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Laserperusteinen maaperän hiilivaraston nopea määritys – Hiililaser

Laser-based assessment of soil carbon content

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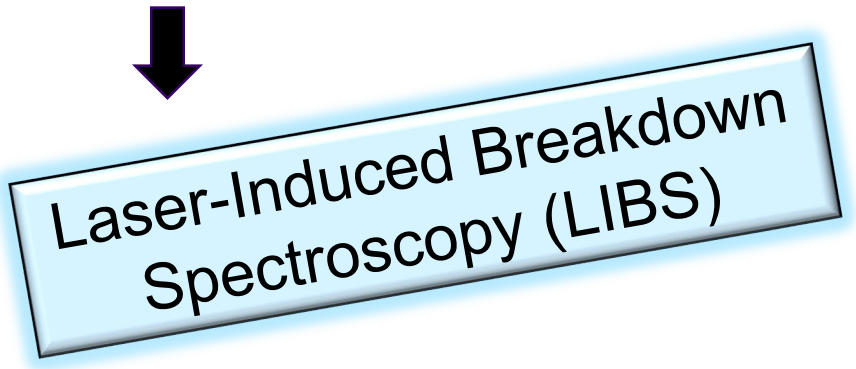
Motivation

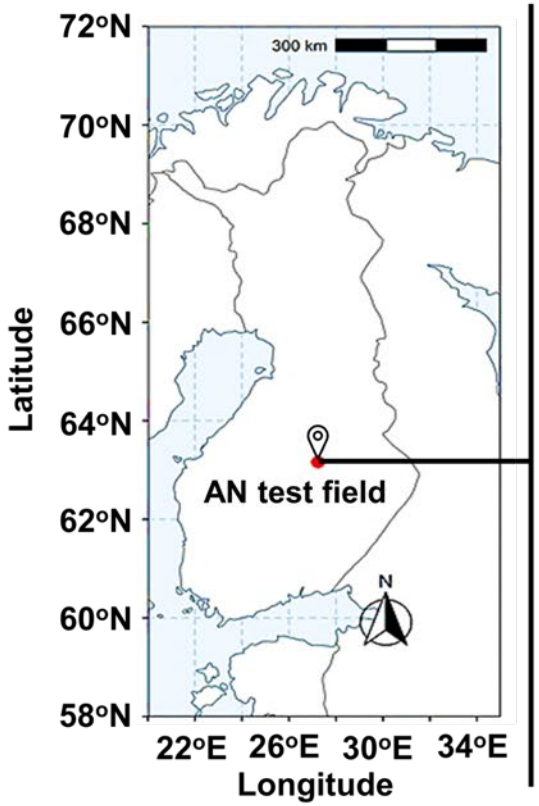
- Soil is the second largest carbon storage on Earth (after Oceans) and plays a crucial role in the global carbon cycles.

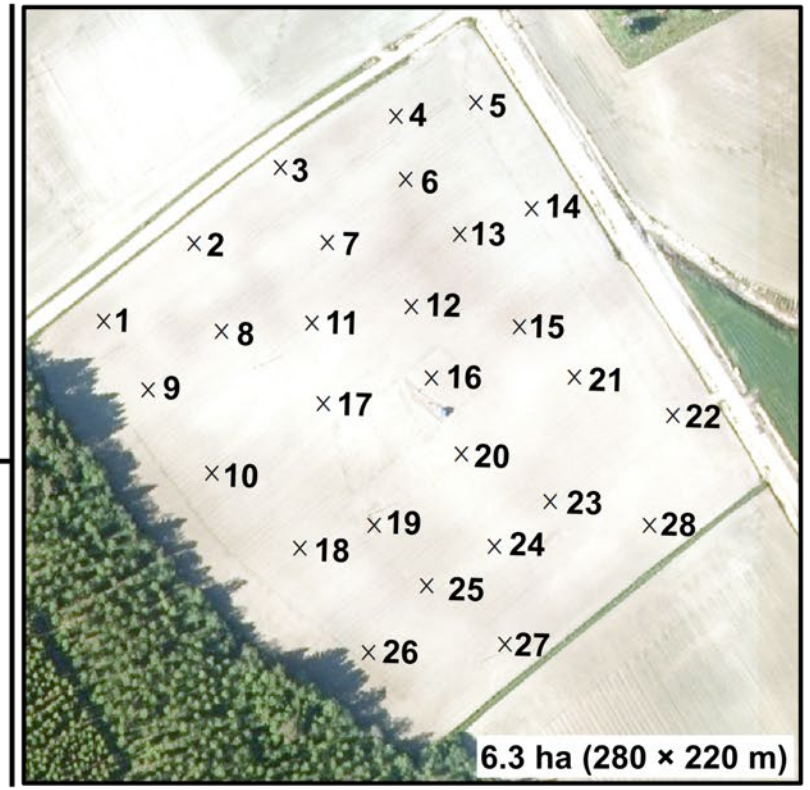
- Current cultivation methods need to be upgraded in order to reverse the C cycle (i.e. instead of releasing C into the atmosphere, it can be stored in the soil).

- Key challenges in Carbon Farming scheme for soil carbon sequestration on mineral soils
  - Expense and uncertainty of measuring soil carbon
  - Difficulty of monitoring soil carbon



Sampling of fields – VALSE samples





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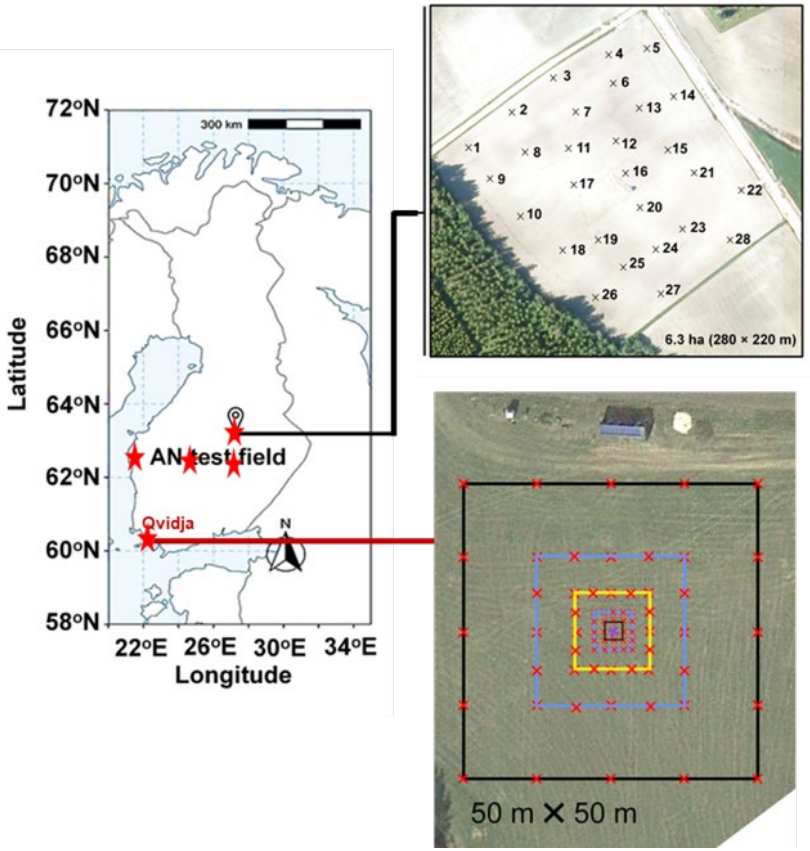
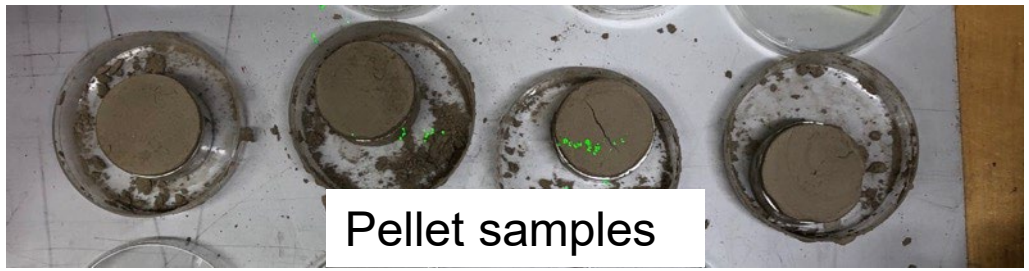
Soil sampling



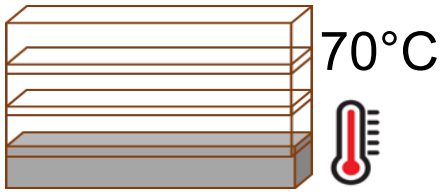


Pellet samples

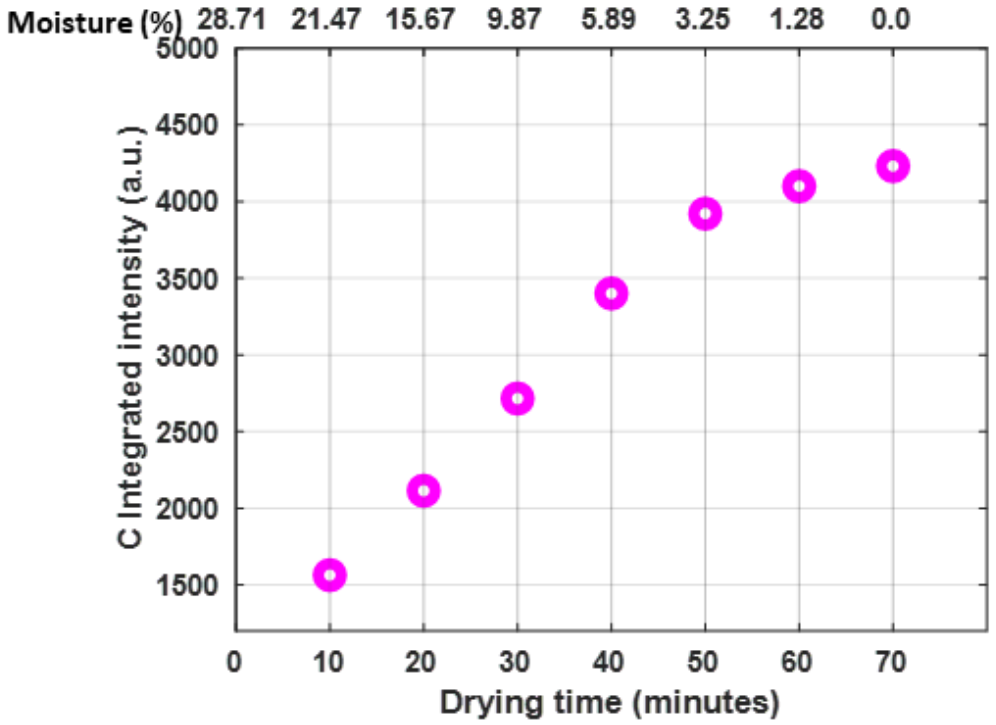
Soil sample preparation for LIBS analysis

Mixing → Pelletization → Drying

Drying cabinet



~ 60 min / 60 samples



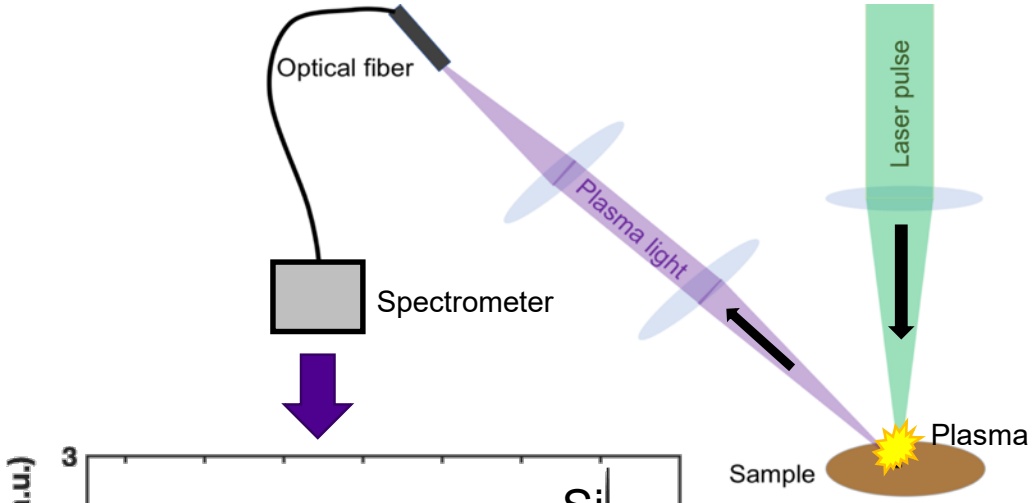
- Avoid sieving, grinding, dry combustion
- Still, sample preparation have strong influence on quality of the results

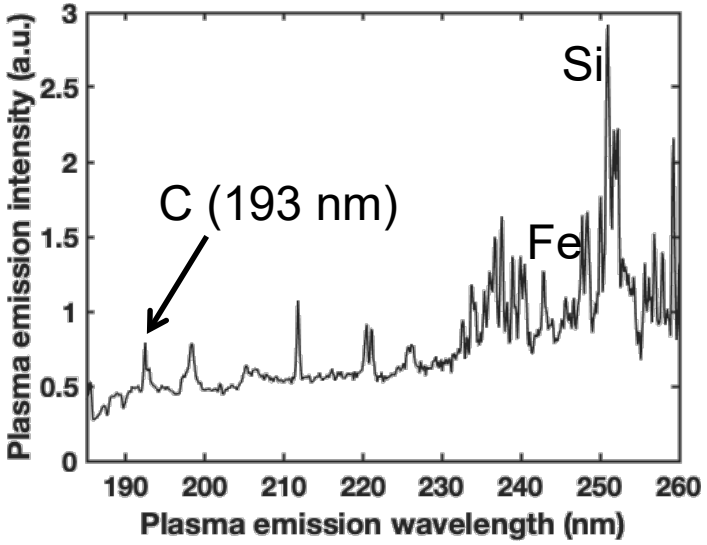
Laser-Induced Breakdown Spectroscopy (LIBS)

- We developed a **laser-based** measurement method that enable comprehensive **on-site monitoring of soil carbon** content.

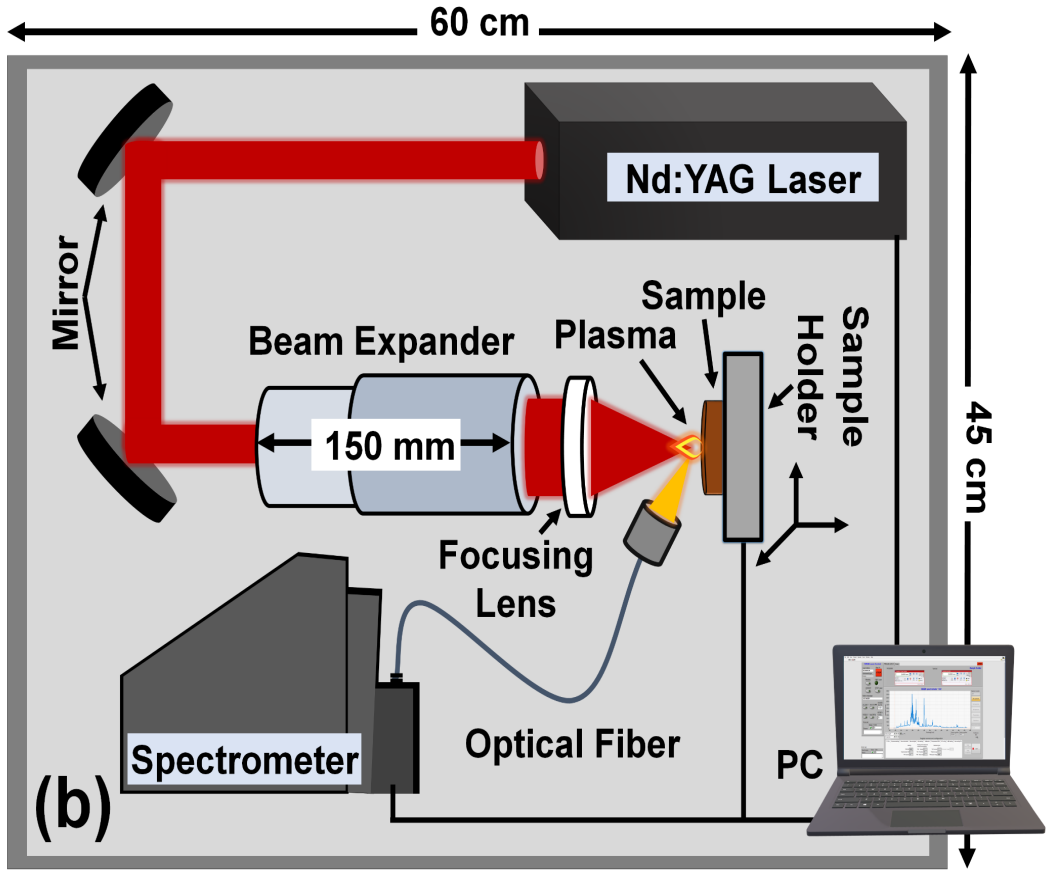
- Measurement at the sampling site
  - Absolute carbon content
  - Carbon depth distribution down to 1 m

- LIBS is information rich
  - Nutrient content
  - Soil classification





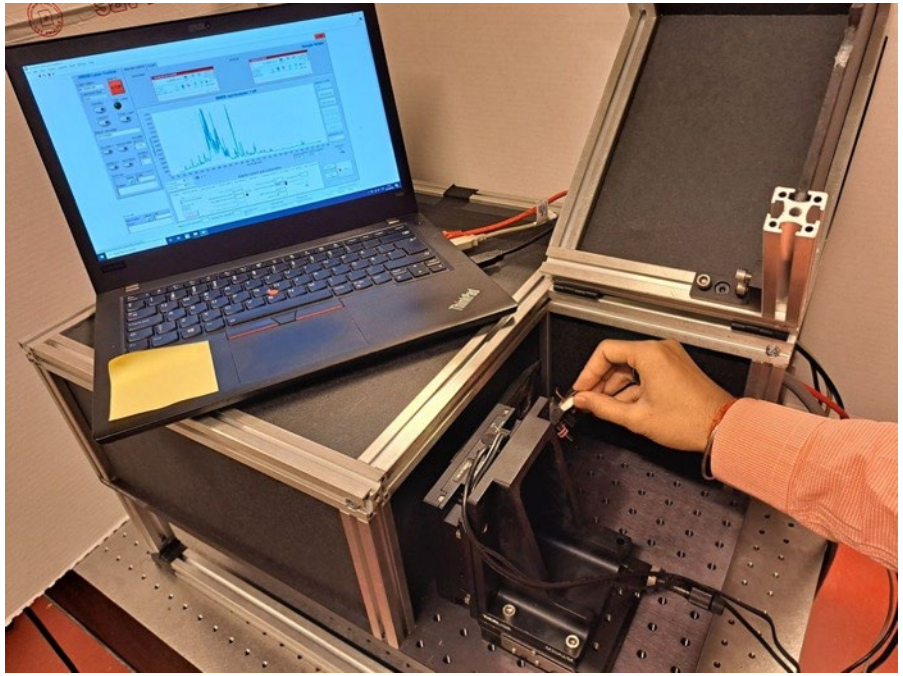
LIBS instrumentation built for soil carbon analysis

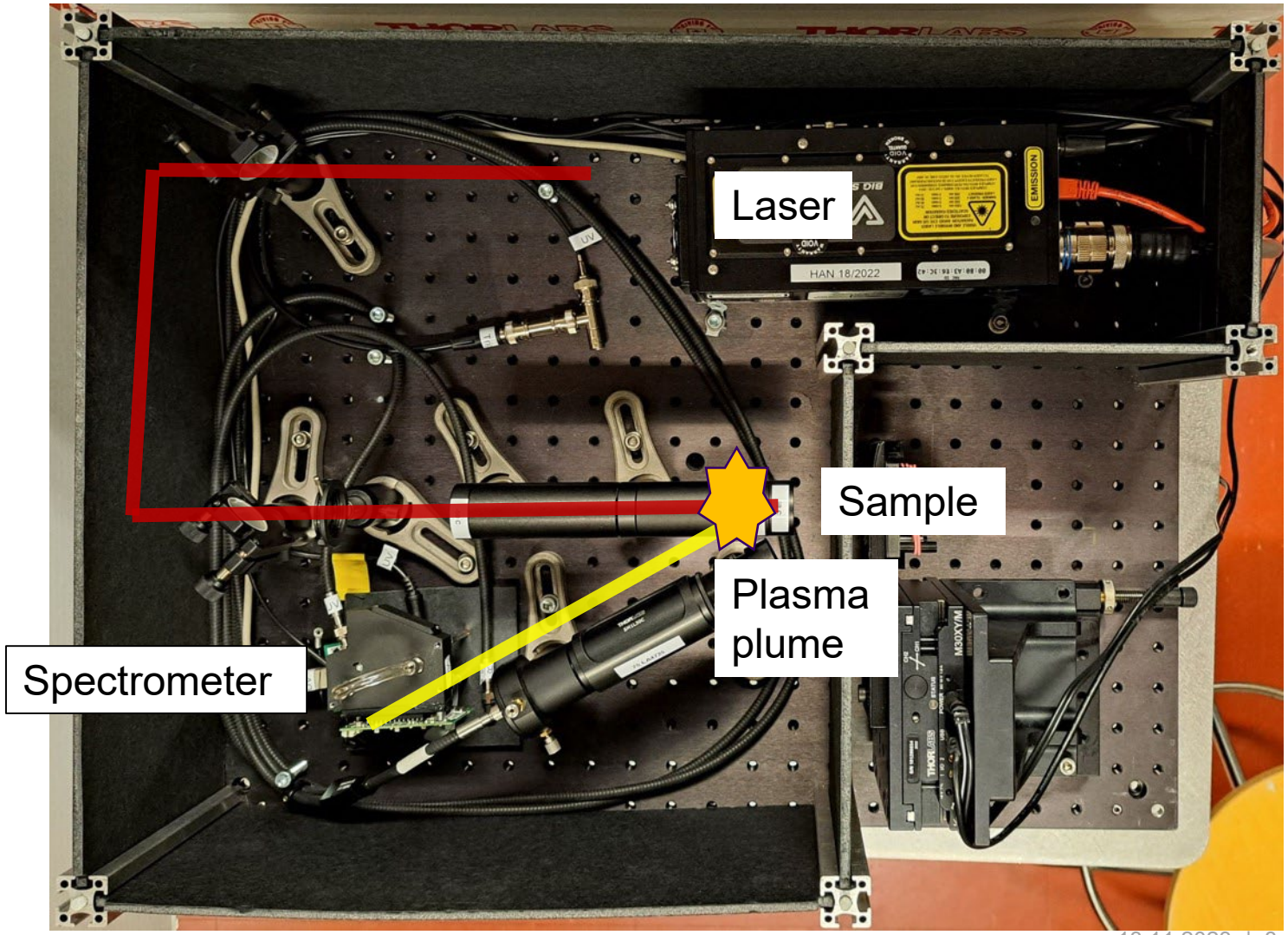


* Battery ~ 35 hours

Field-capable LIBS device

- Laser 1064 nm, 50 mJ, 1-20 Hz
- Spectrometers
  - 178 – 400 nm (C, Si, Al, …)
  - 360 – 820 nm (H, K, Na, …)





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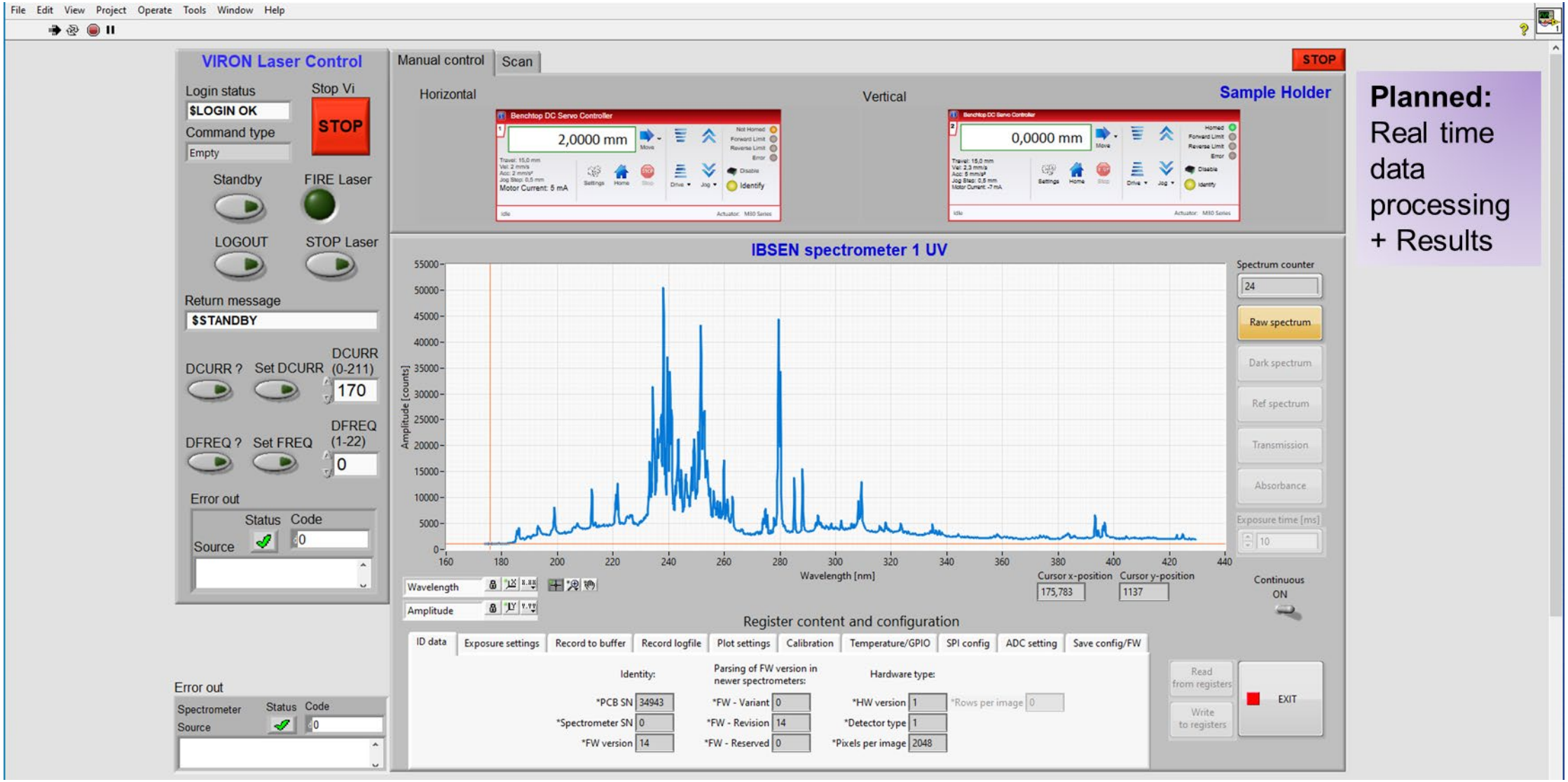
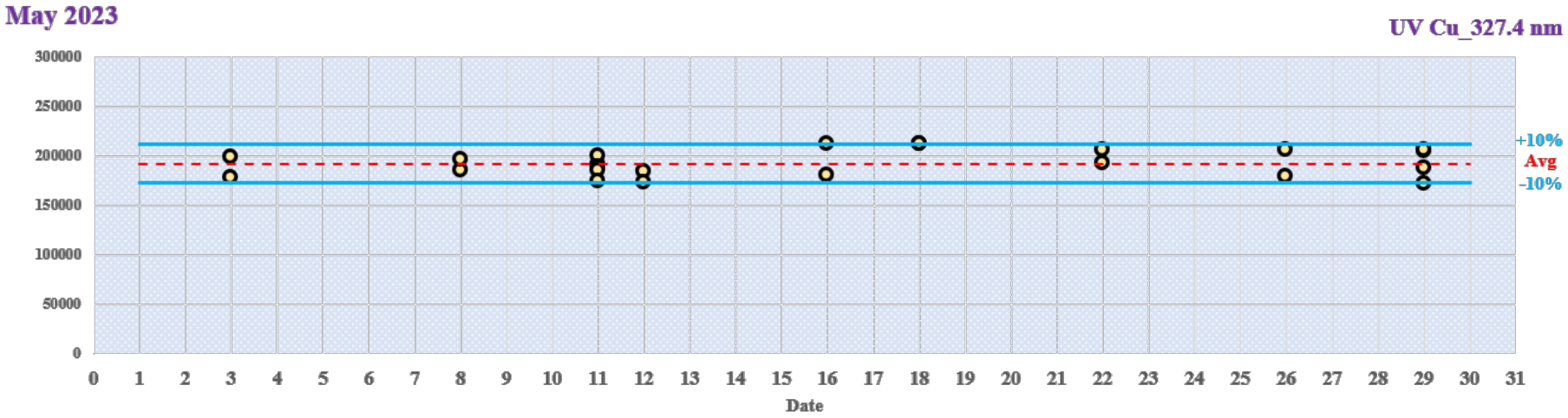
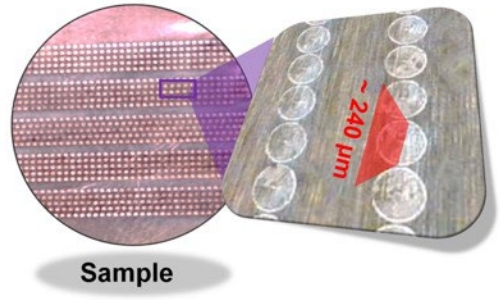
Software programmed with LabVIEW



Planned:
Real time data processing + Results

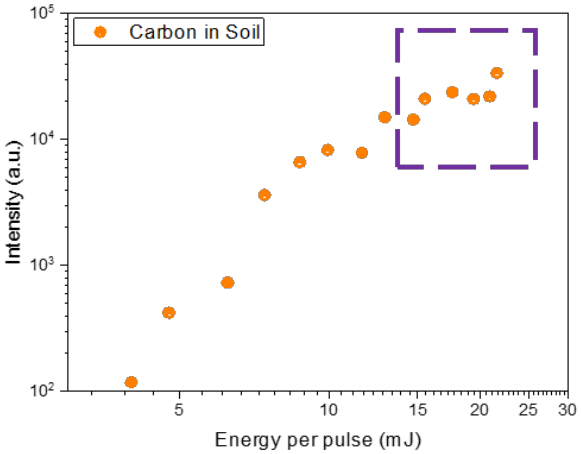
Calibration and Optimization



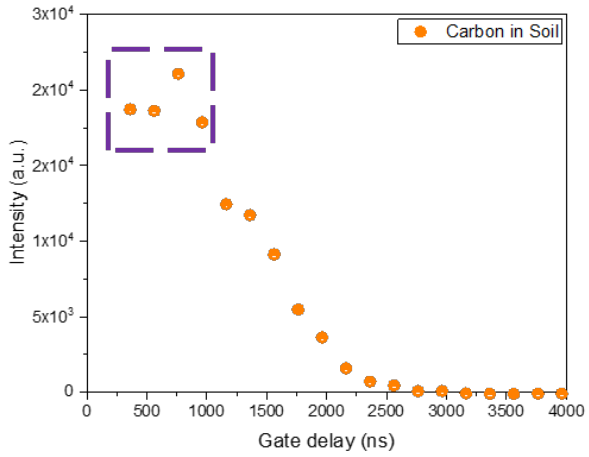


Pure Cu

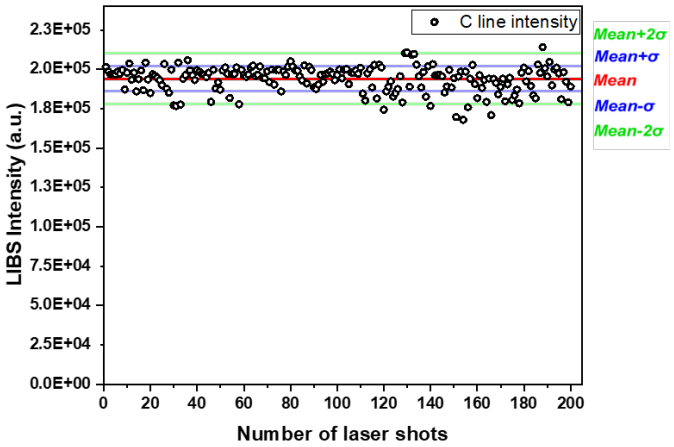
Laser energy per pulse



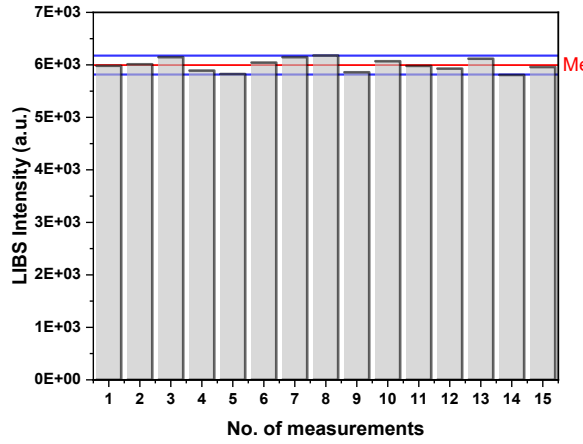
Acquisition delay time



Shot to shot variation



Repeatability



Uncertainty in the LIBS carbon peak intensity is ± 3%

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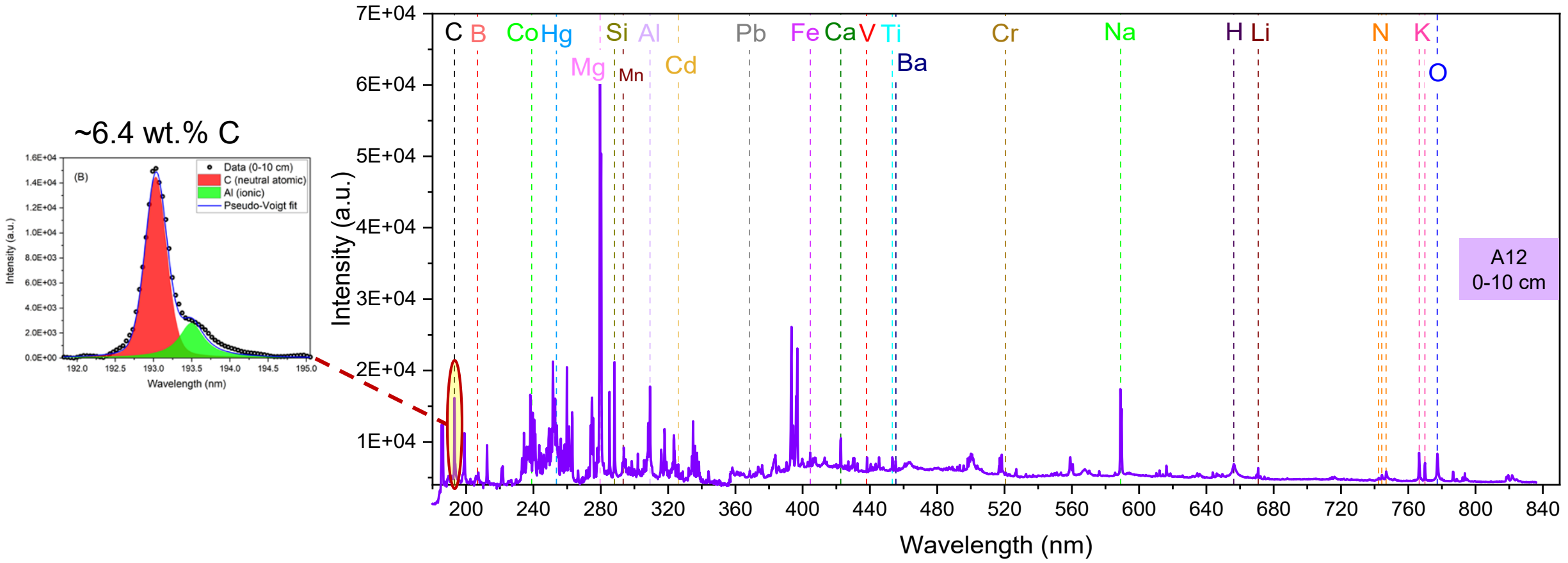
Demonstrations and measurements at field locations

LIBS Spectrum

Average: 200 spectra
Laser energy: 28 mJ/pulse
T_d= 600 ns
T_{exp}= 12 µs



Due to presence of many elements and thousands of spectral lines for some elements (e.g., Fe, Co, etc.), strong interference among the lines needs to be checked and corrected.

Variation of C content with depth in soil

Geoderma 436 (2023) 116550

Contents lists available at ScienceDirect

Geoderma

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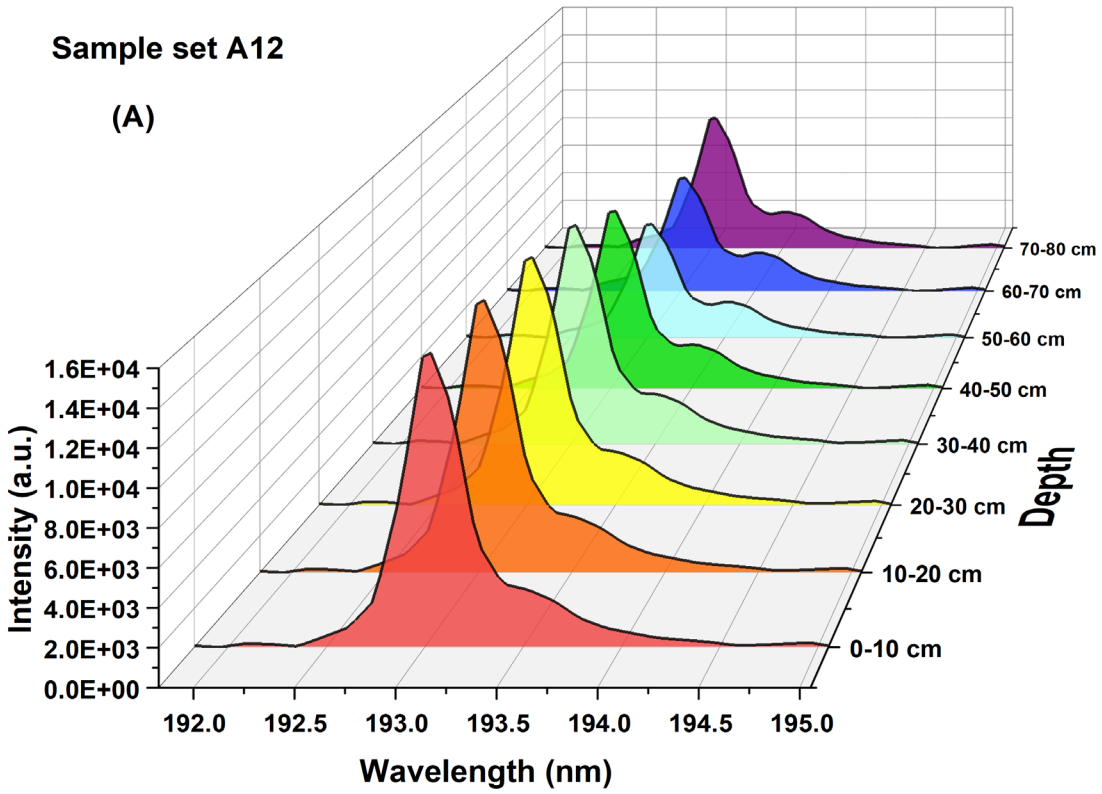
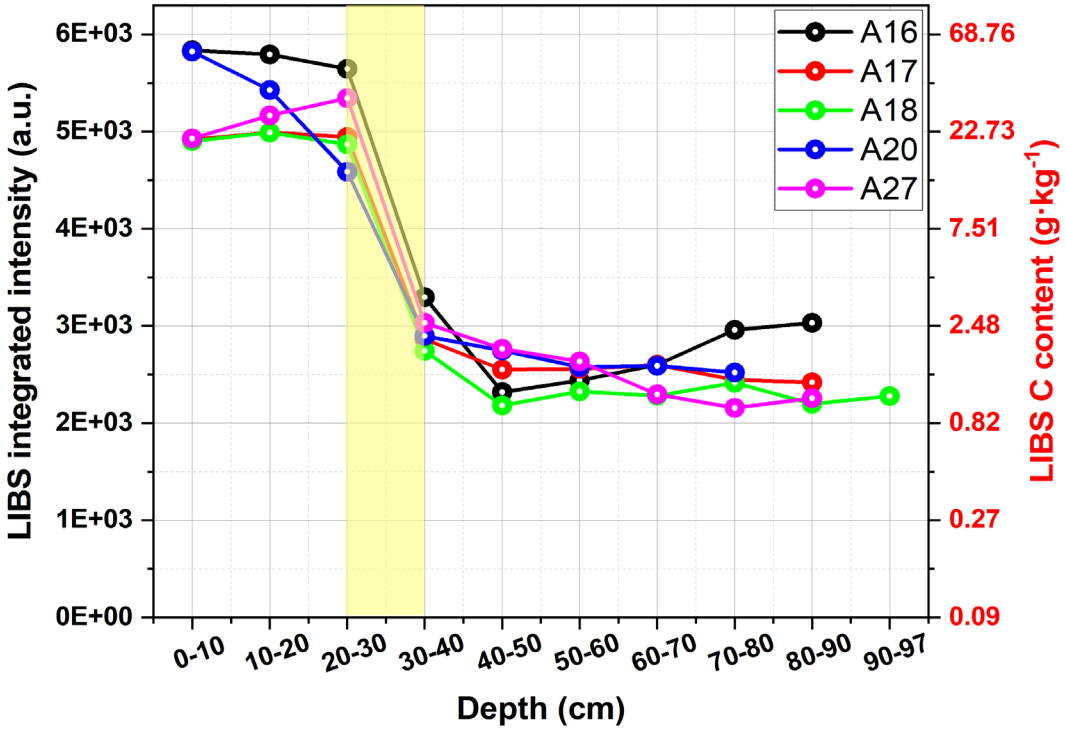
Optical assessment of the spatial variation in total soil carbon using laser-induced breakdown spectroscopy

Vishal Dwivedi [a,*,1], Joni Ahokas [a,1], Jan Viljanen [a], Piotr Ryczkowski [a], Narasinha J. Shurpali [b], Hem Raj Bhattarai [b], Perttu Virkajärvi [b], Juha Toivonen [a]





Soil from first 30 cm have significantly higher C content than the rest

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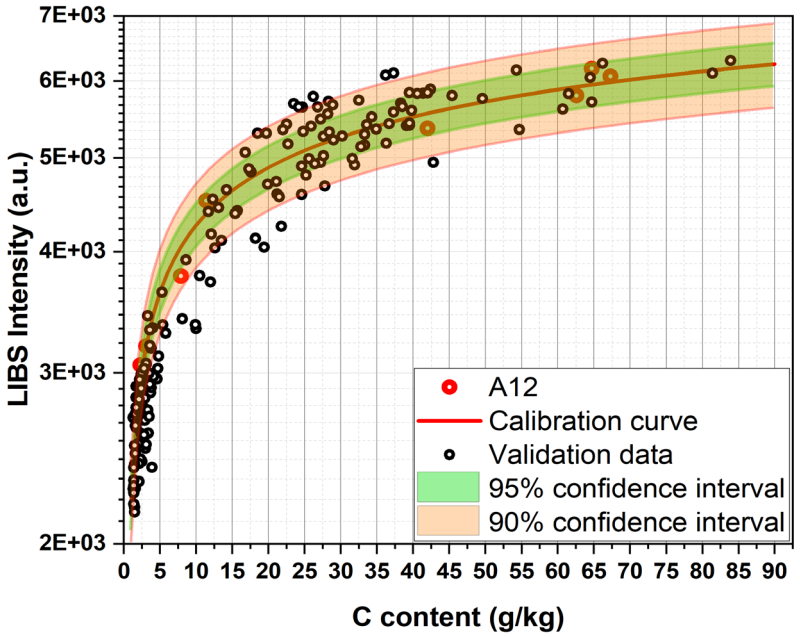
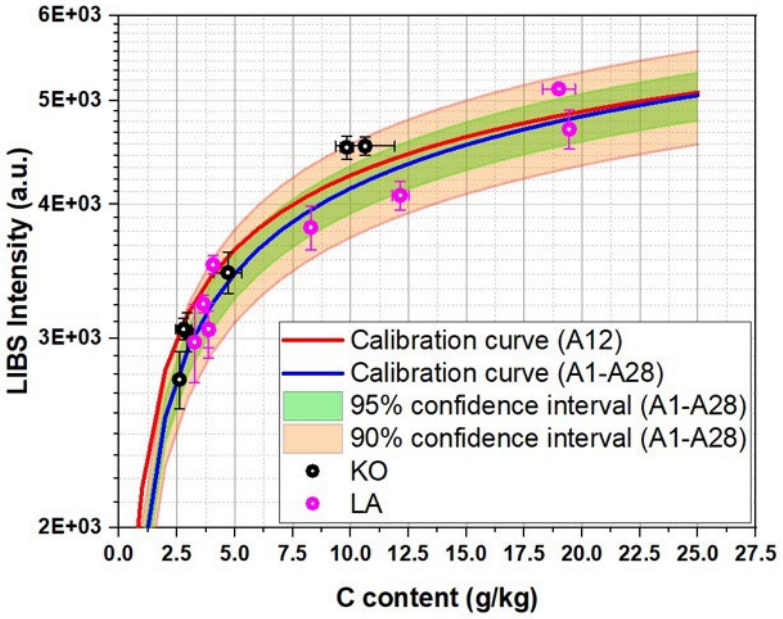
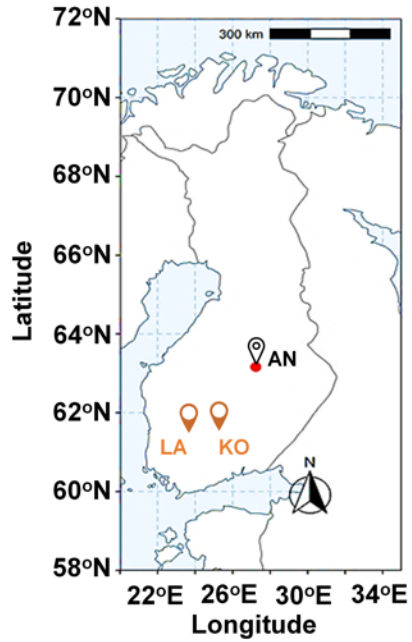
LIBS Calibration

- Samples collected form Anttila (AN, LUKE) field, 28 locations, down to 1 m depth, 167 in total.
- The calibration curve obtained using 8 samples from one randomly chosen sampling location (A12)
- Reference values from Leco measurements



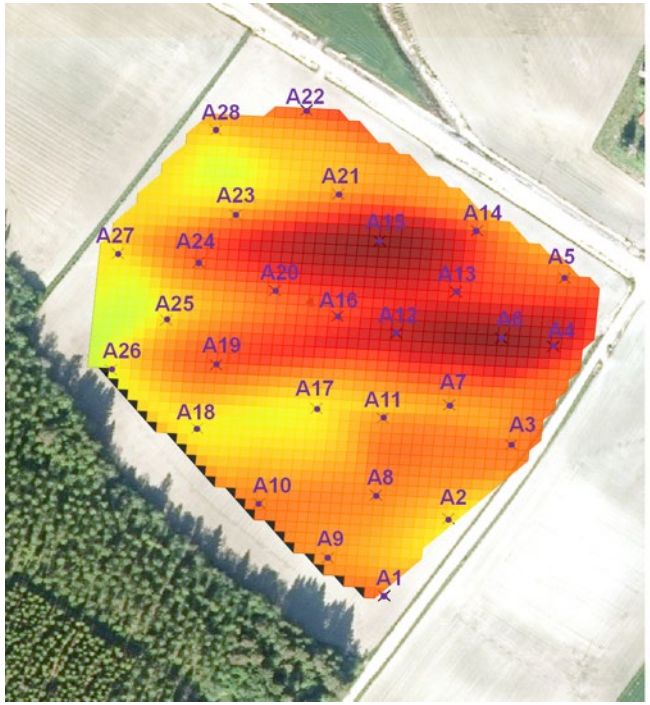
- Calibration curves from A12 and locations A1-28
- Fresh samples from Carbon Action KO and LA fields (only pressed to a pellet and dried) fall within 95% confidence interval of A1-A28 calibration curve
- **Calibration can be used in all (at least most) fields with similar soil type**

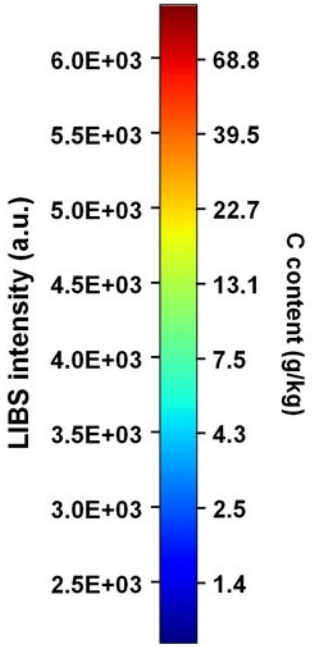


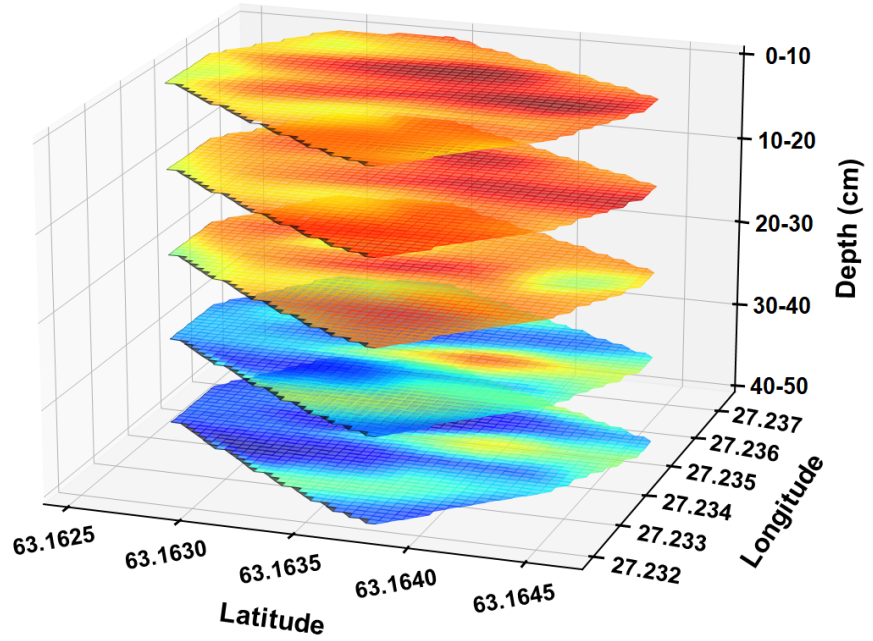


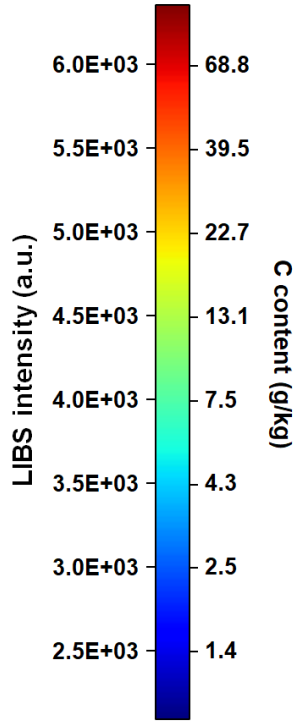
Spatial variation of a field carbon content

- LIBS measurement of one sample ~1min (laser ablation, data acquisition and data processing)
- Measurement speed bottlenecks are in the sampling (drilling, pelletizing, drying) and sample integration in LIBS prototype









Conclusions

- We have demonstrated that the laser-based LIBS analysis allows accurate and fast soil carbon measurement even at field conditions
    - 10 min for drilling and sample separation
    - 2 min for sample preparation
    - ~ 60 min for drying
    - 2 min for LIBS analysis
- We learned that soil type and moisture level affects to LIBS calibration

Next steps

- Increase the level of automation to **speed up** drill sampling & LIBS
- Study how to compensate moisture and soil type variation to **speed up** the method
- Analysis of the whole drill depth (4 – 8 samples) possible in 6 – 10 minutes

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Acknowledgements

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  and Innovation (PREIN)

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