New A Horizon Protocols for Topsoil Characterization in Canada

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Abstract
A new framework for addressing topsoil characterization was developed to provide enhanced capability in A horizon lowercase suffixes for tracking changes and impacts from environmental and anthropogenic stressors especially at landscape and watershed scales. Critical to sustaining agricultural crop and forestry production, the A horizon is the first mineral horizon to respond to these stressors leading to topsoil changes in physical, chemical and biological processes and soil properties. A new system comprised of four levels of lowercase suffixes was developed as an outcome of workshops held in Canada and Germany, review by soil classification and mapping experts and field testing. The first level of new lowercase suffixes identifies genetic processes and impacts from anthropogenic/industrial activities; the second level records the kind of primary soil structure; the third level, range classes of per cent organic matter; and, the fourth level, range classes for pH (0.01 M $CaCl_2$). Examples of the new A horizon lowercase suffixes are shown for selected Canadian soils. The new framework will provide enhanced taxonomic protocols for topsoil characterization of A horizons when undertaking detailed monitoring and assessment studies in determining the effectiveness of remedial measures and beneficial management practices.

Key Words
Horizon suffixes, soil profile descriptions, soil taxonomy, soil change, soil functioning, climate change

Introduction

The A horizon is the dominant portion of the topsoil (upper 30 cm) and the most critical for crop and forestry production. It is essential that its chemical (i.e. nutrients), physical (i.e. morphology), and biological (i.e. soil biota) functioning is ensured for long-term sustainability of food and livestock production and for maintaining forested areas for economic and recreational needs. The A horizon is the first mineral horizon of the topsoil to be impacted by 1) changes in the kinds, duration and intensity of cropping and tillage management systems, forestry, or anthropogenic/industrial activities and 2) changes in climate that can lead to a range of impacts on soil physical, chemical and biological properties and soil functioning.

In many classification systems, in agricultural soils, the A horizon is frequently described as an Ap horizon and, in undisturbed areas, as an Ah. From a taxonomic perspective, major changes in physical, chemical or biological soil properties are not easily included as part of the A horizon designation. Currently, there is no mechanism to capture the essence of such changes in the A horizon designation; the Ap or Ah horizon would still be described taxonomically as either an Ap or Ah. This restricts detailed field characterization especially at watershed scale where remedial soil measures or beneficial management practices have been introduced and one is required to identify major changes in soil properties across the landscape.

We have hypothesized that enhanced horizon designations for soil properties will provide improved capability for tracking changes from environmental and anthropogenic/industrial stressors. This paper will present a new framework for addressing A horizon lowercase suffixes for topsoil characterization.

Methods

Workshops were held both in Canada and Germany during 2008-2010 to define enhanced A horizon lowercase suffixes with respect to identifying critical physical, chemical, biological and anthropogenic processes and attributes. Based on field expertise, reviews of soil horizon descriptions, pedon information and literature sources, new lowercase suffixes for the following A horizon properties were identified: 1. genetic properties 2. soil structure, 3. organic matter and 4. pH. In addition, a framework for lowercase suffixes has been developed,

reviewed by experts in soil classification and mapping, and field tested to refine the new system. This new system for A horizon lowercase suffixes is based on information obtained from both field observations and laboratory analyses.

Results

The new system for enhanced A horizon lowercase suffixes based on a framework of levels is shown in Table 1.

Table 1. Enhanced taxonomic protocols for A horizon description of properties.

First Level	Second Level	Third Level	Fourth Level
Genetic Process: Physical, chemical, biological, or anthropogenic	[Soil Structure]	(% Organic Matter)	{pH in 0.01 *M* $CaCl_2$}
Select lowercase suffix(es) as needed to describe the important soil process(es) observed: Choose from: b; ca; d; e; g; h; i; k; n; o; p; q; r; s; sa; u; w; y; z [A] See lowercase suffix definition below.	[pl]: platy [pr]: prismatic [cpr]: columnar [bk]: blocky [abk]: angular blocky [sbk]: subangular blocky [gr]: granular [cr]: crumb [sg]: single grain [m]: massive	(xl) Extremely Low (< 2%) (lw) Low (2 to < 5 %) (m) Medium (5 to < 9 %) (h) High (9 to < 17 %) (vh) Very High (> 17 to < 29%)	{xa} Extremely Acid pH < 4.5 {sa} Strongly Acid pH > 4.6 ≤ 5.5 {wa} Weakly Acid pH > 5.6 ≤ 6.5 {n} Neutral pH > 6.6 ≤ 7.3 {c} Calcic pH > 7.4 ≤ 8.4 {k} Alkaline pH > 8.5
Example syntax: Ah Ap	Example syntax: Ah[cr] Ap[bk]	Example syntax: Ah[cr](h) Ap[bk](xl)	Example syntax: Ah[cr](h){xa} Ap[bk](xl){wa}

[A] Definition of lowercase suffix

b: Buried soil horizon; ca: Secondary carbonate enrichment; d: Enriched with displaced B or C materials; e: Eluviation of clay, Fe, Al or organic matter; g: Gleying with grey colours and/or prominent mottles; h: Enriched in organic matter (> 2% to < 29 %; % OM = 1.728 x % Organic C); i: Anthropogenic transport of materials from habitation/industrial activities; k: Presence of carbonate; n: Prismatic or columnar structure with Ca:Na ≤ 10; o: Formed through mass movement of soil on slopes; p: Affected by agricultural activities; q: Prominent fungal hyphae and mats throughout; r: Affected by forestry activities such as logging; s: Presence of salts, gypsum; sa: Secondary enrichment of soluble salts; u: Affected by soil fauna activity throughout; w: Disturbed by natural blow down of trees; y: Affected by cryoturbation related to permafrost; z: Frozen layer.

Framework protocols for assigning A horizon lowercase suffixes (Refer to Table 1):

1. **First level**: The first level identifies the dominating processes observed related to genetic soil development (i.e. physical, chemical and biological processes) and anthropogenic activities. Following the horizon designation, choose the lowercase suffix that characterizes the most dominant process (i.e. Ah, Ap, Ae). Choose additional suffixes according to the next most prominent process(es). For example, Aphu identifies an A horizon under agricultural cultivation enriched by organic matter with prominent evidence of faunal activity.

2. **Second level**: Soil structure was selected for the second level as structure was deemed an essential indicator relating to information about pore and aggregate formation and the soil's potential for surface water and air infiltration. The kind (or type) of primary soil structure is recorded within square brackets following the first level lowercase suffixes; i.e. Aphu[gr] identifying granular primary structure. The lowercase suffixes for structure were limited to primary structure. Primary structure observations tend to be more stable with time and to be more representative of major morphology patterns influencing overall pores and aggregates. In addition, primary structure information is recorded in soil databases for most soils. The detailed profile description and

soil database are always available, if needed, for additional information pertaining to size and grade of soil structure and any secondary structures.

3. **Third level**: Organic matter status is entered at the third level to provide information that relates to the soil's potential for nutrients, carbon sequestration and promotion of soil biota populations and biological activity. The per cent organic matter is recorded as a range class using round brackets and is placed following the structure lowercase designation: i.e. Aphu[gr](m) identifying a medium organic matter status within range of 5 to 9%. Note: the conversion factor is as follows if organic carbon data is available: % OM = 1.728(% OC).

4. **Fourth level**: Soil reaction class: pH is recorded as the fourth level lowercase suffix providing information relating to the soil's chemical influence on nutrient availability and mineralization as well as identifying the limitations on soil habitat for supporting specific soil fauna and micro-organisms. Following the third level lowercase suffix designation, pH is recorded as a range class within curly brackets (or braces): i.e. Aphu[gr](m){n} identifying a neutral pH range.

Table 2 shows some examples of applying the new framework for A horizon lowercase suffixes

Table 2. Application of new A horizon lowercase suffixes to selected Canadian soils.

Examples: Selected Canadian Soils (WRB-FAO classification in brackets)	[A] CSSC-98 Designation and Depth (cm)		New Enhanced A Horizon Designation
1. Rego Dark Brown Chernozem (Calcic Kastanozem) Lethbridge, Alberta; lacustrine sediments; loam; dryland agriculture with irrigated cropland. (Peters et al. 1978)	Apk	0-20	Apkh[sbk](lw){c}
2. Orthic Black Chernozem (Haplic Chernozem); Porcupine, Alberta; glacial till; clay loam; native pasture. (Peters et al. 1978)	Ah	0-14	Ah[pr](h){n}
3. Orthic Turbic Cryosol (Gelic Cambisol); Yukon; mixed loess and alluvium; cleared forest; agricultural field. (Tarnocai et al. 1993)	Ahy	0-5	Aphy[gr](h){n}
4. Gleyed Eluviated Dystric Brunisol (Gleyic Cambisol); Kentville, Nova Scotia; glacial till; sandy loam; agricultural forage crops. (Acton et al. 1978)	Ap1 Ap2 Aeg	0-11 11-25 25-29	Aph[pr](m){wa} Aph[pr](lw){wa} Aeg[sbk](xl){sa}

[A] Soil Classification Working Group (1998).

The new lowercase suffixes bring valuable additional information with respect to kind of soil structure, extent of organic matter, and pH status for better understanding of the A horizon. One now has enhanced information for the Rego Dark Brown Chernozem that the A horizon is enriched with low amount of organic matter; has as primary soil structure subangular blocky structure; and has a calcic pH status. Within the context of irrigated cropland, from the A horizon designation, one can interpret that monitoring may be required for crop growth conditions with increased pH and low organic matter and the potential for irrigated water loss through structural cracks. The Orthic Black Chernozem under native grasslands has prismatic primary structure, high organic matter and neutral pH status common for chernozemic A horizon. The Orthic Turbic Cryosol is an example from a forested location cleared for cropland; the new enhanced A horizon designation identifies the agricultural activity and forest history with high organic matter status. The Gleyed Eluviated Dystric Brunisol has three A horizons. The enhanced lowercase suffixes for the Ap1 and Ap2 horizons indicate enrichment in organic matter from the parent material and are both similar with respect to primary soil structure, and pH status. However, the organic matter range class differs for the Ap1, with medium class, and for the Ap2, a low organic matter class; hence, the numerical suffixes (1 and 2) in the new A horizon designation were not included.

Conclusion

International and national soil classification systems have hardly considered improved characterization protocols for topsoils. The FAO Draft (1998) for enhanced surface horizon descriptions is available for international verification and assessment for suitability for inclusion into national systems such as the review by Broll et al (2006) from the German context. The FAO Draft (1998) presents terminology and coding to provide enhanced soil names for topsoil characterization. The new framework with four levels of lowercase suffixes will now further the capability for enhancing topsoil characterization by including critical information about the A horizon with respect to soil development and attributes related to primary soil structure, organic matter and pH.

In applying the framework of enhanced A horizon lowercase suffixes, detailed field and chemical databases can be accessed to establish baseline properties for A horizons with relation to the different classifications levels from soil order to soil types. The lowercase suffixes within the new A horizon designation framework will be key for providing enhanced information for making field and mapping interpretations related to the extent of water infiltration properties and availability of nutrients, potential for organic carbon sequestration and soil conditions for promoting soil biodiversity. The new framework will provide enhanced taxonomic protocols for undertaking detailed monitoring and assessment studies of topsoils at landscape and watershed scales to track changes and record impacts from environmental and anthropogenic stressors.

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References

Acton CJ, Beke GJ, Day JH, MacDougall JI, Marcoux R (1978). 'Guidebook for a soil and land use tour of Eastern Canada, Tour 1 and 10.' 11th Congress International Society of Soil Science, Edmonton, Canada (Eds. DF Acton, LS Crosson) (Saskatchewan Institute of Pedology: Saskatoon) 188 pp.

Broll G, Brauckmann H-J, Overesch M, Junge B, Erber C, Milbert G, Baize D, Nachtergaele F (2006). Topsoil characterization – recommendations for revision and expansion of the FAO-Draft (1998) with emphasis on humus forms and biological features. *Journal of Plant Nutrition and Soil Science* **169,** 453-461.

Food and Agriculture Organization of the United Nations (1998) 'Topsoil characterization for sustainable land management.' (Land and Water Development Division, Soil Resources, Management and Conservation Service: Rome) www.fao.org/AG/aGL/agll/wrb/topsoil.stm.

Peters TW, Shields JA, Ellis JG (1978) 'A tour to observe soil landscapes and cropping systems in Central and Southern Alberta and Southwestern Saskatchewan, Tours 5 and 13.' 11th Congress International Society of Soil Science, Edmonton, Canada (Eds. DF Acton, LS Crosson) (Saskatchewan Institute of Pedology: Saskatoon, SRI No. 652) 171 pp.

Soil Classification Working Group (1998) 'The Canadian system of soil classification.' (Agriculture and Agri-Food Canada: Publ. 1646, Revised) (NRC Research Press: Ottawa), 187 pp.

Tarnocai C, Smith CAS, Fox CA (1993) 'International tour of permafrost affected soils: The Yukon and Northwest Territories of Canada.' (Agriculture Canada, Research Branch: Ottawa, Canada), 197 pp.