Investigating the Spatial Variability in Soil Geochemical and Colour Properties Across Two Contrasting Land Uses

Maria Luna[a], Alexander J Koiter[b,*], Taras E Lychuk[c], Arnie Waddel[c], Alan Moulin[c]

[a] *Brandon University, Masters in Environmental and Life Sciences, 270 18th St, Brandon, R7A 6A9*

[b] *Brandon University, Department of Geography and Environment, 270 18th St, Brandon, R7A 6A9*

[c] *Agriculture and Agri-Food Canada, Brandon Research and Development Centre, 2701 Grand Valley Road, Brandon, R7A 5Y3*

Abstract

Quantification and accurate assessment of the spatial variability and distribution of soil physical and biogeochemical properties (fingerprints) are vital components of agri-environmental research and modeling, including sediment source fingerprinting. Understanding the distribution of soil properties at a range of spatial scales is crucial in the development of appropriate, reliable, and efficient sampling campaigns. This study was aimed to investigate the spatial variability in soil geochemical and colour (i.e., spectral reflectance) fingerprints across two contrasting land uses. The main objectives of this study are to: 1) quantify the spatial variability of geochemical and colour fingerprint properties at a field-scale (~ 40 ha) across agricultural and forested sites; 2) evaluate the spatial variability and distribution of soil fingerprint properties and its relation to a range of terrain attributes (e.g., slope); and 3) identify the possible sources of variation in each land use, primarily environmental factors. A combination of univariate analysis and geostatistical methods were applied to analyze the soil geochemistry and colour properties. This information was used to both quantify and assess the variability in commonly used fingerprints. Terrain attributes derived from digital elevation model (DEM) were used to investigate spatial variation of soil geochemical and colour fingerprint properties. The ability of terrain attributes to explain the observed variability in soil fingerprints played

*Corresponding author

Email addresses: LUNAMIMA56@brandonu.ca (Maria Luna), koitera@brandonu.ca (Alexander J Koiter), taras.lychuk@AGR.GC.CA (Taras E Lychuk), arnie.waddell@AGR.GC.CA (Arnie Waddel), apmaafc7788@gmail.com (Alan Moulin)

an important role across all properties. The present study suggest that kriging interpolation can directly reveal the spatial distribution of soil fingerprint properties and quantify the variability at a field-scale.

Keywords: Soil geochemistry, Soil colour, Spatial analysis

---

1. Introduction

2. Methods

2.1. Site description

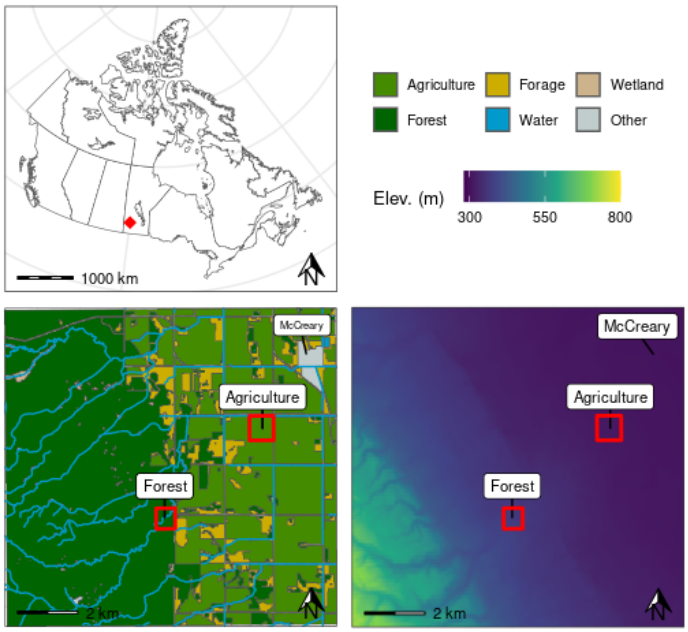


Figure 1: Map showing the location of the study sites within Canada, and the regional land use and topography.

Source: Research Site Locations

3. Results

3.1. Univariate summary

Table 1: Summary statistics for for six examples of for six examples of geochemical and colour soil properties, specific surface area, and organic matter content for each site.

Element	Mean	SD	Max	Min	Skewness	CV
			Forest			
Li	6.47	0.90	8.60	4.30	−0.02	13.89
Nb	0.37	0.06	0.56	0.17	−0.68	17.10
Zn	109.55	53.27	318.00	42.00	1.43	48.62
h*	1.13	0.05	1.23	1.06	0.34	4.13
L	47.45	6.35	59.48	34.34	−0.02	13.37
v*	4.79	1.04	6.62	2.77	0.31	21.74
SSA	763.48	133.48	1,032.61	492.59	−0.08	17.48
Org	11.55	5.99	26.99	1.37	0.37	51.89
			Agriculture			
Ca	4.00	2.19	8.78	0.95	0.28	54.66
Mo	0.93	0.41	2.35	0.47	1.18	43.95
U	1.48	0.19	1.94	1.20	0.59	12.64
a*	3.38	0.32	4.15	2.59	−0.03	9.53
c*	9.47	1.02	11.32	7.17	−0.19	10.74
h*	1.20	0.01	1.23	1.18	0.19	1.12
SSA	1,853.02	187.32	2,195.72	1,458.53	0.00	10.11
Org	8.51	1.37	11.36	5.86	0.07	16.13

Source: Univariate summary

Table 2: Summary statistics for the interpoloated values (10m resolution) for six examples of geochemical and colour soil properties, specific surface area, organic matter content, and seven terrain attributes for each site.

Property	Mean	SD	Max	Min	Skewness	CV
			Forest			
Li	6.44	0.63	8.57	4.34	−0.16	9.73
Nb	0.37	0.03	0.43	0.29	−0.32	8.32
Zn	111.46	43.21	317.76	42.15	1.11	38.76
h*	1.13	0.04	1.23	1.06	0.30	3.38
L	47.25	4.72	59.48	34.38	0.10	9.98
v*	4.78	0.73	6.62	2.77	0.28	15.28
SSA	760.40	120.58	1,102.95	483.70	0.12	15.86
Org	11.53	1.97	16.13	7.37	−0.12	17.10
Elevation	369.28	3.34	377.24	358.29	−0.21	0.90
Rel. Slope Position	0.22	0.26	1.00	−0.12	1.55	116.75

Table 2: Summary statistics for the interpoloated values (10m resolution) for six examples of geochemical and colour soil properties, specific surface area, organic matter content, and seven terrain attributes for each site.

Property	Mean	SD	Max	Min	Skewness	CV
Vert. Dist. Channel	0.47	0.57	4.90	−0.67	2.75	122.69
SAGA Wetness Index	6.00	1.26	9.96	0.09	−0.86	20.92
Catchment Area	565.06	5,109.73	209,263.22	0.67	17.83	904.28
Profile Curvature	0.00	0.03	0.45	−0.47	−0.34	−15,245.25
Plan Curvature	0.00	0.01	0.30	−0.26	0.56	3,382.34
			Agriculture			
Ca	4.10	2.09	9.11	1.03	0.09	51.01
Mo	0.89	0.31	1.96	0.51	0.76	35.03
U	1.46	0.14	1.81	1.24	0.25	9.24
a^*	3.34	0.22	3.93	2.77	0.03	6.60
c^*	9.35	0.76	11.08	7.39	−0.16	8.17
h^*	1.20	0.01	1.23	1.18	−0.13	0.72
SSA	1,867.79	129.71	2,056.35	1,579.16	−0.43	6.94
Org	8.62	0.68	10.30	7.08	0.34	7.89
Elevation	309.92	0.59	311.82	309.01	0.62	0.19
Rel. Slope Position	0.72	0.34	28.79	−33.19	−3.62	47.84
Vert. Dist. Channel	0.06	0.04	0.33	0.00	1.07	73.73
SAGA Wetness Index	9.64	0.72	11.27	7.63	−0.11	7.43
Catchment Area	475.21	1,884.43	41,848.99	1.05	10.24	396.55
Profile Curvature	0.00	0.00	0.00	0.00	−0.15	−5,332.23
Plan Curvature	0.00	0.00	0.00	0.00	0.23	27,643.82

Source: Univariate summary

3.2. Spatial analysis

Table 3: Geostatistical parameters of the fitted semivariogram models for six examples of geochemical and colour fingerprint properties for each site.

Property	Model[1]	Nugget (Co)	Sill (Co)	Range (m)	C/(C + Co) (%)	Class[2]	R2	
					Agriculture			
Ca	Exp	0	1.49	72.52	0	S	0.27	
					Forest			
Ca	Exp	0	1.49	72.52	0	S	0.27	

[1] Models are all isotropic.

[2] S = strong spatial dependency (C/(C + Co) % >75); M = moderate spatial dependency (C/(C + Co) % b

Source: Semivariograms

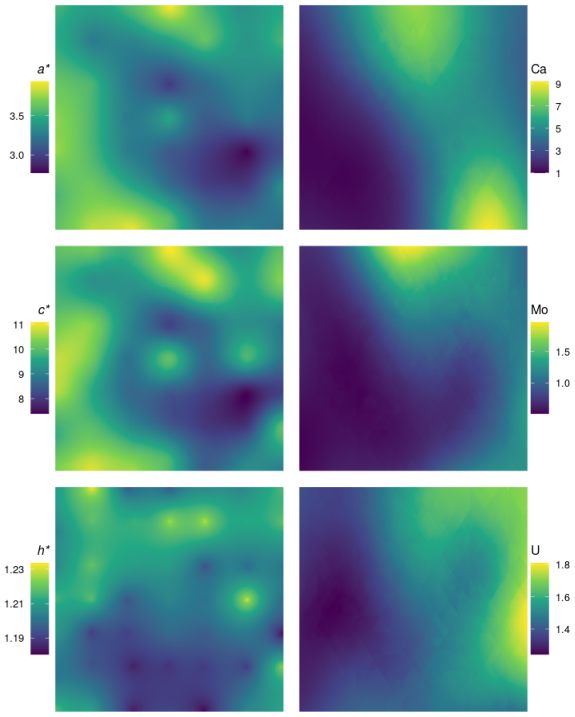


Figure 2: Kriged map of select colour ($a*$, $c*$, $h*$) and geochemical (Ca, Mo, U) properties across the agricultural site.

Source: Soil property mapping

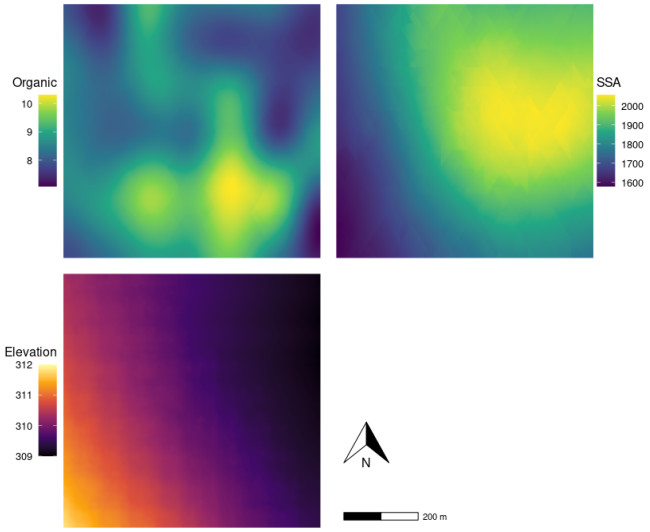


Figure 3: Kriged map of organic matter content (%), specific surface area (m2 kg-1), and elevation (m) across the agricultural site.

Source: Soil property mapping

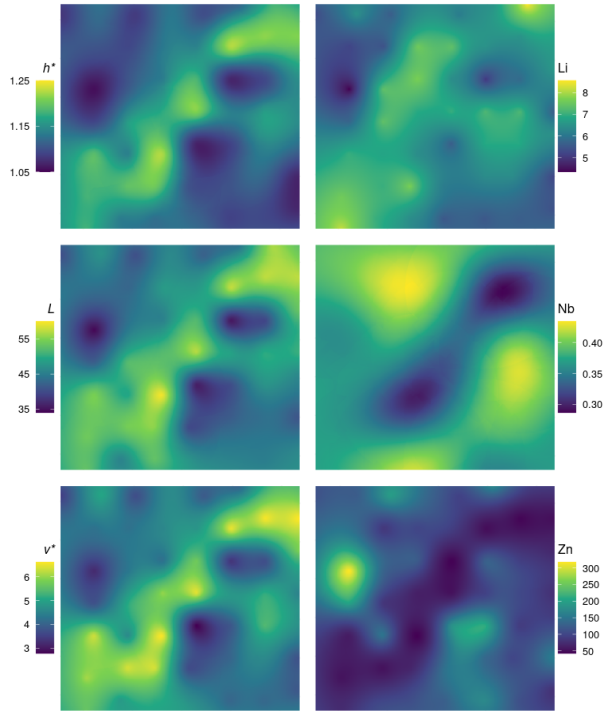


Figure 4: Kriged map of select colour ($h*$, $c*$, $v*$) and geochemical (Li, Nb, Zn) properties across the forested site.

Source: Soil property mapping

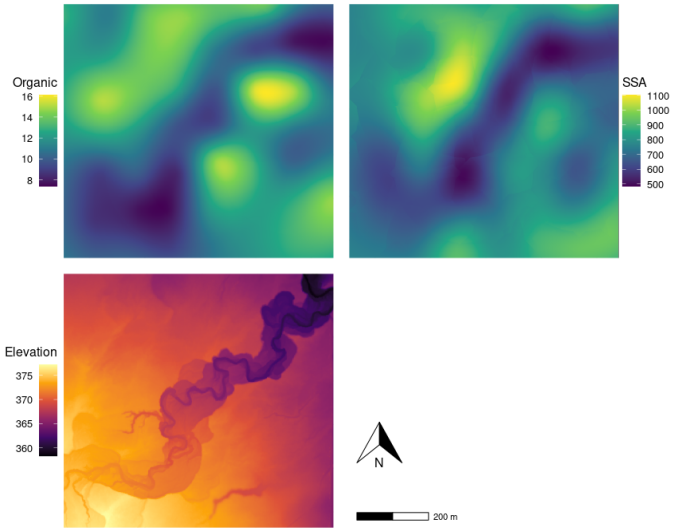


Figure 5: Kriged map of organic matter content (%), specific surface area (m2 kg-1), and elevation (m) across the forested site.

Source: Soil property mapping

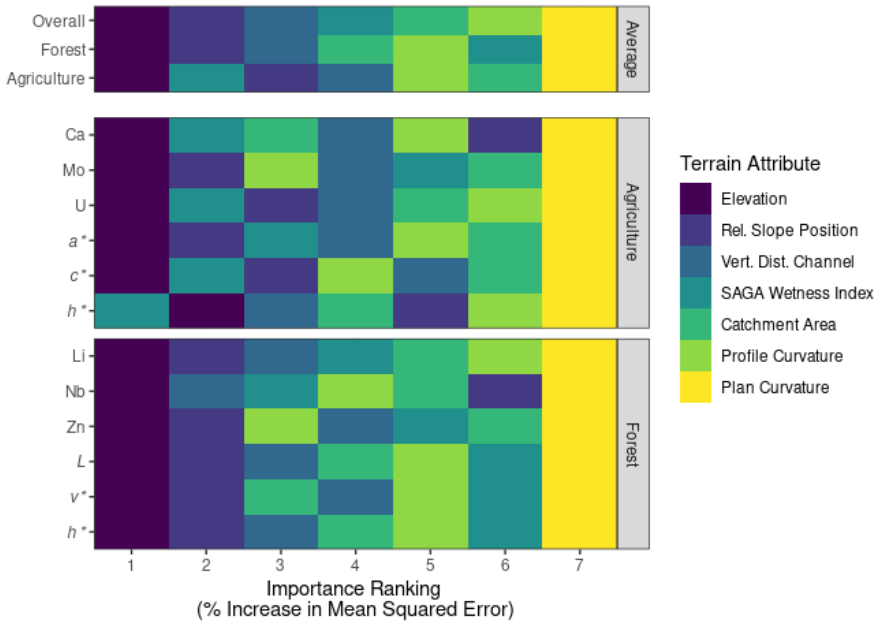
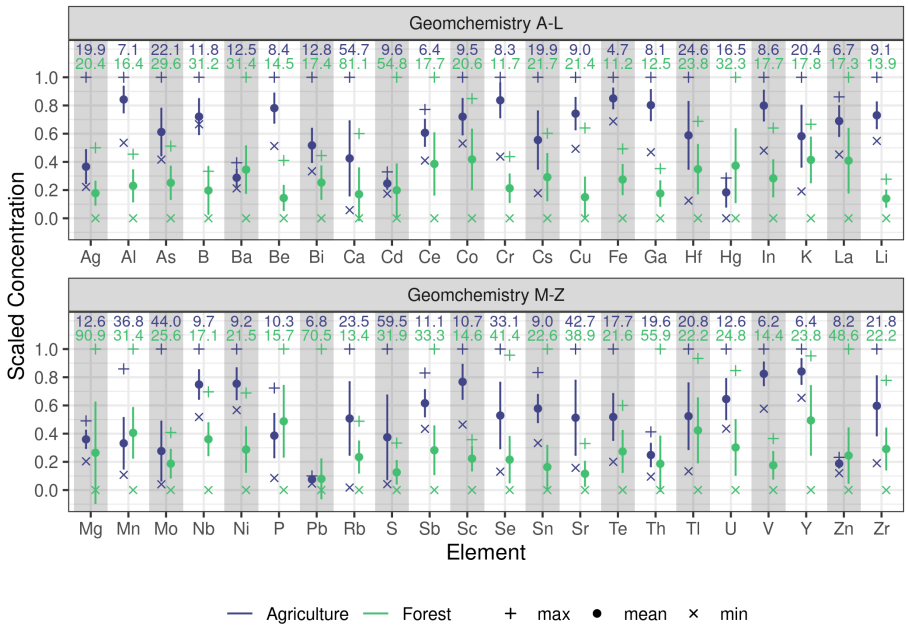


Figure 6: Heat map of the Random Forest regresssion results showing the ranking of the importance of terrain attributes (based on % increase in Mean Squared Error) in explaining the spatial variabilty of selected colour and geochemical properties within the agricultural and forested sites. Top panel shows an average ranking for each site and across both sites.

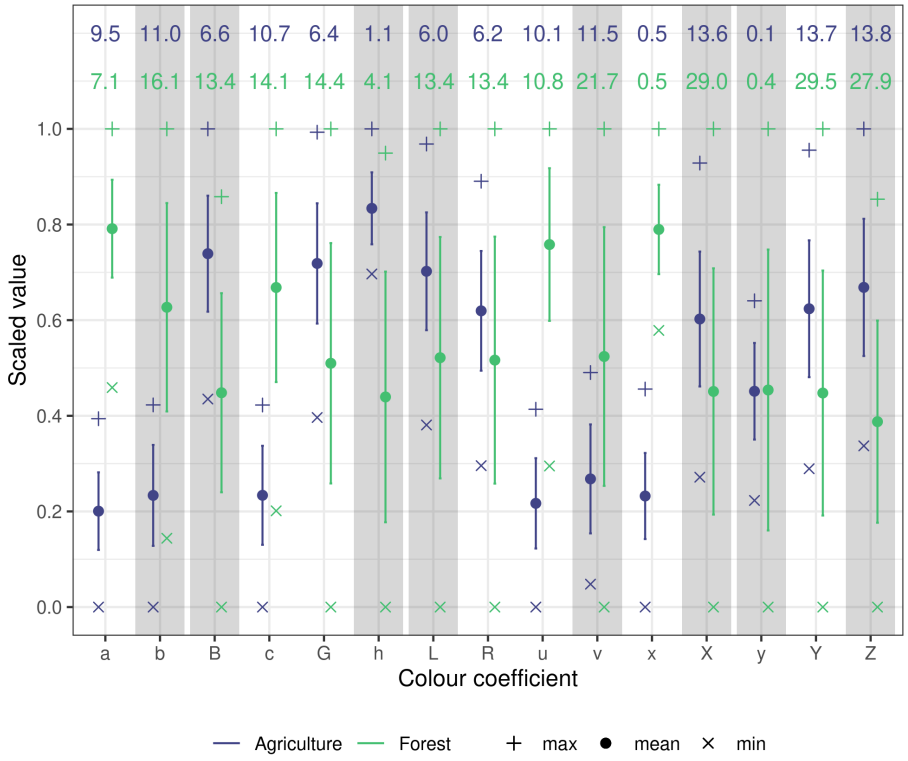
Source: Random Forest results

References

Supplemental materials



Summary statistics of all measured geochemical soil properties at both sites. Error bars represent 1SD and the numeric values indicate the CV.



Summary statistics of all measured colour soil properties at both sites. Error bars represent 1SD and the numeric values indicate the CV.