Reviving the Soil Classification Working Group

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The Canadian System of Soil Classification
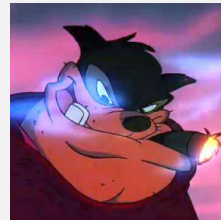
Third Edition

NRC·CNRC

Outline

- Past: Where did the Canadian System of Soil Classification (CSSC) come from?

- Present: Where is the CSSC now?

- Future: Where is the CSSC headed?

- Objective pedologists in a subjective world….

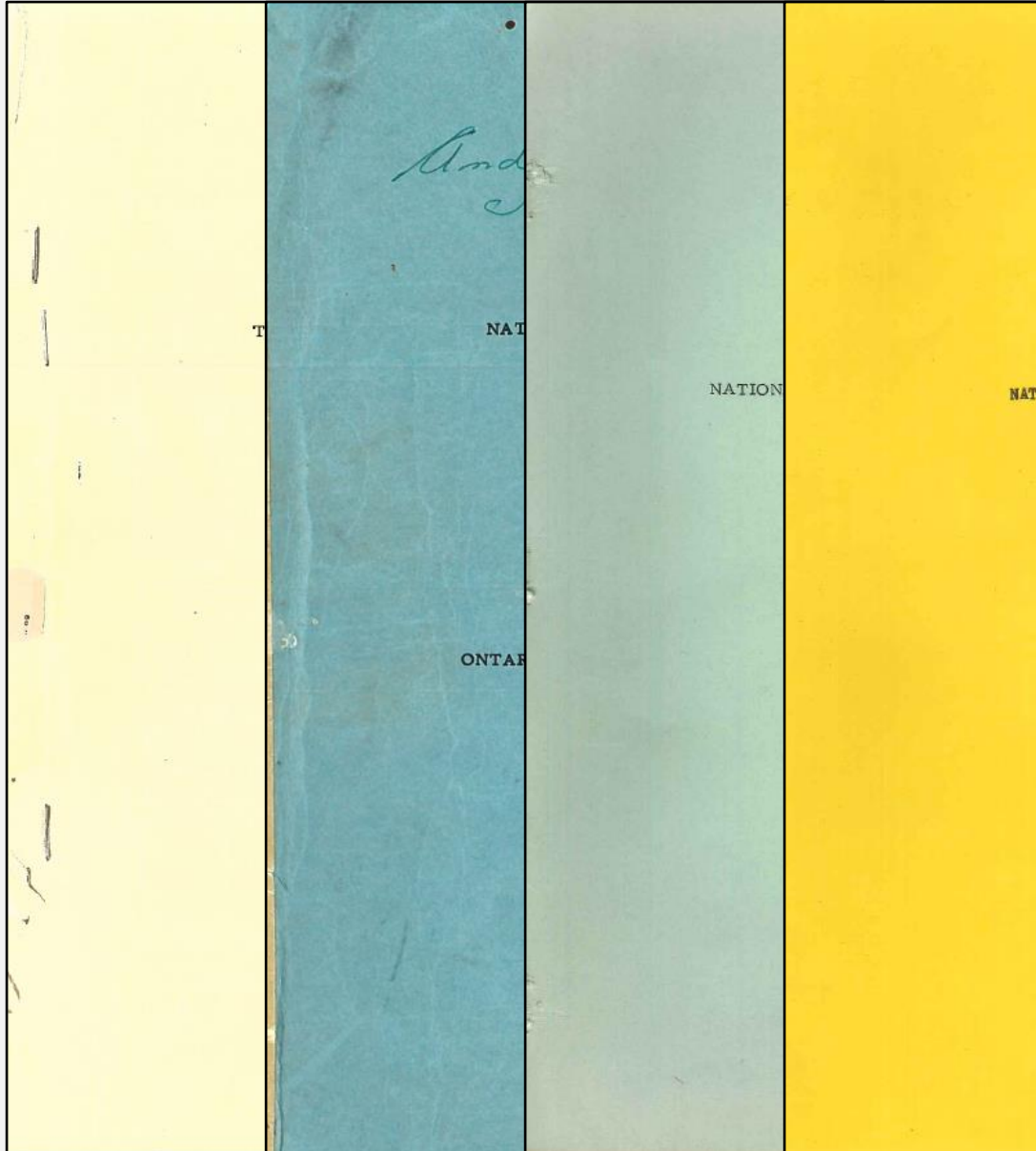# Where did the Canadian System of Soil Classification (CSSC) come from?

Ghost of Pedology's Past

Where did the CSSC come from?

- Development of a soil classification system for Canada was formalized in 1945.

- For 5 decades, Canada had a structured, democratic process in developing and refining our taxonomic system which was overseen by:
    - National Soil Survey Committee (1945-1968)
    - Canada Soil Survey Committee (1970-1978)
    - Expert Committee on Soil Survey (1979-1992)
    - Soil Classification Working Group (1992-1998)

- There were also Western and Eastern Sections – ever notice any regional bias in the orange book….

Soil Classification in Canada

Where is the CSSC come from?

- Dr Leahy's (Chair) opening remarks to the inaugural NSSC meeting (1945):

   "a momentous occasion in the history of soil surveying in Canada"

- Perhaps a telling sign of the struggles ahead, the same we share today, he also noted:

   "our field of work has passed through several vicissitudes...I feel that we have passed the worst of our misfortunes"
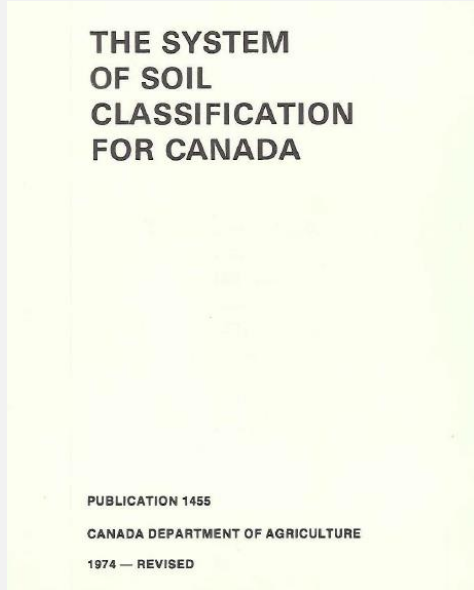
Soil Classification in Canada

- Five "official" iterations of soil classification were published:
  1. System of Soil Classification for Canada (NSSC, 1970)
  2. System of Soil Classification for Canada - Revised (CSSC, 1974)
  3. Canadian System of Soil Classification – 1st edition (CSSC, 1978)
  4. Canadian System of Soil Classification – 2nd edition (ECSS, 1987)
  5. Canadian System of Soil Classification – 3rd edition (SCWG, 1998)

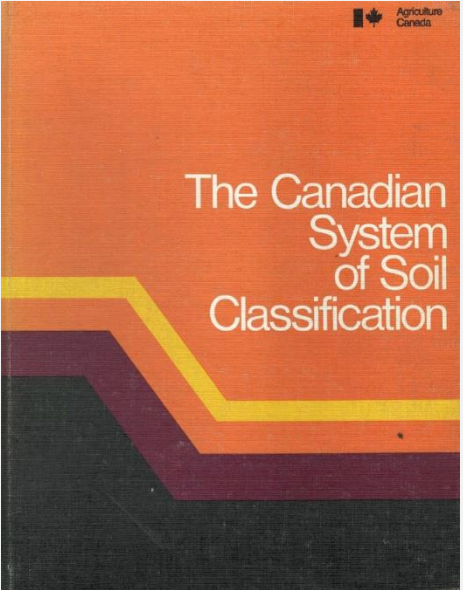# System of Field Classification for Canadian Soils (1945)

- Although never officially published, the first system was proposed in 1945 with six hierarchical levels:

  1. Regions
  2. Zones
  3. Subzones
  4. Associations or Catenas
  5. Type or Class
  6. Phase

System of Field Classification for Canadian Soils (1945)

1. Soil Regions $\longrightarrow$

- **Tundra**: Soils with ever-frozen subsoil

- **Woodland**: Soils developed under forest with organic matter concentrated at the surface

- **Grassland**: Soils developed under grass cover where organic matter is mixed with the mineral fraction

System of Field Classification for Canadian Soils (1945)

1. Soil Regions
2. Soil Zones

Grassland

- Brown
- Dark Brown
- Black

Woodland

- Grey Wooded
- Podsol
- Grey Brown Podsol
- Brown Podsol
- Soils of the Pacific coast

Tundra

?

System of Field Classification for Canadian Soils (1945)

1. Soil Regions

2. Soil Zones

3. Soil Subzones – climatic or vegetative changes, e.g., "Deep" vs "Shallow" black zones

4. Soil Associations or Catenas – drainage, salinity, degradation, where individuals are "series"

5. Soil Type or Class – textural variations

6. Soil Phase – stoniness, topography, etc.

This really highlights the fact our system has **not changed drastically** since inception

System of Soil Classification for Canada (1970 & 1974)

1. Soil Order
2. Soil Great Group
3. Soil Subgroup
4. Soil Family
5. Soil Series
6. Soil Phase

- **Chernozemic**
- **Solonetzic**
- **Luvisolic**
- **Podzolic**
- **Brunisolic**
- **Regosolic**
- **Gleysolic**
- **Organic**

Canadian System of Soil Classification (1978)

1. Soil Order
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3. Soil Subgroup
4. Soil Family
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- **Chernozemic**
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- **Brunisolic**
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- **Gleysolic**
- **Organic**

+ Cryosolic

Canadian System of Soil Classification (1998)

1. Soil Order
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- **Chernozemic**
- **Solonetzic**
- **Luvisolic**
- **Podzolic**
- **Brunisolic**
- **Regosolic**
- **Gleysolic**
- **Organic**
- **Cryosolic**

+ Vertisolic

Soil Classification in Canada

- Since 1998, no organization has taken responsibility for the CSSC

- There has also been a decline in expertise in the public sector, which was largely responsible for the CSSC and the legacy of the development of our national taxonomic system

- In response, the Pedology Committee (previously Canadian Land Resource Network) was created in 2005 and accepted the mandate of updating soil taxonomy in Canada

Where is the CSSC now?

**Ghost of
Pedology's Present**

Pedology Committee

- Committee under the Canadian Society of Soil Science (https://csss.ca/pedology-committee/)

- Co-chairs: Dr. Angela Bedard-Haughn (academia) & Daniel Saurette (government)
- Secretary: Dr. Brandon Heung (academia)

- Mandate of the Pedology Committee:
  1. Improvement of the taxonomic classification system for Canadian soils through revision of the system supported by new information.
  2. Maintenance of contact with the international pedological community on new developments in soil genesis and classification.
  3. Compilation and dissemination of information about the genesis, distribution, classification and wise use of Canadian soils.

Pedology Committee

- Five major achievements since the mid-2000s

    1. Soils of Canada website (https://soilsofcanada.ca/)

    2. Special Issue of the CJSS in 2011 (https://cdnsciencepub.com/toc/cjss/91/5)

    3. Archiving the NSSC, CSSC and ECSS conference proceedings (https://soilsofcanada.ca/link_items/national-soil-survey-committee-annual-meeting-proceedings.php)

    4. Archiving iterations of the Canadian System of Soil Classification (https://soilsofcanada.ca/link_items/canadian-system-of-soil-classification---edition-archive.php)

    5. Special Collection of the CJSS in 2022 – Advances in Soil Survey and Classification in Canada (https://cdnsciencepub.com/topic/cjss-soil-survey)

Pedology Committee

- In 2018, the Pedology Committee prioritized developing the 4th edition of the CSSC

- Initial meetings with small group in 2019 to initiate the project

- Contact initiated with current publisher to have copyright assigned to CSSS

- Consensus was that any Major Revisions required peer-review publication
  - Special Collection!! https://cdnsciencepub.com/topic/cjss-soil-survey
  - Guest Editors: Bedard-Haughn, Heung, Bulmer, Saurette

- Minor revisions could be submitted through a form and reviewed

Soil Classification Working Group

- January 2023, launched the Working Group

- Why re-invent the wheel? – Soil Classification Working Group

- Open to any interested soil scientists/pedologists
  - Emails went out through societies and private sector contacts
  - If interested, email csss.pedology@gmail.com

- Mandate is to review, discuss, and debate the proposed revisions, with initial focus on 10 manuscripts published in CJSS (special collection)

Soil Classification Working Group

- What does the SCWG look like:
  - 82 participants
  - 9 provinces
  - 24% private sector (key)
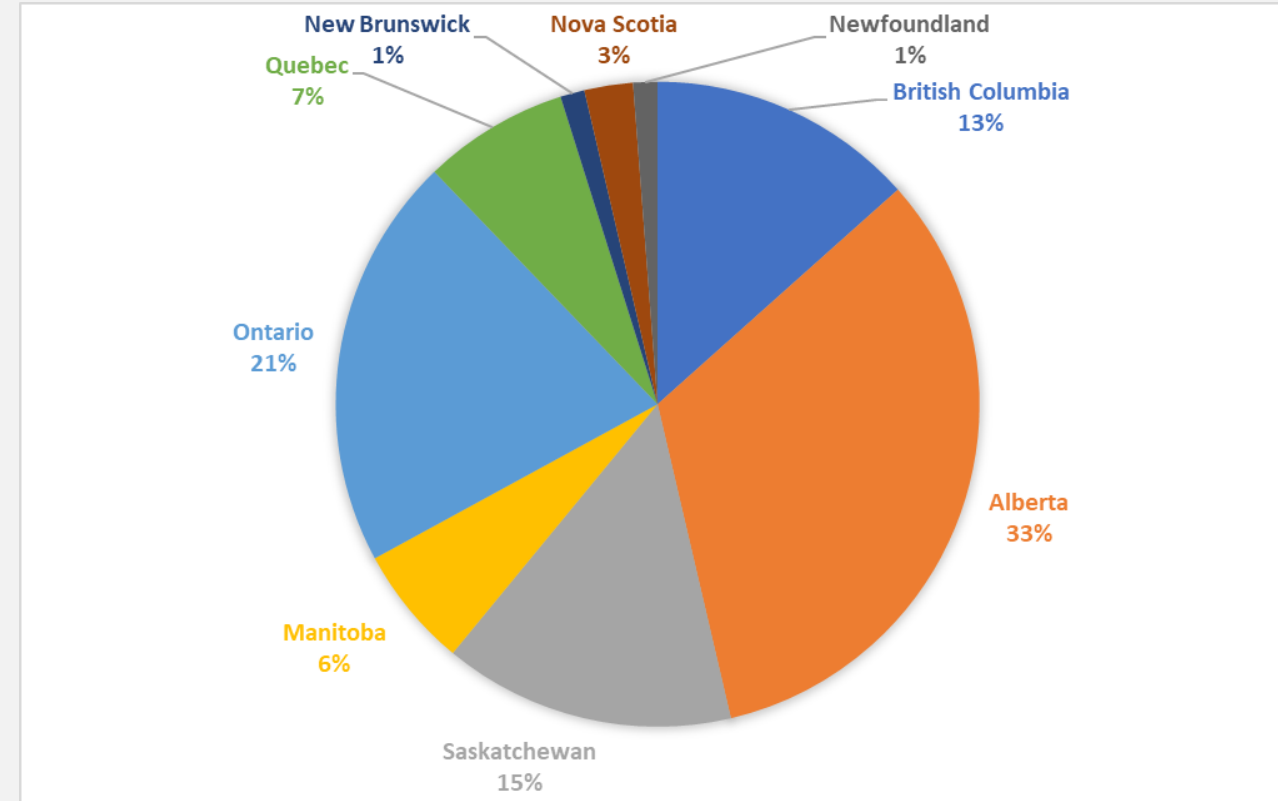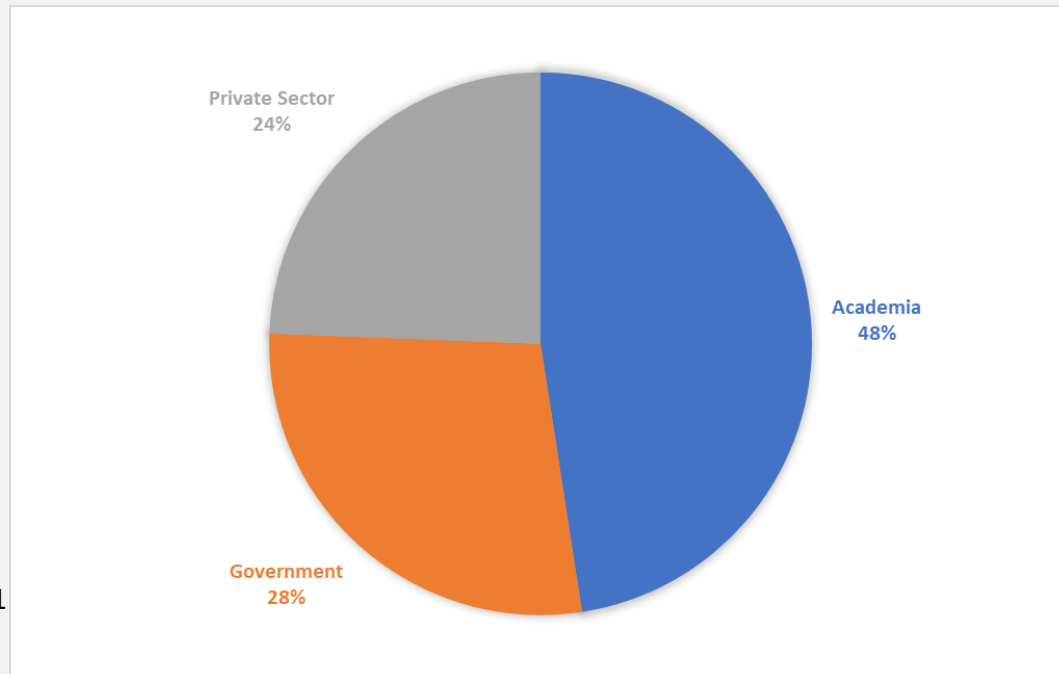
- Good balance of experience from early, mid, late career scientists and retirees

Soil Classification Working Group

- Schedule: Third Friday of every month, 12-2pm (eastern), Zoom Meeting
- Upcoming Sessions:

Date	Topics
March 17	1. Non-illuvial Bt horizons 2. Luvisols are Polygenetic
April 21	1. Leptosols 2. Updating artwork, diagrams, and photos
May 19	1. Soil Family Updates 2. Update from the Anthroposol Working group
June 16	1. Review of Minor Changes (online submissions) 2. Update from the Mottles & Gley Working Group

Soil Classification Working Group

- [Google Drive](#) set up with reference materials
  - Recorded meetings – YouTube
  - Slide decks
  - Reference Articles from CJSS

- The Process
  - Authors provide 15-minute presentation of their proposal
  - Discussion and debate, typically lasts ~45 minutes
  - Chairs work with author(s) on revisions to proposal based on discussion
  - Recap email goes out with link to register a vote

Soil Classification Working Group

- Revision and publication – target 2025
  - CSSS will hold copyright of the third edition of CSSC (being assigned from CSP, previously NRCan), and future editions
  - Editorial team will be created
    - Incorporate accepted revisions
    - Review existing manual and correct issues (there are many!!)
    - Update all diagrams and photos
    - Compile new document
  - Vision is an Open Access document, likely through PressBooks
    - Electronic PDF and e-book format, with print-on-demand option
    - PressBooks gives us control of the document and it can be updated as needed

Where is the CSSC headed?

A Glimpse at Pedology's Potential Future

1. Revised Proposed Classification for Human Modified Soils in Canada: Anthroposolic Order

Naeth, Leskiw, Brierley, Warren, Keys, Dlusskiy, Wu, Spiers, Laskosky, Krzic, Patterson, Bedard-Haughn;
https://doi.org/10.1139/CJSS-2022-0033

- Human modified soils have been added to soil classification systems around the world

- There is a need for these soils to be recognized in Canadian soil classification

- This paper revises the proposal from Naeth et al. (2012) after field testing and consultation with pedologists across Canada

- Working Group focused on this new Order, email Anne Naeth if interested!!

26

2. Proposed New Soil Order – Leptosolic Order for CSSC

Warren, Saurette, Heck and Comeau; https://doi.org/10.1139/CJSS-2021-0186

- Shallow soils are recognized as Leptosols in the World Reference Base system

- Despite the abundance of shallow soils in Canada, they are only recognized at the soil family level (which typically is ignored in CSSC)

- This paper proposed recognizing a Leptosolic Order for soils with <25 cm material over a leptic contact

3. Time for Non-Illuvial Bt Horizons?

Pennock and Fisher; https://doi.org/10.1139/cjss-2021-0088

- Bt horizons in CSSC must be formed through the process of lessivage

- An analysis of a Luvisolic catena in SK showed that sandy Ae/Bm overlying IIBt horizons contributed negligible clay to the IIBt, and suggest lithological discontinuity

- Analysis of lab data from an additional 63 profiles confirms these findings

- Authors recommend broadening the criteria for Bt horizons in CSSC

28

Photo Credit: Pennock & Fisher, 2021
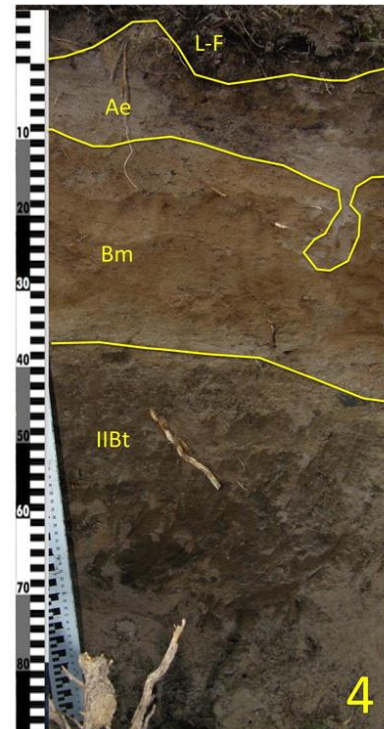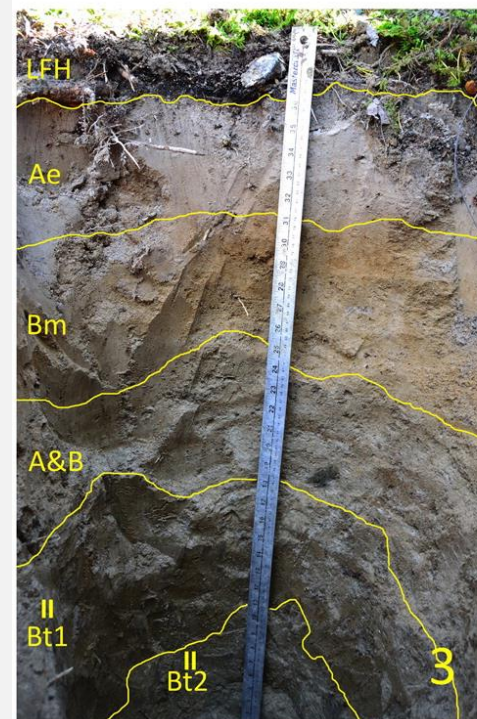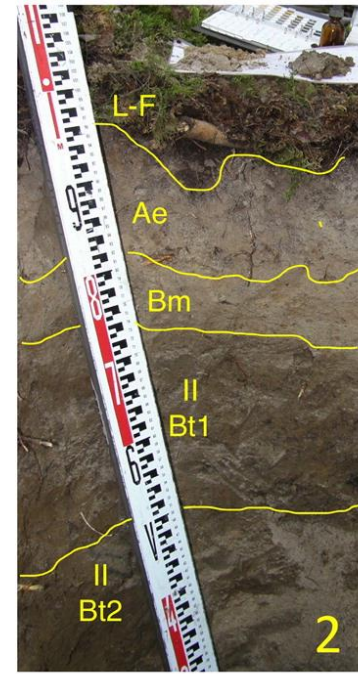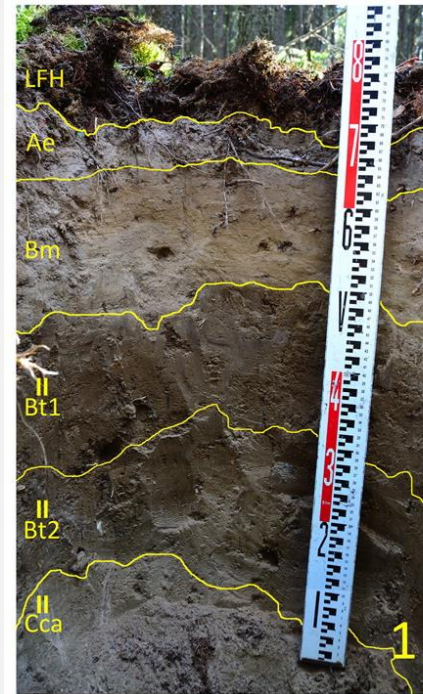
4. A Proposed Folic Subgroup for the Organic Cryosols

Sanborn, Bulmer, Geertsma, and Smith; https://doi.org/10.1139/CJSS-2021-0182

- Organic Cryosols subdivisions mirror that of the Organic Order

- Refinements of the Folisol GG were never reflected in the Organic Cryosols

- Field work in northern Cordillera of BC confirms the need for Folic Organic Cryosol

Photo Credit: Sanborn et al., 2021
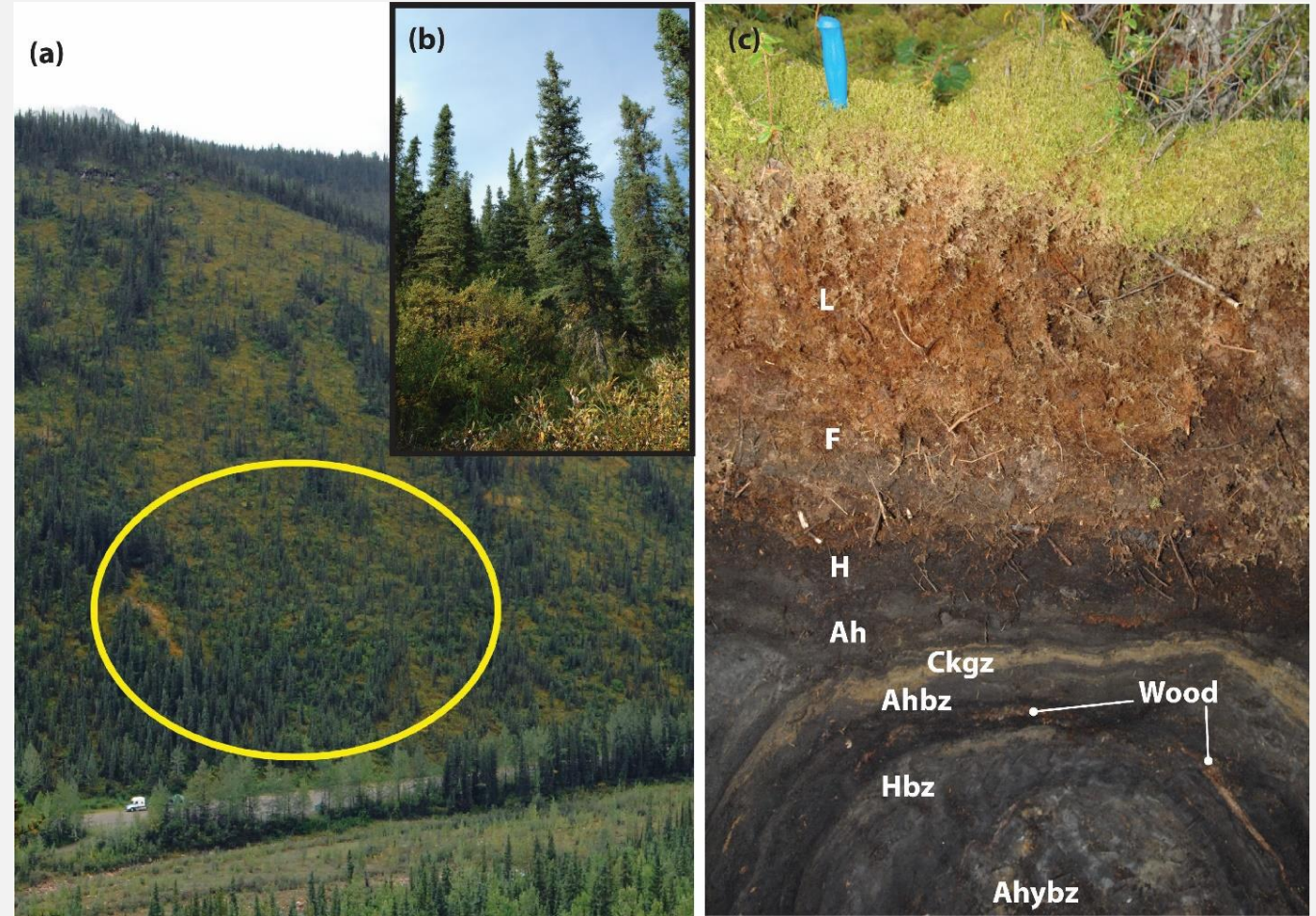
5. Better Recognition of Limnic Materials at the Great Group and Subgroup Levels of the Organic Order of the CSSC

Saurette and Deragon; https://doi.org/10.1139/cjss-2022-0030

- The CSSC recognizes 4 organic horizons: Of, Om, Oh, and Oco

- Only the Oco are not recognized at the Great Group level

- Large organic deposits in Canada have extensive limnic materials that dominate the middle tier, and thus cannot be classified in CSSC

- Authors report a potential of over 32,000 ha in Canada, and proposed adding a new Great Group - Limnisol

6. Proposed Revision to Canadian System of Soil Classification: Broaden Taxonomic Criteria for Applying LFH Horizons to Include Non-Forest Soils

Miller, Chanasyk, and McNeil; https://doi.org/10.1139/CJSS-2021-0152

- LFH to describe surface organic materials was allowed for soils with imperfect to well drainage class in CSSC until the 3rd edition

- LFH were then limited to application in forested soils only

- No-till and native and tame pastures systems show accumulation of organic materials, but lack horizon designations

- Authors propose the broadening the definition of LFH to include non-forested soils

7. A Proposed Framework for Assigning Soil Drainage Classes to Non-Redoximorphic Soils in the CSSC

Saurette, Warren, and Heck; https://doi.org/10.1139/CJSS-2022-0024

- How does a pedologist assign drainage class to soils without redoximorphic features (mottles and gley)? – i.e., MW, W, R, VR

- The CSSC refers to guidance based on AWHC as described in Day 1983, but these ranges are obviously incorrect

- McKeague (1986) provides more realistic ranges of AWHC

- Authors recommend a matrix for assigning drainage classes to non-redoximorphic soils based on texture class and coarse fragment content and depth to bedrock

8. Rationalizing Mottling and Gleying in the Characterization and Classification of Canadian Soils

Heck, Saurette, and Warren; https://doi.org/10.1139/CJSS-2022-0036

- Mottling and gleying are key criteria for the classification of soils in Canada

- Minimal refinement has occurred since the mid-1940s

- Definitions are outdated, as are standards for field characterization of redoximorphic features

- Inconsistencies exist with the CSSC (e.g., "gleyed" vs "gleysolic" subgroups and "Gleysols") and across provincial systems

9. Proposed Revisions to the Soil Family Taxon of the CSSC

Warren and Saurette; http://dx.doi.org/10.1139/cjss-2021-0146

- Family Particle Size classes boundaries to be revised to follow breaks in the soil texture classes
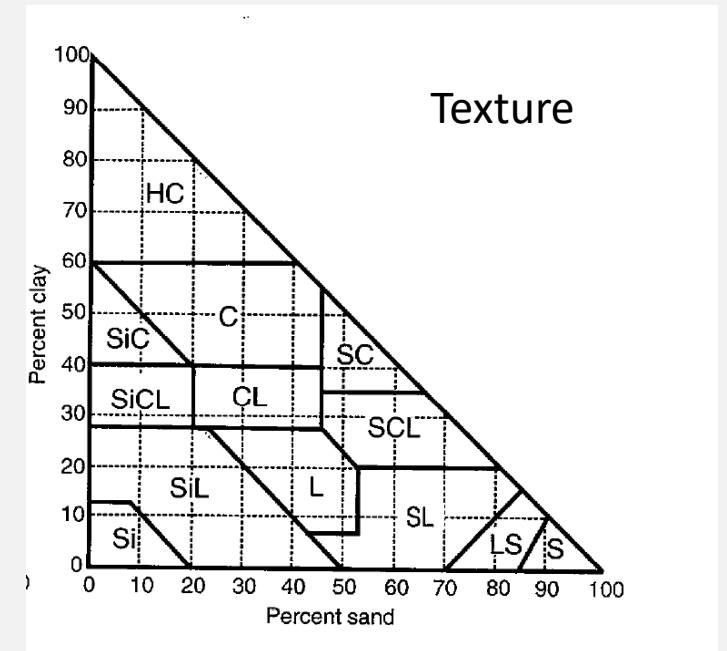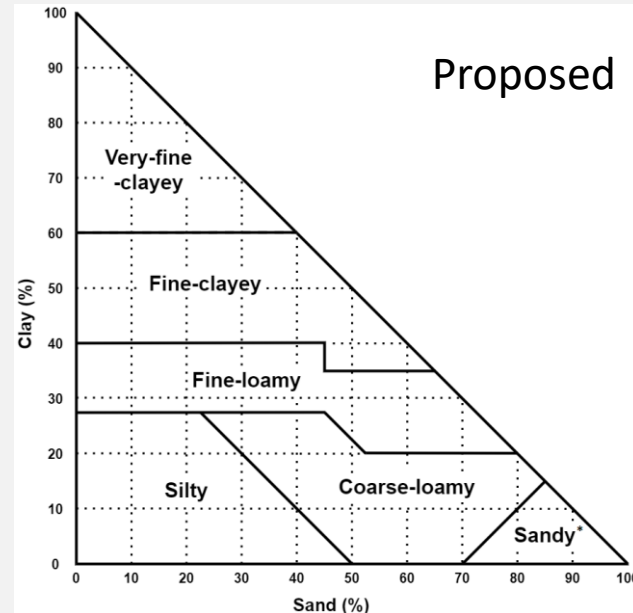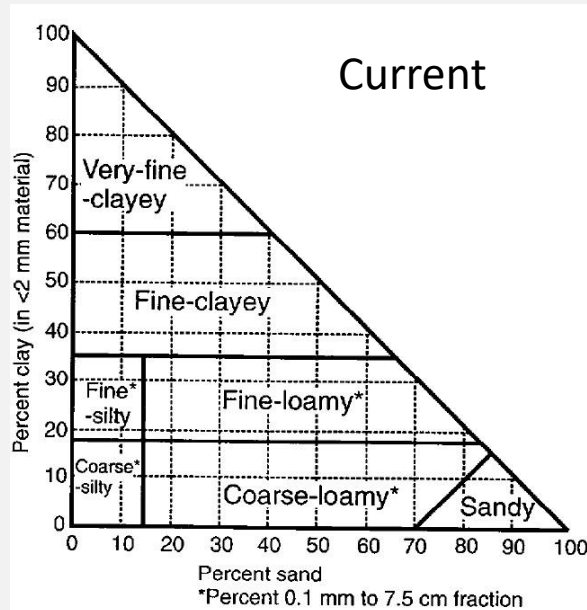
10. Gray Luvisols are Polygenetic

- Propose a polygenetic, 2-stage, model of Gray Luvisol formations:
    1. Through climate forcing of the Holocene; and,
    2. Human-driven disturbances and anthropogenic climate change

- Dark Gray Chernozems and Dark Gray Luvisols have the same diagnostic horizons, with only the thickness of the Ae to differentiate. But if tillage has occurred…

- Propose 2 potential modifications to CSSC:
    - Create a Dark Gray Great Group in the Luvisolic Order
    - Restrict all Dark Gray soil profiles with Bt horizon to the Luvisolic Order, even when a Chernozemic A is present

Objective Pedologists in a Subjective World

Objective Pedologists in a Subjective World

- Access to high performance computing, machine learning, and Big Data provides the tools to re-examine soil taxonomy

- Quantitative evaluation of soil taxonomy is possible

- Quick look at 2 examples:
    1. Pedometric evaluation of soil taxonomy
    2. Global nomenclature algorithms

Pedometric Evaluation

- Based on the concept of taxonomic distance

- Using a soil database with key soil properties and classified profiles, you can determine centroids (in this case mean) for each taxonomic unit of interest

- Then, the multivariate distance can be calculated between the observations and the taxonomic unit they belong to, and the distance to all other groups

- A real example to illustrate the concept

39

Pedometric Evaluation

The Data – 3569 soil profiles with key soil properties and classified to Soil Taxonomy

Soil property	Soil property
Coarse fragments	Exchangeable Mg
Clay content	Exchangeable Na
Silt content	Exchangeable K
Sand content	Exchangeable Mg
Color in RGB triplets	Exchangeable acidity
Organic carbon content	Presence of redox features (based on genetic horizon index
CaCO₃ content	or redox feature property stored in the database)
Gypsum content	
Electrical conductivity	
pH (measured in soil water solutions)	
Cation exchange capacity	Evidence of permafrost (based on genetic horizon index
Base saturation	or permafrost related feature stored in the database)
Exchangeable Ca	

Pedometric Evaluation

- Specific attributes can be plotted based on different groupings

- Here, the Organic C content is plotted for the Mollisol Order, and 5 Great Groups

- We can quickly see that the GG does not conform to the central concept of the Order

- But this is just one soil property...

41

Michéli et al. 2016 https://doi.org/10.1016/j.geoderma.2015.09.008
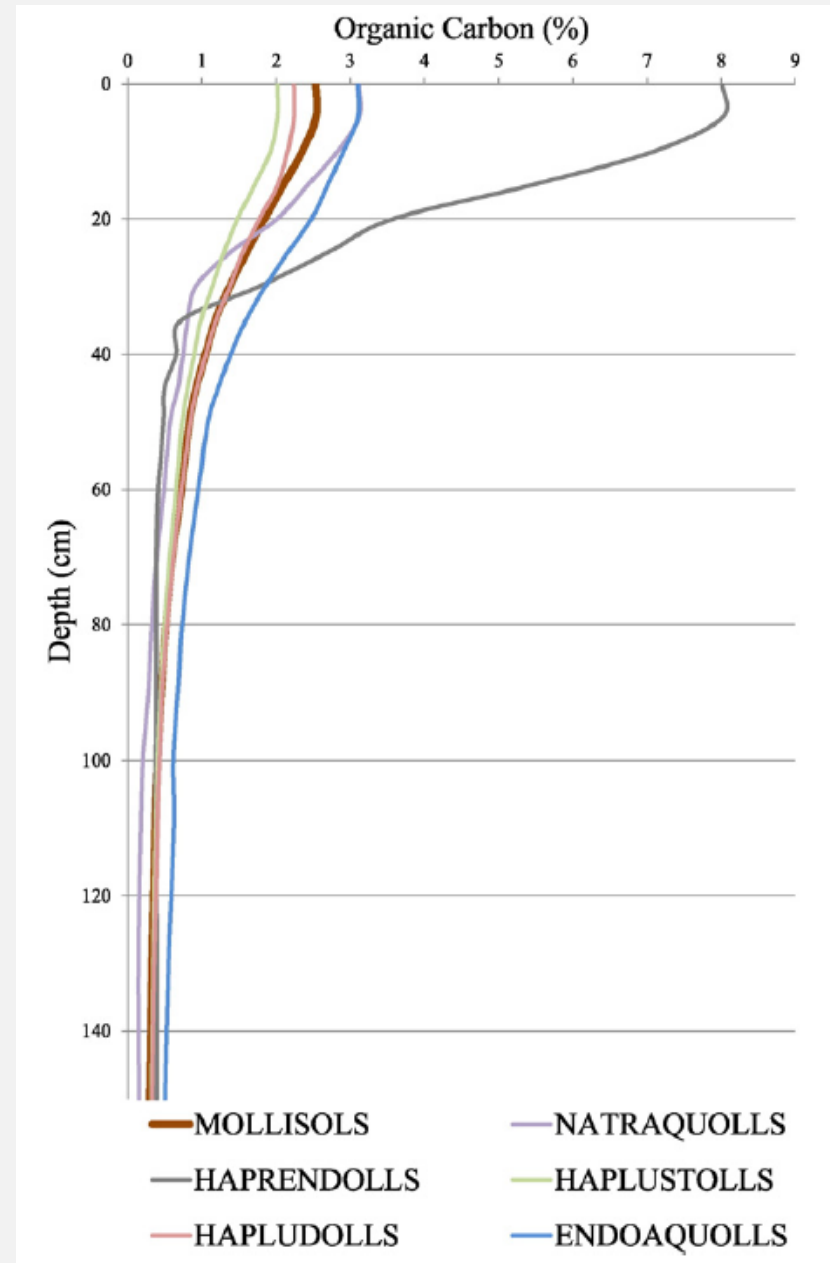
Pedometric Evaluation

- Matrix of distances between the 12 Soil Orders (US Soil Taxonomy)

- Small values indicate similarity, while large values indicate dissimilarity

- Distances are normalized to a range of 0-100

- Histosols and Gelisols stand out

- Others not so much, e.g., Entisols (Regosol) vs Inceptisol (Brunisol) have a distance of only 18

Normalized Mahalanobis distance values between the centroids of the 12 orders of Soil Taxonomy.
(Soil Survey Staff, 2010)

	Vertisols	Ultisols	Spodosols	Oxisols	Mollisols	Inceptisols	Histosols	Gelisols	Entisols	Aridisols	Andisols	Alfisols
Vertisols	0	42	48	46	31	35	92	58	32	28	41	37
Ultisols	42	0	22	24	28	20	97	64	16	35	21	15
Spodosols	48	22	0	31	36	27	100	66	28	39	23	26
Oxisols	46	24	31	0	37	32	92	61	24	38	27	24
Mollisols	31	28	36	37	0	24	95	63	20	25	33	25
Inceptisols	35	20	27	32	24	0	97	63	18	31	28	18
Histosols	92	97	100	92	95	97	0	85	95	99	95	97
Gelisols	58	64	66	61	63	63	85	0	58	57	58	63
Entisols	32	16	28	24	20	18	95	58	0	23	22	13
Aridisols	28	35	39	38	25	31	99	57	23	0	34	29
Andisols	41	21	23	27	33	28	95	58	22	34	0	24
Alfisols	37	15	26	24	25	18	97	63	13	29	24	0
Mean	41	32	37	36	35	33	87	58	29	37	34	31

42

Michéli et al. 2016 https://doi.org/10.1016/j.geoderma.2015.09.008

Pedometric Evaluation

- Histosol Great Groups vs Soil Orders

- Look at relationships between different levels of the taxonomy

- In this case, all Histosol Great Groups are closest to the Histosol Order

- This is expected, organic soils are chemically and physically quite different from mineral soils

Normalized Mahalanobis distance values between the centroids of great groups of the Histosols order to the centroids of all orders of Soil Taxonomy.
(Soil Survey Staff, 2010)

|	Vertisols	Ultisols	Spodosols	Oxisols	Mollisols	Inceptisols	Histosols	Gelisols	Entisols	Aridisols	Andisols	Alfisols
Udifolists	64	65	67	63	62	66	**58**	64	64	65	64	66
Sulfisaprists	50	53	53	52	53	54	**45**	52	52	52	51	53
Sulfihemists	62	64	65	63	65	65	**62**	63	64	64	63	65
Haplosaprists	32	36	36	36	34	34	**26**	39	35	36	35	35
Haplohemists	36	41	41	39	39	38	**29**	38	38	39	41	39
Cryosaprists	44	45	43	44	43	44	**46**	49	45	46	45	45
Cryohemists	49	49	48	50	51	48	**49**	54	50	53	48	48
Cryofolists	44	45	44	44	45	46	**34**	37	44	44	43	45
Mean	48	50	50	49	49	49	**44**	50	49	50	49	49

Pedometric Evaluation

- Robust and quantitative evaluation of existing taxonomic system

- Can identify where differentiating criteria are maybe not as clear in the real world as they are in our conceptual frameworks

- These analyses could provide quantitative reasoning for reconsidering or re-evaluating taxonomic relationships

- Still some subjectivity – assigning the key soil properties!!

44

Global Nomenclature Algorithms

- Designed to harmonize different taxonomic systems into a new, overarching system

- Driven by the IUSS project to develop a Universal System of Soil Classification

- Similar to the previous approach, databases of soil profiles with key soil properties and taxonomic assignment are used

- In this case, multivariate distances are used to develop a dendrogram from the profile data, and using a bottom approach, individuals a grouped, then groups are re-groups into larger and larger groups to eventually form "supergroups"

Global Nomenclature Algorithms

- Algorithm builds a "tree" where individual taxonomic units are the "leaves", and distance is used to create groups

- In this example, New Zealand, Australia, World Reference Base and Soil Taxonomy were evaluated

- Once developed, the algorithm can be used to classify "unknown" profiles

- Can also be used to assess similarities between different taxonomic systems

46

Hughes et al. 2018 https://doi.org/10.1016/j.geoderma.2018.02.020
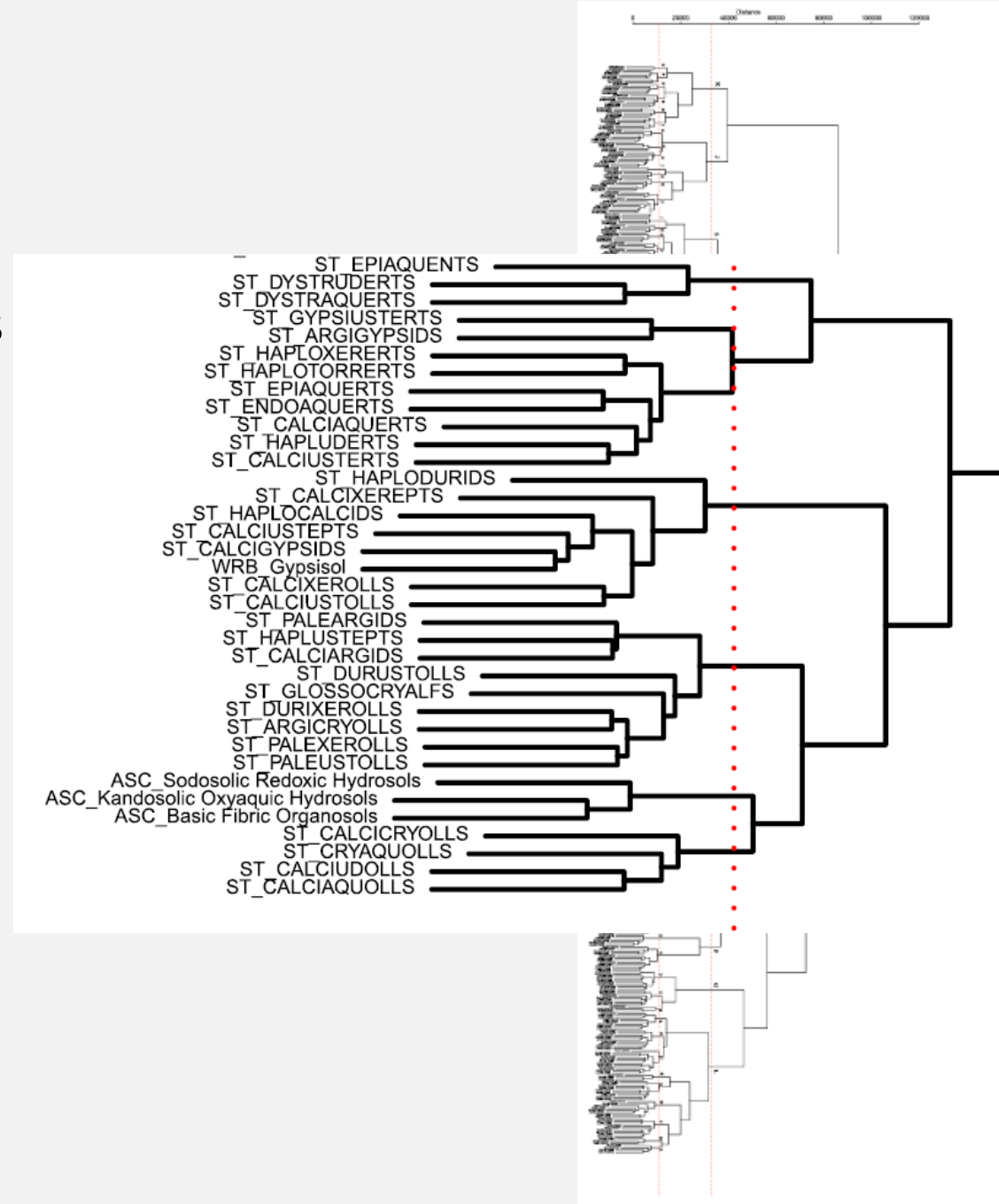
Concluding Remarks

- Soil classification in Canada advanced in-line with other international systems until 1998

- Soil classification in Canada stalled with the retreat of government oversight

- Many new exciting changes are being proposed for the 4th edition, and we aim to make future updates much easier to propose

- Quantitative soil taxonomy is providing new insight and understanding of theoretical frameworks for soil classification. There is huge potential to explore these new tools.

Reviving the Soil Classification Working Group

I would like to acknowledge the work of:

1. Authors of the soil classification papers in the Special Issue of CJSS 2022

2. Drs. Bedard-Haughn and Heung

3. All participants in the SCWG meetings!

Thank you!!!