FCC-OPEN SKY LABORATORY

Towards a sustainable and local use of excavation materials

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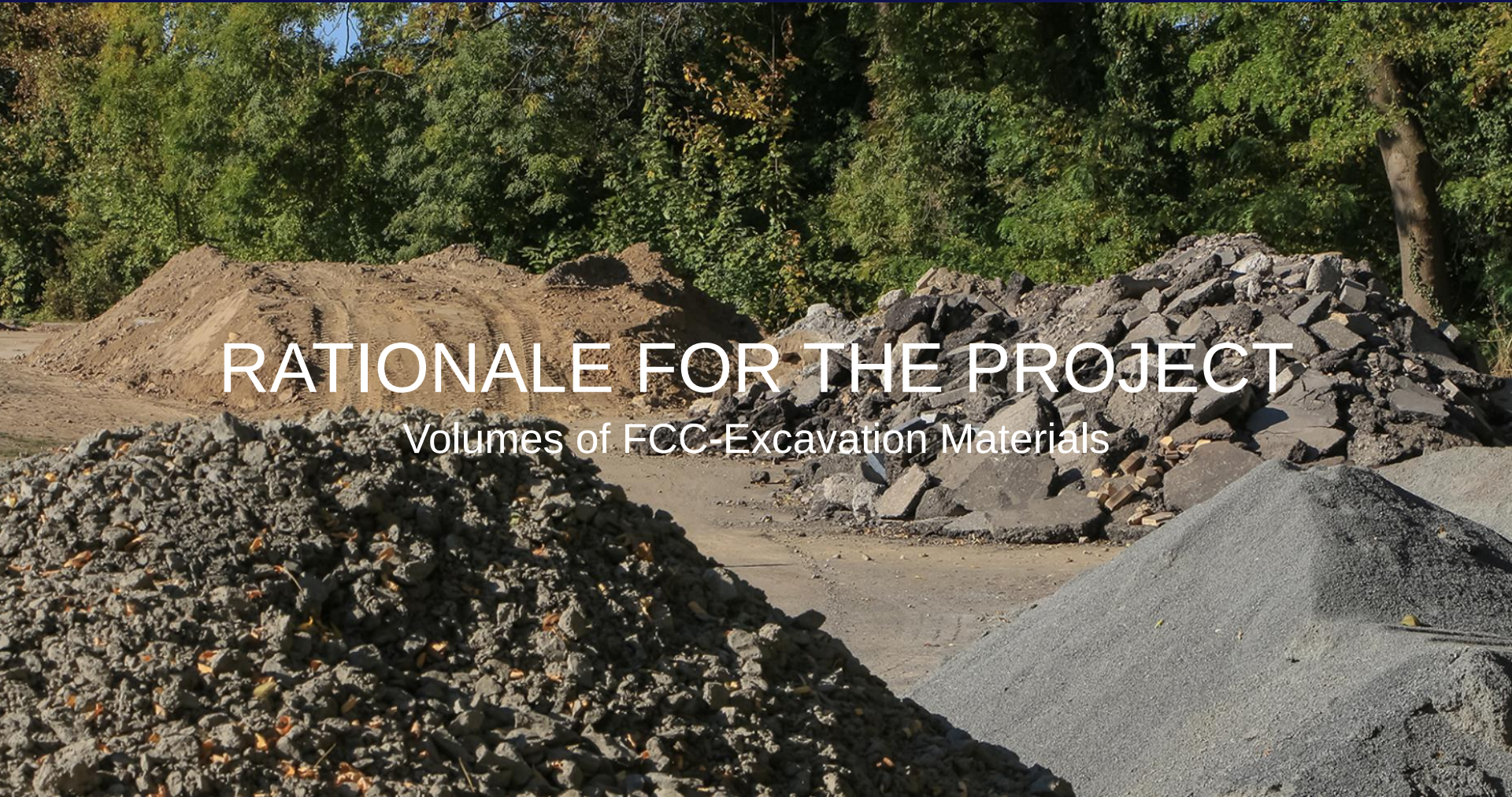


RATIONALE FOR THE PROJECT

Volumes of FCC-Excavation Materials

Amounts of excavated materials

	Vol. total (m^3) after excavation	Weight total (t)	Moraines (t)	Limestone (t)	**Molasse (t)**
Total	**8,180,819**	16,361,637	467,501	367,055	**15,527,081**
France	6,871,888	13,743,775	440,270	367,055	**12,936,450**
Switzerland	1,308,931	2,617,862	27,231	-	**2,590,631**

Preliminary possible distribution among France and Switzerland, based on vertical projection of border[1]. Established re-uses: see presentation by Leslie Alix.

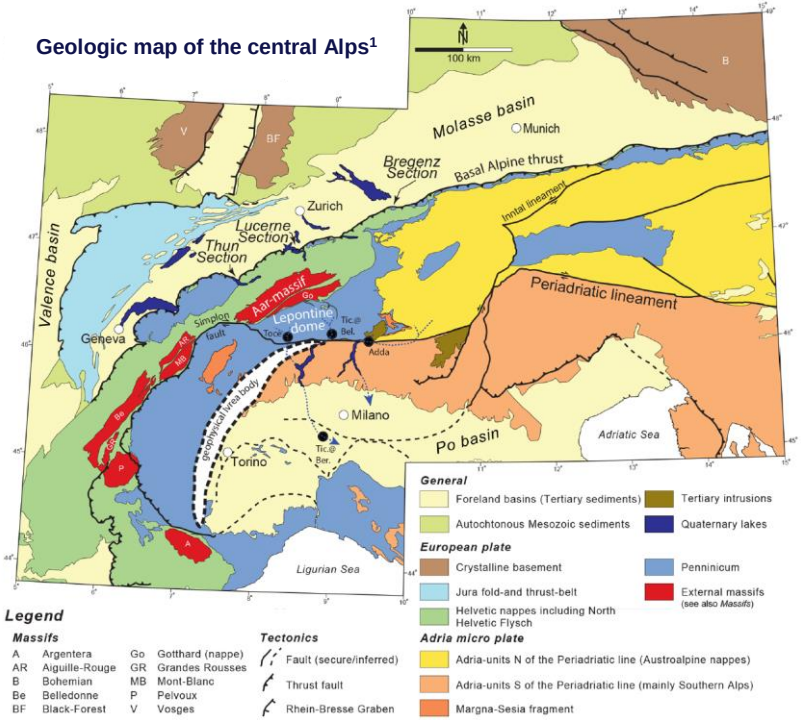
Molasse Rouge lithotypes along tunnel alignment[2]

To the best of our knowledge, there is no established industrial reuse pathway of molasse.

[1] April 2024, [2] Haas & Moscariello 2022

The molasse basin extends over ~1000 km

Geologic map of the central Alps[1]



[1] Afinson et *al*., 2020

Molasse general composition:
Mainly marls, sandstone, silt, gompholite

- 36 - 48 % clay (< 2 µm)
- 10 - 15 % limestone (2 µm - 63 µm)
- 10 - 15 % sand (63 µm - 4 mm)
- 15 - 20 % sandstone particles (> 4 mm)

If molasse reuse pathways are established, they can be useful for society in the framework of circular economy principles.

REUSE PATHWAYS FOR MOLASSE EXCAVATION MATERIALS

Innovative ideas for the reuse of excavated molasse from FCC

- **International competition Mining the Future launched in 2022 with the support of the EU Horizon 2020 grant agreement 951754**
- **Purpose: Find innovative solutions for the excavated materials (molasse) reuse. « From waste to opportunity »**
- **4 finalists, selected by an international panel of experts,** targeted at the
  - reuse for construction components (bricks, concrete)
  - separation of materials in view of increasing the re-use potential
  - reuse via soil engineering for agriculture, renaturation and forestry

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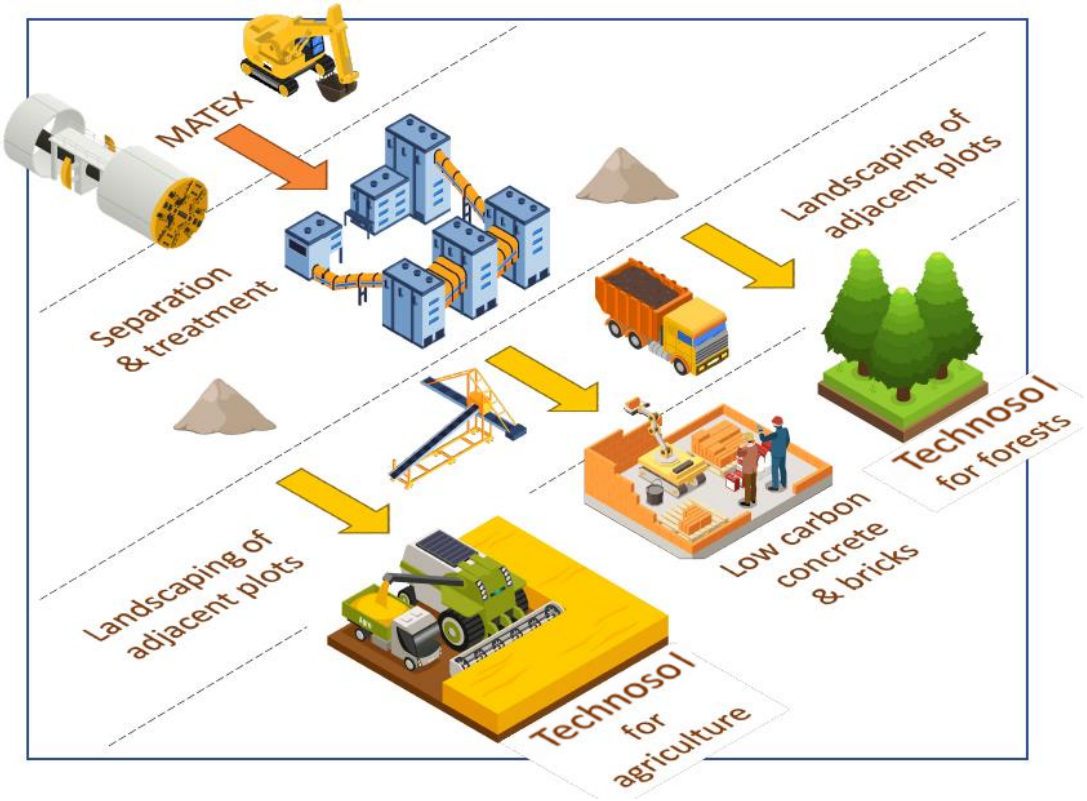
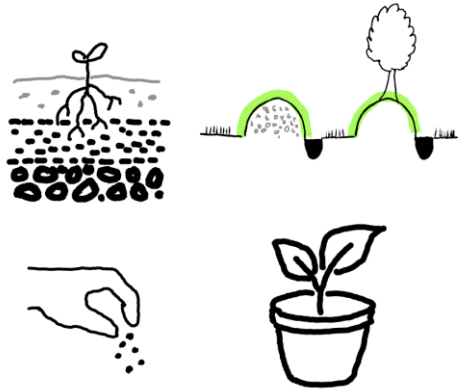
Innovative local approach for materials management



Reuse as constructed soil, substrate or amendment



Why the focus on constructed soils?

- Agriculture and forestry are promising use cases for transformed molasse materials
- Functional soils contribute to CO_2 capture and human health[1,2]

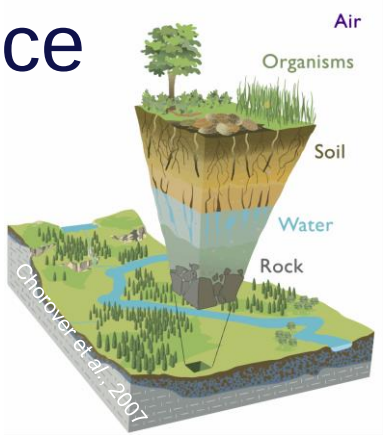
[1] Amundson et *al.*, 2021, [2] Banerjee et *al.*, 2023

Soil is a threatened resource

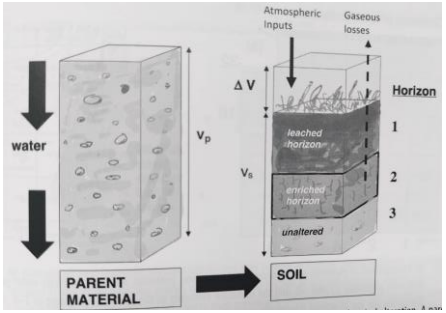
Soil is the planetary surface layer extending from unaltered bedrock to the vegetation canopy and is under intense pressure from human demands for biomass, water and food resources. Soil functions sustain life on Earth.

- Erosion[2]:
  - 100-fold acceleration over natural rates in conventional tillage agriculture (20-30 Gt y^{-1})
  - Median depth of soil loss: 1 mm y^{-1}
  - Geological rate of soil formation: 0.01 mm y^{-1}
- Contamination[3]:
  - Pesticide pollution affects 52% of European arable land or 1.1 Mio km^2, heavy metal pollution 31%
- Soil organic carbon (SOC) depletion due to land use change, low SOC is associated with low fertility

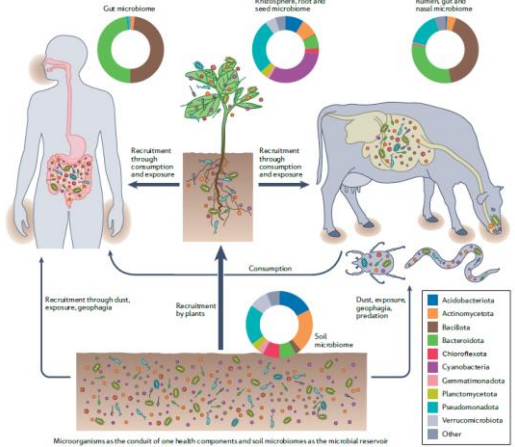
[1] Amundson et *al.*, 2021, [2] Banwart et *al.*, 2019, [3] Prăvălie et *al.*, 2024, [4] Banerjee et *al.*, 2023



Soil formation[1]



Soil, plant, animal and human microbiomes are linked[4]



EU aims at healthy soils by 2050

EU Soil Observatory supports implementation of

EU soil strategy 2030
Proposal of a Soil Monitoring and Resilience Law (first world-wide international legislation protecting soil health)

Farm2Fork Strategy
Reduction of pesticide use by 2030

Common Agricultural Policy (CAP)
Investment of 40 B € in sustainable management

European agricultural fund for rural development (EAFRD): financial support for farmers to protect and increase biodiversity enhancing landscape features on agricultural land[1]

- Maintain non-productive areas (min. 3% of agricultural land)
- Management and creation of new landscape features

[1] EC, 2023. CAP Strategic plans 2023-2027.

Potential molasse reuse scenarios

if agreements with materials offtakers are established, before the material is produced

Soil construction

Revegetation of industrial wasteland,

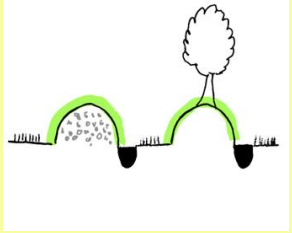
Replacement of polluted soils,

Park soils,

Creation of green surfaces on tunnels:

60 cm soil depth → 6 000 m^3 ha^{-1}

(Tree plantation pits: ~25 m^3 pit^{-1} for medium sized trees)



Soil construction for landscaping

Roadside vegetation: ~ 4000 m^3 km^{-1}

Noise protection: ~ 85 000 m^3 km^{-1}

Elevated hedgerows: min 2 000 m^3 km^{-1}

OpenSky Laboratory tests scenarios for which

> 100 000 m^3 of molasse may be reused
+
multi-year monitoring is required

Amendment

Liming material (for adjustment of soil pH): ~40 m^3 ha^{-1} every 3 years

Horticulture

Contribution to substrates for green roofs: ~ 0.2 m^3 m^{-2}

Contribution to substrates for horticulture (nurseries)

Regulatory framework

France

- *Ministry of Ecological Transition: Guide to valorization of excavated material from non- polluted sites and soils in development projects www.ecologie.gouv.fr*
- *Soils for agricultural production (topsoils) must comply with the conditions outlined in the French standard NF U44-551*
- French law considers excavation materials as waste if it leaves the excavation site

Article L. 541-1 of the **Environmental Code** requires that **all re-use cases are examined before sending the material to an authorized waste treatment or elimination facility.**

Switzerland

- *LPE (Environmental Protection Law, 01.01.2024)*
- *OSOL (Ord. on soil protection) (12.04.2016)*
- *OLED (Ord. On limitation and elimination of waste, 04.12.2015)*
- *ORRChim (Ord. on risk reduction from chemical substances 26.01.2017)*
  Annex 2.6, ch. 3.2.2. Restrictions on compost

GUIDELINE for the application of OSOL: « Requirements for making artificial topsoil from waste» . OFEV 1993

Art. 30d USG/LPE (Environmental Protection Law) empowers the Federal Council to prescribe re-use cases for classes of waste if they are economically viable and environmentally less impacting than disposal.
The re-use conditions remain to be agreed with a notified body in Switzerland.

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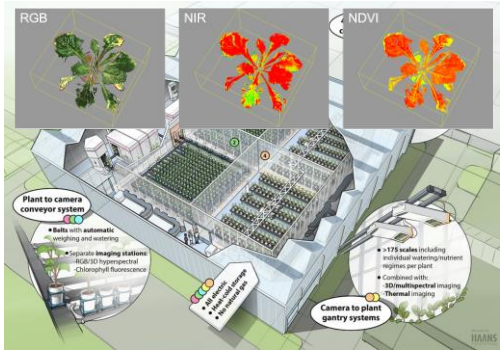
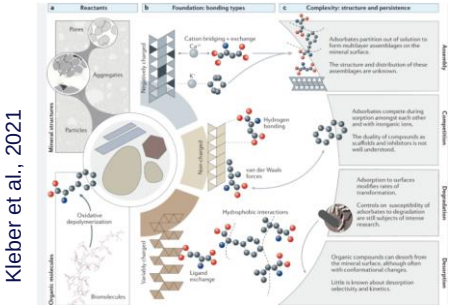
Soil engineering process

1) **Design phase -** After mineralogical, physical, biological and chemical assessment of raw materials:

Germination tests	Complexation experiments	Mixing method tests
> identify mixture optimal for germination of pioneer plants	> predict mineral-organic matter interactions in the field	> define optimum large-scale protocol



Parameters: plant biomass, stress indicators



Kleber et al., 2021

Parameters: mineral associated organic matter bond-strength, etc.

Parameters: dust formation, throughput, energy input

2) **Management phase –** choice of plant species, soil biota and management practices enhancing soil formation

Mixing

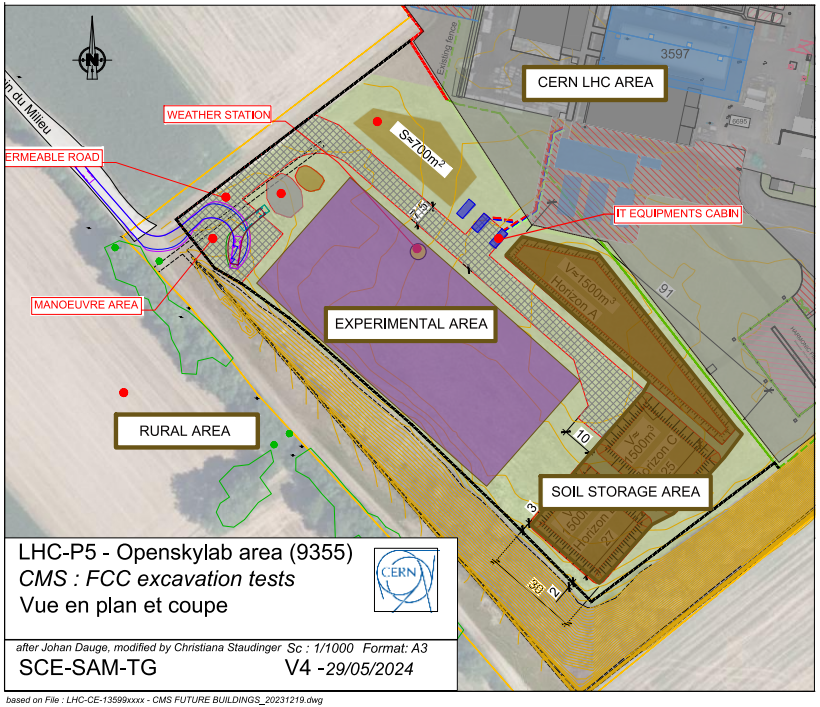
Homogenisation

Granulation

Settlement

Seeding

A collaboration of academia and industry



Experimental site at Cessy provided by CERN (1 ha, France, 2024-2028)

- Scientific monitoring of the process of soil construction and pedogenic processes during first 4 years → predict future outcomes
- Demonstration of soil construction from molasse for different use cases and plant species
- Tests of different mixing techniques and inoculation techniques

Monitoring system (OpenSky View)

- Online and offline meteorological, soil and plant data

A collaboration of academia and industry

hepia Haute école du paysage, d'ingénierie et d'architecture de Genève
Géosciences pour une Terre durable brgm
EDAPHOS
BOKU UNIVERSITY
micro humus Ingénierie des sols
MONTAN UNIVERSITÄT LEOBEN
BECC EST 2018
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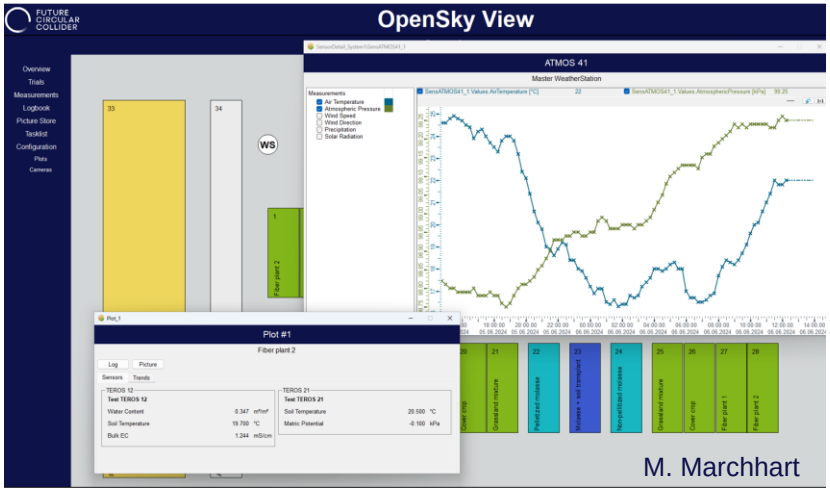
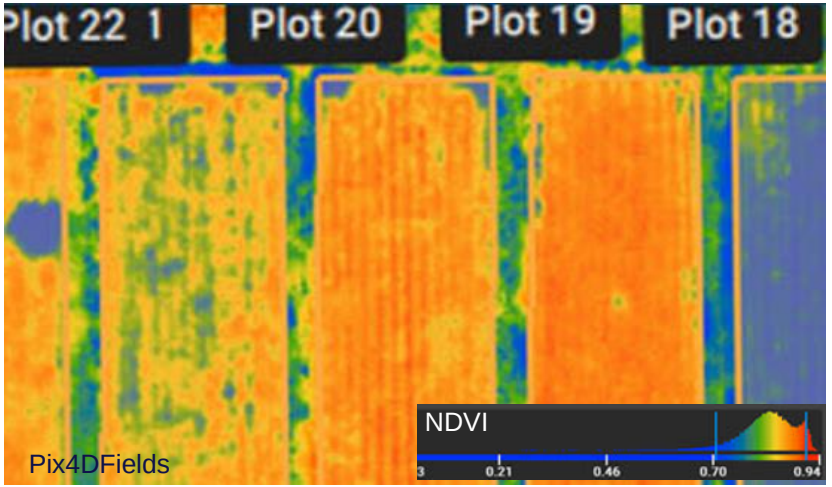
Monitoring system (OpenSky View)



Multispectral imaging of plant performance



Progress and status

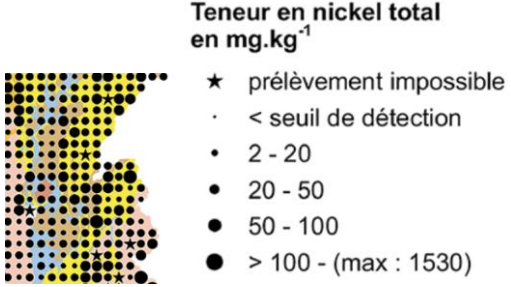


1) Experimental site available at CERN
2) Building permit requested
3) Molasse recovered from HL-LHC excavations
4) Laboratory tests on-going
5) Procurement of sensors on-going
6) Field preparation on-going
7) Fist preliminary field-scale results in June 2025

Challenges:
- Quantity and quality of compost to be added
- Natural Ni and Cr concentrations in molasse is highly heterogeneous and above 50 mg kg^{-1}

Field preparation	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
Civil Work								
Building permit instruction								
Work preparation and contract implementation								
Work (excavation, technical installation)								
Bungalows/container installation								
Open Sky Lab set up								
Molasse transport								
Amendment transport								
Molasse mixing and spreading in the test plot								
Monitoring system set up								
Sensor installation								

Ni and Cr are elevated in naturally grown soils in the “FCC-region”, see gissol.fr



Conclusions

The OpenSky Laboratory aims at:

(i) **demonstrating reuse pathways** for functional soil created from molasse minerals

(ii) **developing quality-assured pathways and products for soil construction** from heterogeneous molasse minerals (legal and regulatory prerequisite)

A reuse of molasse material as functionalised soil along roadsides, as support for elevated hedgerows, has potential to valorise important volumes and create beneficial outcomes for the region in terms of biodiversity, climate resilience, regional independence[1,2].

The creation of new terrestrial surfaces may contribute to C sequestration and could lead to further agronomic or forestry uses.

A successfully developed industrial-scale reuse pathway for molasse materials is of value for construction projects beyond the “FCC-region”.

Filling the gaps:

- More data on Ni and Cr concentrations in naturally grown soils of the “FCC-region”

- Define locations for local reuse pathways near surface sites (regional needs and expectations)
- Link between excavation methods/rates and reuse pathways has to be established
- Discuss adjustments to the regulatory framework for reuse for agricultural production

[1] Montgomery et *al.*, 2020, [2] OFB, 2023

Thank you for your attention!

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