Optimizing Site Characterization in Boreal Podzolic Soils with Integrated Ground-penetrating Radar and Electromagnetic Induction Techniques

Sashini Pathirana[1], Lakshman Galagedara[1], Sébastien Lambot[2], Mumtaz Cheema[1], Manokararajah Krishnapillai[1]

[1]School of Science and the Environment, Memorial University of Newfoundland, Canada
[2]Earth and Life Institute, Environnemental Sciences, Université Catholique de Louvain, Belgium

Introduction

- Site characterization in the agricultural landscape is crucial for precision agriculture (PA)
- Traditional site characterization methods (soil coring and open pit excavation) provide valuable insight into soil profiles, although they are tedious, destructive and limited to point scale measurements [1,2]
- Near-surface geophysical techniques; **ground-penetrating radar (GPR),** and **electromagnetic induction (EMI)** have emerged as alternative methods to estimate soil properties and state variables in the agricultural landscape to support PA [3]
- Integrated GPR-EMI technique can overcome inherent limitations associated with traditional methods by providing **rapid** and **non-invasive approaches** that offer **high spatial resolution (vertical and horizontal scale)** and **deeper penetration depths** [3,4,5]
- Application of **Integrated GPR-EMI technique** for detailed site characterization in boreal podzolic soils remains underexplored

Objective

- Evaluate the effectiveness of an integrated GPR-EMI technique for understanding soil stratification and subsurface distributions within a podzolic soil site in Newfoundland

Methodology

1. Study area

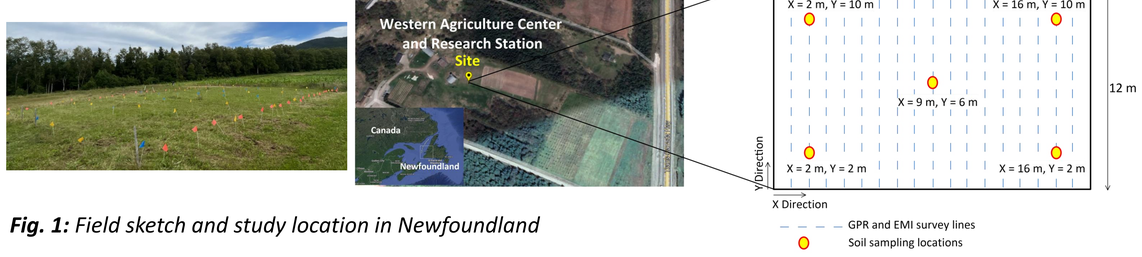

Fig. 1: *Field sketch and study location in Newfoundland*

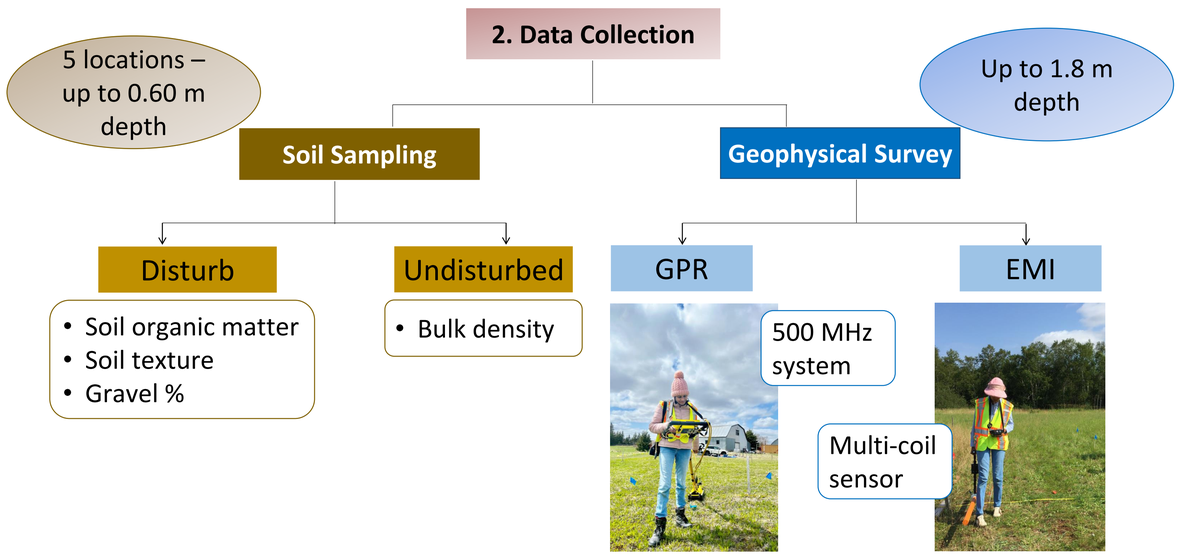

Fig. 2: *Flow chart of field data collection with soil sampling and geophysical surveys*

3. Data analysis

- **Statistical analysis –** soil sampling
- **Visual correlation –** GPR and EMI data

Results

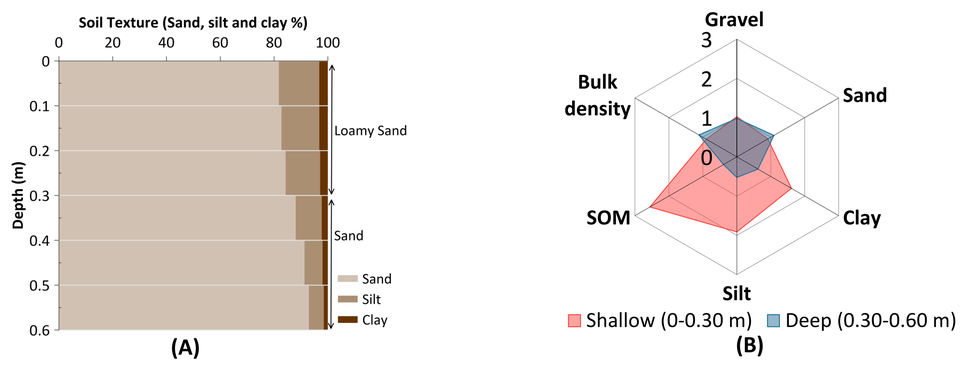

Fig. 3: *(A) Average soil texture at 0.1 m intervals of five soil sampling locations from 0 to 0.60 m depth and (B) Radar plot showing the ratio of soil properties at shallow (0 to 0.30 m) and deeper (0.30 to 0.60 m) depths.*

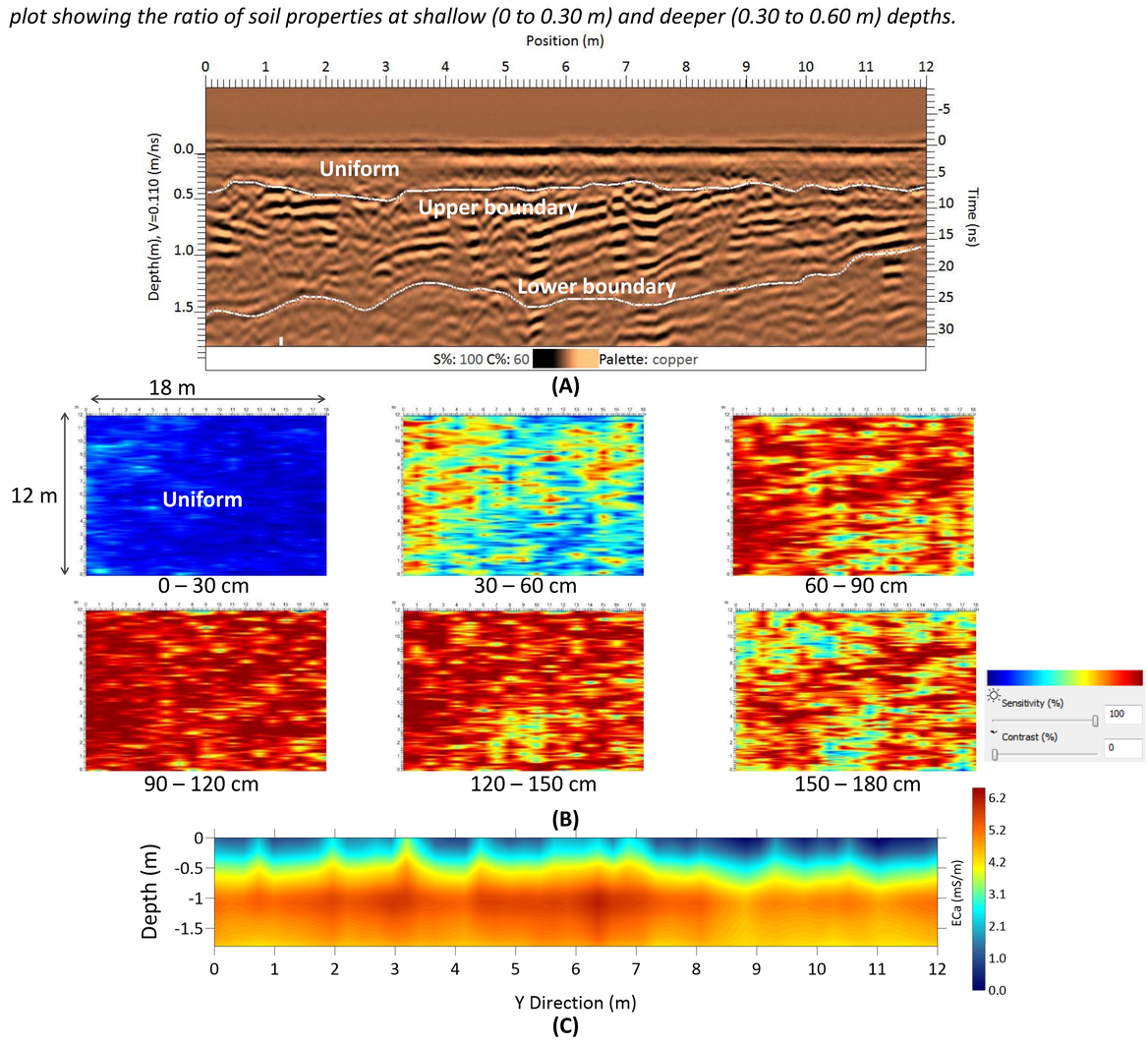

Fig. 4: *Geophysical imaging of subsurface stratigraphy: (A) 2D profile of GPR showing the reflection of the bottom and top of the layer (marked with a solid line), (B) GPR depth slices with 0.30 m thickness from the surface, and (C) depth inversion of apparent electrical conductivity measured with EMI showing a 3-layer system of the soil profile.*

- Basic properties assessed for **shallow soil layers** (0 to 0.30 m) **showed a significant difference** ($p<0.05$) from **deep soil layers** (0.30 to 0.60 m)
- Both soil sampling and geophysical data show **consistent patterns**
- **Three distinct layers** were identified from **GPR and EMI**

Conclusions and Future Direction

- The integrated **GPR-EMI technique**
  - confirmed each method's findings
  - provided insights into the **soil stratification**
  - revealed the **spatial variability** of **soil density** and **electrical conductivity** in the soil profile non-destructively
- This approach could be further expanded for mapping water table and capillary fringe, identifying hardpans, soil horizons, and peat layer thickness

Key References

1. Evans, L.J., and Cameron, B.H. 1985. Color as a criterion for the recognition of podzolic B horizons. Can. J. Soil Sci., *65*(2), 363–370. https://doi.org/10.4141/cjss85-040
2. Anderson, D.W., and Scott Smith, C.A. 2011. A history of soil classification and soil survey in Canada: Personal perspectives. Canada. Can. J. Soil Sci., 91(5), 675–694. https://doi.org/10.4141/cjss10063
3. Pathirana, S., Lambot, S., Krishnapillai, M., Cheema, M., Smeaton, C., and Galagedara, L. 2023. Ground-penetrating radar and electromagnetic induction: Challenges and opportunities in agriculture. Remote Sens. 15(11), Article 11. https://doi.org/10.3390/rs15112932
4. Dal Bo, I., Klotzsche, A., Bol, R., Moradi, G., Weihermüller, L., Vereecken, H., and Van Der Kruk, J. 2021. GPR and EMI characterization of the hyperarid study site of Yungay, Chile: Implications of applying geophysical methods on mars. Earth and Space Science, 8(12), e2021EA001790. https://doi.org/10.1029/2021EA001790
5. Davis, J.L., and Annan, A.P. 1989. Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophysical Prospecting, 37(5), 531–551. https://doi.org/10.1111/j.1365-2478.1989.tb02221.x

Acknowledgement

Funding: Natural Sciences and Engineering Research Council of Canada (NSERC), Memorial University of Newfoundland (MUN) and Industry, Energy and Innovation of the Govt. of Newfoundland and Labrador (IET).

Collaborators: Western Agriculture Center and Research Station – Department of Fisheries, Forestry and Agriculture, Govt. of Newfoundland and Labrador.

Contacts

Sashini Pathirana
Ph.D. Candidate
epspathirana@mun.ca

ResearchGate