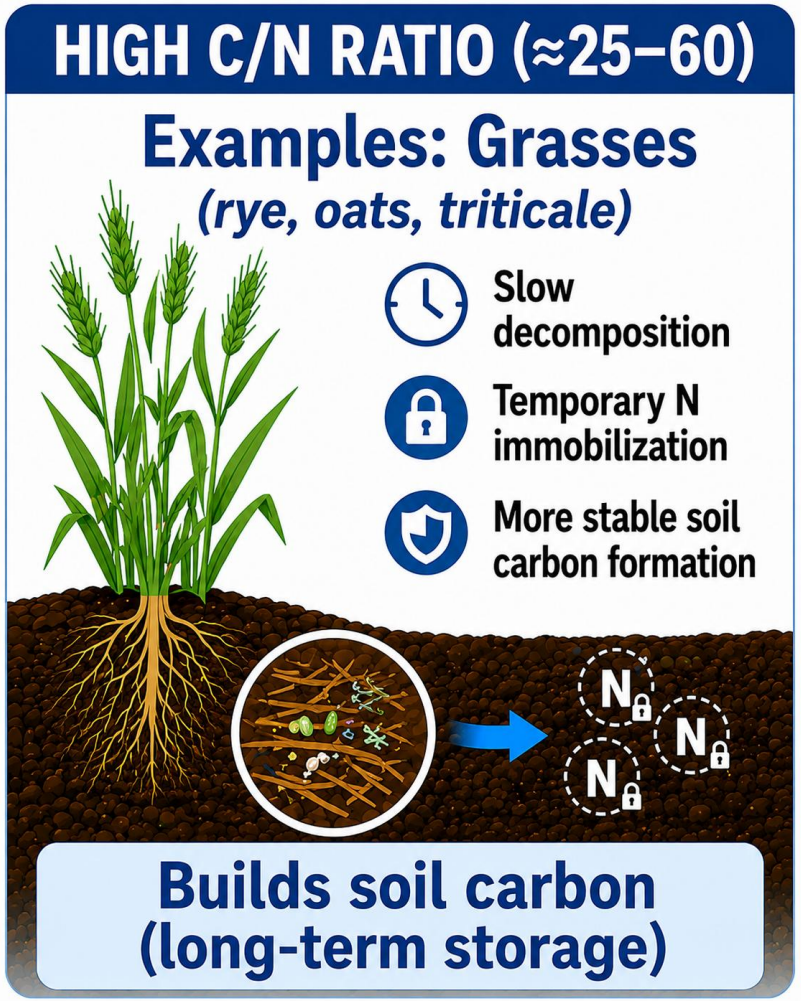
High C/N residues decompose more slowly





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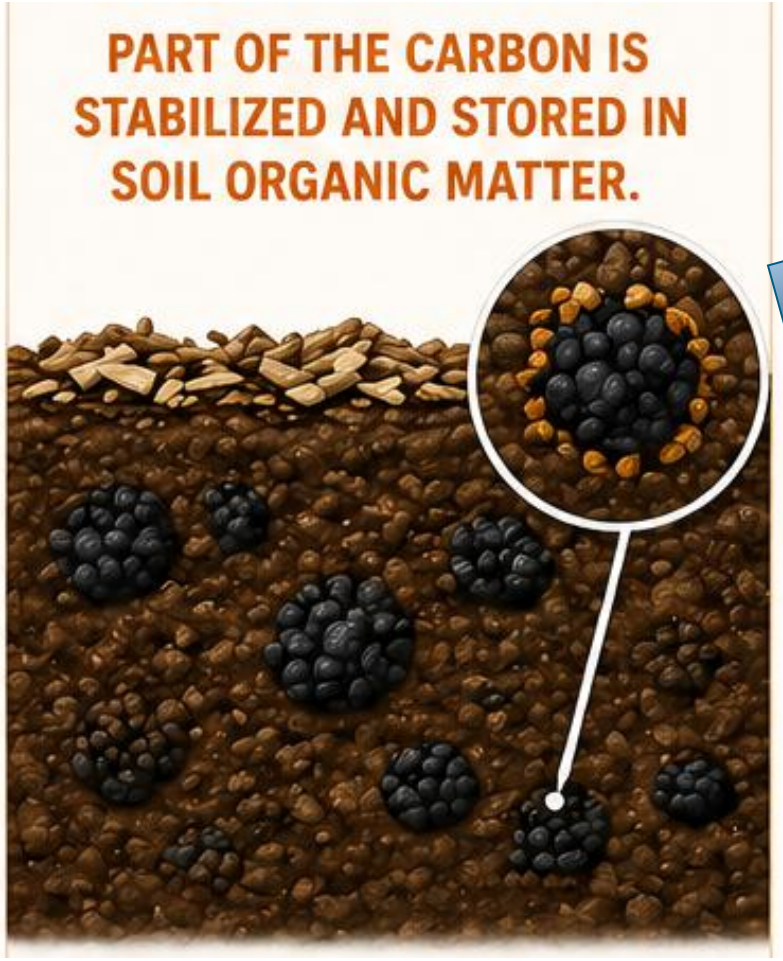
Soil carbon storage is a slow process



ONLY ABOUT **10–20%** OF THE CARBON INPUT BECOMES STABLE SOIL CARBON.

80–85% of carbon is lost as:

- microbial respiration
- CO_2 (mineralization)

Graphic generated with assistance from ChatGPT/OpenAI; scientific content reviewed and edited by the author.

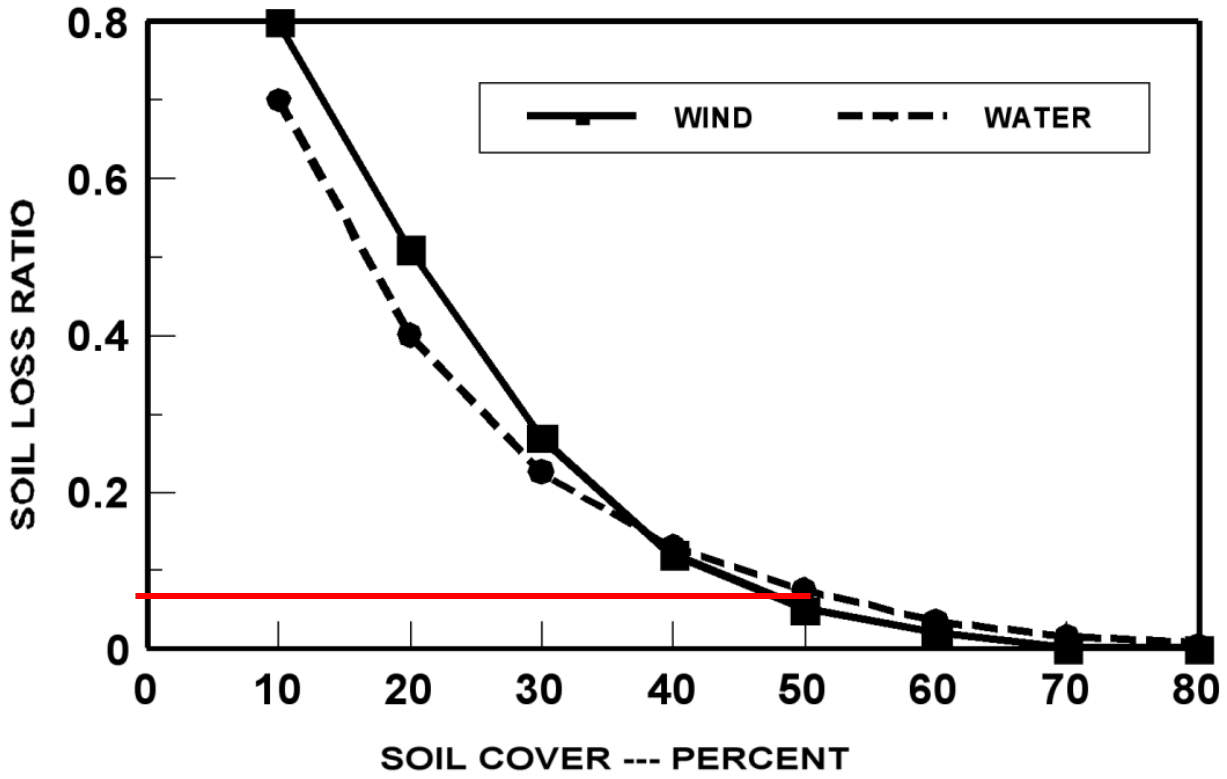
Indirect effects of cover crops on carbon sequestration

Prevention of water and wind erosion

Source and photo: Lešnik, 2022

Source and photo: Kisić, 2022

Cover crops provide soil cover and reduce soil loss



- Compared with bare soil, 50% soil cover may reduce soil losses by up to tenfold

50% plant cover is usually reached 3–4 weeks after sowing.

Soil cover → Reduced **temperature fluctuations** → slower decomposition

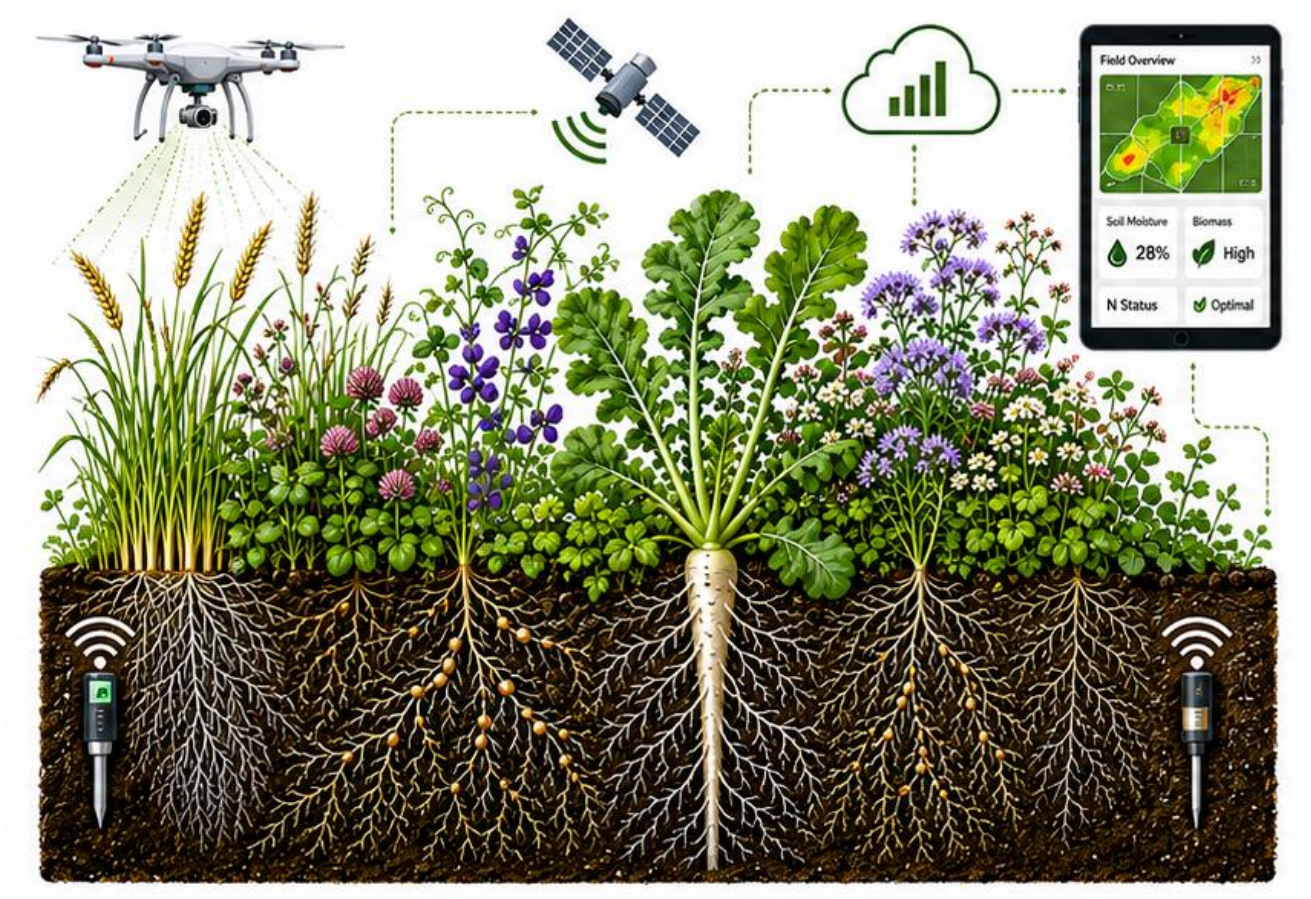
Source: Papendick et al., 1977

Photo: R. Leskovšek, 2023

Take Home messages

- Healthy soils need living roots and continuous cover.
- Cover crops offer a practical, feasible and multifunctional solution.
- Their greatest potential lies in well-designed mixtures of functional groups.
- The strongest benefits develop over time, through repeated use and good integration into crop rotations.
- In future farming systems, cover crops should become a standard practice for soil protection and resilience.

What is future of cover cropping?



1. **Precision mixture design**
   tailored species mixes for specific goals
2. **Smart establishment**
   drones, robotics and improved seeding
3. **Real-time monitoring**
   soil sensors, remote sensing and field diagnostics
4. **Decision support & AI**
   better timing, management and adaptation
5. **A standard practice in digital climate-smart farming**
   integrated with data-driven farm management

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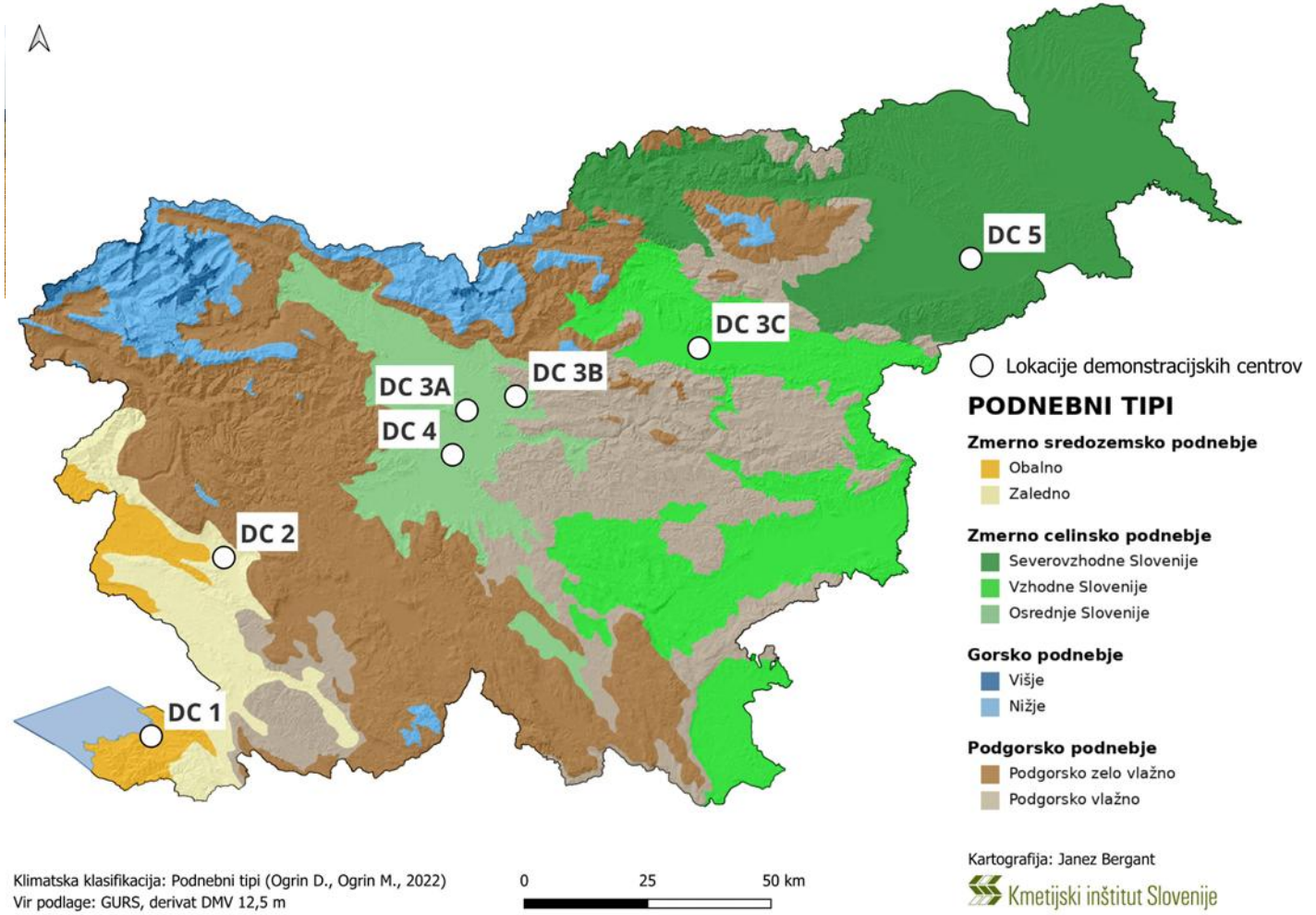
LIFE4ADAPT project

Aim:

To demonstrate agricultural adaptation strategies to climate change, including reduced tillage, precision irrigation, **cover crops** and other practices.

Cover cropping activities:

- Improving soil cover
- Optimising cover crop mixtures with legumes
- Improving methods of cover crop establishment, such as undersowing and drone seeding



Project LIFE4ADAPT (101147797 — LIFE23-IPC-SI-LIFE4ADAPT) is funded by the European LIFE programme, the Climate Change Fund, and the project partners.

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