IDENTIFYING HYDRIC SOILS IN THE LOWER MAINLAND-FRASER VALLEY, BRITISH COLUMBIA: A COMPARISON OF METHODS

Jace Standish[1] and Julia Alards-Tomalin[2]

ABSTRACT

In the Lower Mainland-Fraser Valley region of British Columbia, the accurate identification of hydric soils is crucial for effective wetland assessment and management amidst intense land use competition. This study compares five methods for identifying hydric soils in the region: USDA Hydric Soil Indicators (NTCHS), soil moisture regime (SMR), Actual Soil Moisture Regime (ASMR), soil drainage class (SDC), and a region-specific method, Lower Mainland-Fraser Valley (LMFV). Since there is no existing absolute standard for hydric soil, the study assessed hydric soil classifications by comparing each method's results against the NTCHS as a standard. The LMFV method exhibited the highest agreement (96%) with NTCHS, demonstrating strong correlation and minimal discrepancy, while ASMR showed the lowest agreement with NTCHS. If we regard NTCHS as the standard, the LMFV is the highest ranking in terms of accuracy, followed by RSMR, SDC, and ASMR. These findings suggest that for the Lower Mainland-Fraser Valley, methods like LMFV, which focus on detailed soil characteristics, may offer superior accuracy for hydric soil identification compared to other methods.

INTRODUCTION

Assessments of jurisdictional wetlands have become increasingly important in the Lower Mainland-Fraser Valley region of British Columbia, Canada, over the last 25 years. The region is located on the southwest coast of British Columbia (Figure 1). The combination of high precipitation, subdued topography, and moderately to slowly permeable soils have favored the development of wetlands. Wetlands covered a significant proportion of the region in pre-settlement times, in the early nineteenth century, but now much of it has been developed for agricultural or urban land use (Boyle et al. 1997; North et al. 1979). Land use competition is intense and accelerating.

Wetlands are administered mainly under Provincial government statutes and regulations, such as the Water

1 J. T. (Jace) Standish, Terrestrial Ecologist, McTavish Resource & Management Consultants Ltd., Jace@mctavishconsultants.ca
2 Julia Alards-Tomalin, Instructor, Renewable Resources, British Columbia Institute of Technology, jalardstomalin@bcit.ca

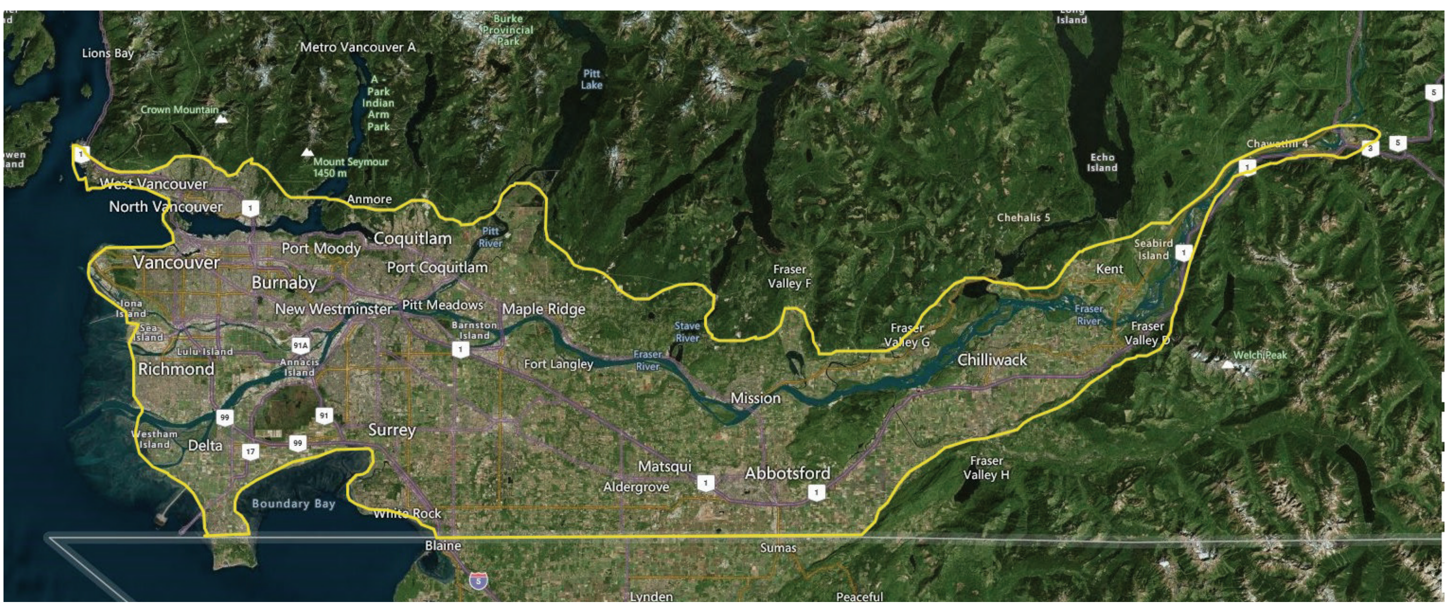

Figure 1. The Lower Mainland-Fraser Valley region in British Columbia, Canada, as referred to in this study (outlined in yellow). Precise locations of soil samples used in this research are not shown with respect to client confidentiality.

Sustainability Act (WSA 2016) and Riparian Area Protection Act (RAPA 1997). Wetland assessment is required before land development is permitted. Most practitioners assess wetlands according to the presence of hydrophytic vegetation, hydric soils, and wetland hydrology: methods like those used by the U.S. Army Corps of Engineers (USACE 1987). Hydric soils are defined as soils formed under conditions of saturation, flooding, or ponding of sufficient duration in the growing season to develop anaerobic conditions in the upper part of the soil profile (USDA 2018).

Hydric soils in the region have been identified by several methods. They include hydric soil indicators (USDA 2018), Canadian pedological soil classification (SCWG 1998), soil moisture regime defined from ecosystem classifications (Pojar et al. 1987; MacKenzie and Moran 2004), and soil drainage classes (Agriculture Canada Expert Committee on Soil Survey 1983). Various combinations of those methods have also been used. The method described below that we call "LMFV" (Lower Mainland-Fraser Valley method) is an example of a combination of existing methods.

The purpose of this paper is to compare hydric soil identification methods used in the Lower Mainland-Fraser Valley region. An obstacle to comparison is that there is no single, absolute standard for identifying hydric soil. We chose to use the United States Department of Agriculture (USDA) Hydric Soil Indicators (USDA 2018) developed by the National Technical Committee on Hydric Soils (NTCHS) as a relative standard for comparison for several reasons:

- It rests on a large and diverse body of soil data,
- It has been used and improved through an expert review process over a period of more than three decades,
- It is thoroughly documented (e.g., Tiner 2017; USDA 2018; WTI 2022), and
- It is well known among many wetland practitioners.

OVERVIEW OF LOWER MAINLAND-FRASER VALLEY SOILS

Soils in the region have been described and mapped at a reconnaissance scale by Luttermerding (1981). Mineral soil parent materials are glacial drift along with post-glacial fluvial deposits. Aeolian cappings are sometimes present. Loamy to clayey soil textures are common. Typical soil taxa in the Canadian System of Soil Classification (SCWG 1998) include Brunisolic, Gleysolic, Organic, Podzolic, and Regosolic soil orders (approximate USDA soil taxonomy equivalents are, respectively, Inceptisols, various aquic suborders, Histosols, Spodosols, and Entisols). Many, but not all, of the mineral soils (including Gleysolic soils and gleyed subgroups of other soil orders) are hydric soils. With the exception of soils in the Folisol great group (the Folist suborder in the USDA soil taxonomy), undrained soils in the Organic soil order are hydric. Many soils have been modified by tillage, on-site or off-site drainage, construction, or other soil disturbances.

Acronyms used in this paper are shown in Table 1.

ASMR	Actual Soil Moisture Regime
BEC	Biogeoclimatic Ecosystem Classification
LMFV	Lower Mainland-Fraser Valley method for identifying hydric soil
NTCHS	(National Technical Committee on Hydric Soils) Hydric soil indicators as defined in USDA (2018)
RME	Reliable Minimum Estimate
RSMR	Relative Soil Moisture Regime
SDC	Soil Drainage Class
SMR	Soil Moisture Regime
WREC	Wetland and Riparian Ecosystem Classification

Table 1. Key acronyms used in this paper.

OVERVIEW OF METHODS OF HYDRIC SOIL IDENTIFICATION

As previously mentioned above, we have defined four methods of hydric soil identification used in the Lower Mainland-Fraser Valley region. We compare their results to those from the NTCHS hydric soil indicators (USDA 2018). An overview of each method is given below. Because the NTCHS method is widely known and well documented (Tiner 2017; USDA 2018) it is not described here. Methods based on soil moisture regimes

(SMRs) and Canadian soil drainage classes (SDC) are briefly described below. Because the LMFV has not been published, it is described in greater detail.

Soil Mosture Regime (SMR)

SMRs are a key component of two major ecosystem classification systems used in British Columbia: the Biogeoclimatic Ecosystem Classification (BEC) system and the Wetland and Riparian Ecosystem Classification (WREC) system. SMR, including both relative soil moisture regime (RSMR) (Krajina 1969; Pojar et al. 1987) and actual soil moisture regime (ASMR) (Klinka et al. 1989; MacKenzie and Moran 2004), have been used in wetland assessments, either by themselves or as a component of ecosystem classifications. For purposes of this paper, hydric soil is defined as soil with very moist, wet, or very wet ASMR or as hygric, subhydric, or hydric RSMR. These definitions gave the greatest degree of similarity to USDA hydric soils.

Relative Soil Moisture Regime (RSMR)

RSMR is an ordinal measure of the average annual amount of soil water annually available for plants over a period of years and is relative to the climate in a Biogeoclimatic Subzone (Pojar et al. 1987). Assessment of RSMR is carried out by field observations, integrating site properties, soil properties, and vegetation (Krajina 1969; Pojar et al. 1987). Soil properties include texture, coarse fragment content, gleying, soil depth, and depth to water table (Green and Klinka 1994). Vegetation is assessed either by comparison to vegetation tables representing advanced seral or climax plant communities, or by indicator species group analysis (Green and Klinka 1994). RSMR is an important element of British Columbia's BEC.

Actual Soil Moisture Regime (ASMR)

ASMR is conceptually similar to RSMR but is not relative to the climate of any one Biogeoclimatic Subzone. It is defined by annual water balance, estimated from meteorological data, and depth to the growing season water table (Klinka et al. 1989). In practice, ASMR is often identified by matching field observations of site, soils, and vegetation to descriptions in field guidebooks (e.g., Green and Klinka 1994). ASMR is incorporated in the BEC and is also an important feature of the WREC (MacKenzie and Moran 2004).

Soil Drainage Class (SDC)

SDCs (Agriculture Canada Expert Committee on Soil Survey 1983) were originally intended to show soil wetness limitations for agriculture crops. They have also been used in wetland assessments as both primary and secondary indicators of hydric soils. SDCs are defined by the Agriculture Canada Expert Committee on Soil Survey (1983) and are more or less similar to Natural Drainage Classes described in Soil Survey Division Staff (1993). Classes are defined according to estimated available water storage capacity and source of soil water. Classes are subjectively assessed in the field based on soil properties, such as texture, coarse fragment content, structure, gleying, and kind of parent material (organic versus mineral), along with site characteristics such as topographic position, slope length, and slope gradient. Very poorly and poorly drained SDCs are considered to represent hydric soils.

Lower Mainland-Fraser Valley Method (LMFV)

The LMFV method is a region-specific, home-grown method that developed out of a need for more detailed criteria for hydric soil assessment in wetland identification and delineation in our area. The LMFV method has been used successfully in the field by wetland practitioners in our region for many years and has undergone periodic revisions. It is based on the hydric soil criteria presented in the WREC system (MacKenzie and Moran 2004) but with additional details added. The Canadian pedological soil classification (SCWG 1998) has useful information applicable to hydric soils that was used to supplement the WREC criteria. These additions include specifics around the matrix colours, redoximorphic features, and the degree of decomposition of the organic soil layers. Information from those two sources, augmented by local knowledge, was combined to create the LMFV method. Important features of the LMFV are shown in Table 2.

MINERAL SOILS	1. All soils with chromas predominantly less than (<) 1 in upper 30 cm
	2. Matrix hues in upper 30 cm predominantly 7.5 YR and 10YR with chromas greater than or equal to (≤2) and distinct or prominent mottles ≥ 1 mm in cross-section and occupying ≥ 2 percent (%) of the exposed, unsmeared layer
	3. Matrix hues in upper 30 cm predominantly yellower than 10YR with chromas less than or equal to (≤3) and distinct or prominent mottles ≥ 1 mm in cross-section and occupying ≥ 2% of the exposed, unsmeared layer
	4. Matrix hues predominantly in upper 30 cm bluer than 10Y (mottles may or may not be present
ORGANIC SOILS	Organic soil is defined as 17% organic carbon or 30% organic matter by mass (SCWG 1998). 5. Surface horizon is organic (greater than (>) 17% organic carbon by weight) and a. ≥ 60 cm deep if material is fibric b. ≥ 40 cm deep if material is mesic or humic
ALL SOILS	6. Hydrogen sulfide (H2S) odor [rotten egg smell] is emitted from the upper 30 centimeters (cm) of soil.
	7. Secondary criteria: a. Subhydric or hydric relative soil moisture regime (RSMR) b. OR, Very Moist (VM) or, more commonly, Wet (W) or Very Wet (W) actual soil moisture regime (ASMR) c. OR water table presence ≤ 30 cm from soil surface during growing season.

Table 2. LMFV method for identifying hydric soils in the Lower Mainland-Fraser Valley. Secondary criteria are from MacKenzie and Moran (2004) which, by themselves, do not indicate a hydric soil.

METHODS

Forty-five soils, representing a wide range of soil moisture regimes, drainage classes, and Canadian Soil Classification taxa, were randomly selected from a list of 130 Lower Mainland-Fraser Valley region jurisdictional wetland assessments. Actual SMRs (Klinka et al. 1989) ranged from slightly dry to very wet, RSMR from mesic to hydric. Canadian soil taxa (SCWG 1998) included soils of the Gleysolic, Organic, Podzolic and Regosolic orders and gleyed subgroups of Podzolic and Regosolic soils. USDA Hydric Soil Indicators included A1, A2, A4, S5, F1, F2, F3 and F6.

Soil pits were excavated to a depth of 70 to 100 cm. Where necessary, greater depths were sampled by soil auger. For each soil layer, depth, Munsell colors, texture, percent coarse fragments, redoximorphic features, rooting depth and abundance, and presence of a water table or seepage were recorded following the procedures in Province of B.C. (2010), USDA (2018); and WTI (2022). Degree of decomposition of organic matter was determined with the von Post scale. Each soil was classified as hydric or non-hydric using five methods: NTCHS, LMFV, RSMR, ASMR, and SDC. RSMR and ASMR were determined using methods in Green and Klinka (1994). SDCs were determined from descriptions and guidelines in Agriculture Canada Expert Committee on Soil Survey (1983). The phi coefficient (φ) was used to test the level of agreement (as a binary: agree/disagree variable) between the NTCHS method and the other methods at classifying a soil as hydric or non-hydric. The phi coefficient represents the strength of the association of two binary variables and is related to the chi-squared (χ^2) statistic for a 2 x 2 contingency ($\varphi^2 = \chi^2/n$), with n = the number of observations. The Reliable Minimum Estimate (RME) at the 95% confidence level was calculated to provide a simple, conservative, probabilistic estimate of the minimum percentage of agreement of NTCHS with the other methods. In statistical language, RME is a 1-tailed, lower confidence limit (Dawkins 1957; Husch et al. 1972).

RESULTS AND DISCUSSION

Overview of Soils

Soil taxa, in the Canadian Soil Classification (SCWG 1998) along with their approximate equivalents in the USA (Soil Survey Staff 1975; shown in parentheses) included Gleyed Sombric Brunisols (Humbric Dystrocrepts), Gleysols (Aquents and Aquepts), Humic Gleysols (Aquolls and Humaquepts), Luvic Gleysols

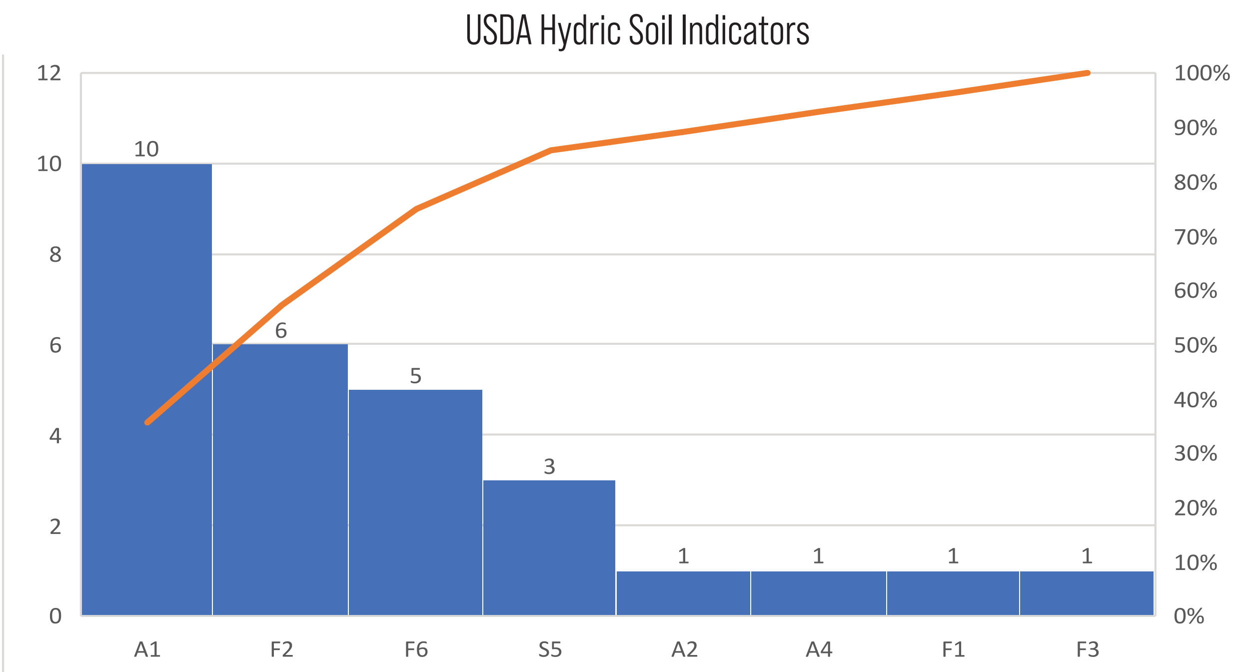

Figure 2. USDA hydric soil indicators (USDA 2018) in the sample are shown in decreasing order of frequency, from left to right. Number of samples is shown on the left-hand vertical axis and at the top of each column. The line shows the cumulative percentage of soils in each class. A1 = Histosols, F2= Loamy Gleyed Matrix, F6 = Redox Dark Surface, S5 = Sandy Redox, A2 = Histic Epipedon, A4 = Hydrogen Sulfide, F1 = Loamy Mucky Mineral, F3 = Depleted Matrix.

(Argiaquolls), Typic and Terric Mesisols (Hemists), one Humic Folisol (Hemist), Humo Ferric and Ferro Humic Podzols (Haplorthods), and Orthic, Humic, and Gleyed Regosols (Entisols). SDCs included moderately well drained (20%), imperfectly drained (11%), poorly drained (39%), and very poorly drained (25%). RSMRs were mostly (60%) hygric, subhydric, or hydric. Soil ASMRs were wet to very wet (41%), very moist (18%), and moist or drier (41%).

Eight USDA hydric soil indicators were sampled and are summarized in Figure 2. Seventy-five percent of the hydric soils were either Histosols (A1), Loamy Gleyed Matrix (F2), or Redox Dark Surface (F6).

Figure 3 shows the number of hydric and non-hydric soils classified by each of the five methods.

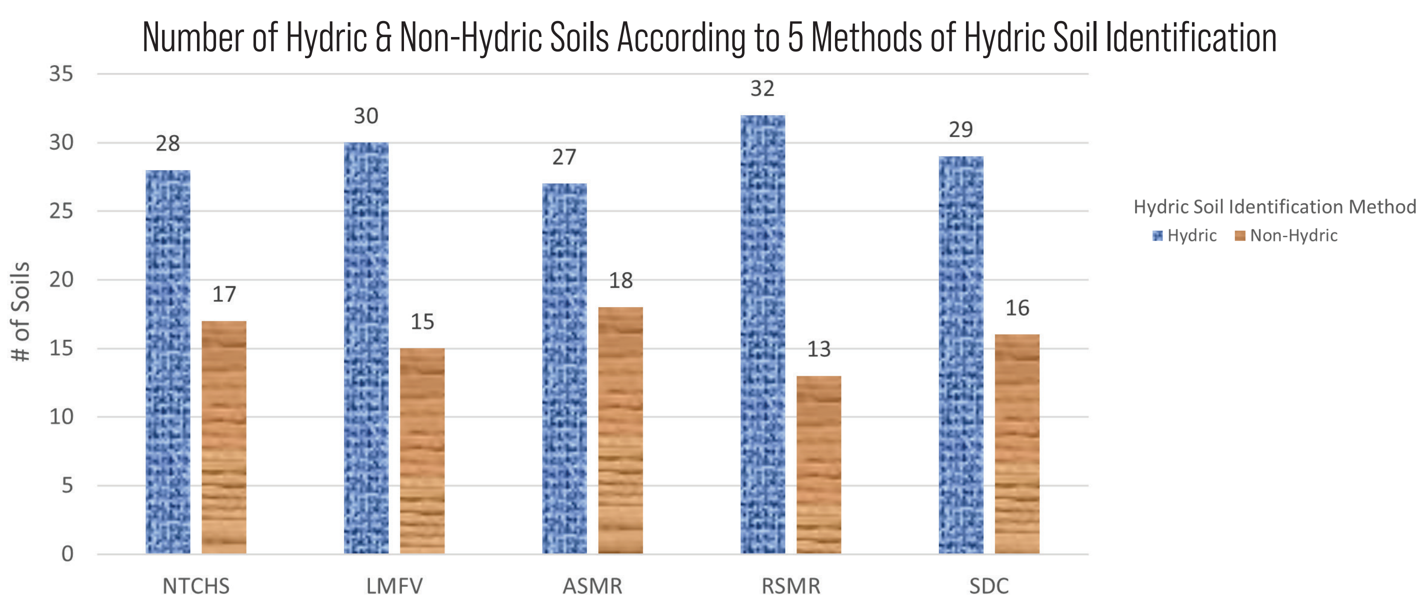

Figure 3. Number of hydric and non-hydric soils according to five hydric soil classifications.

Agreement of NTCHS with Four Alternative Hydric Soil Classifications

Data limitations prevent rigorous statistical hypothesis testing, so results are shown as the percentage agreement between NTCHS and the other four methods, along with correlation (expressed by the phi coefficient) and RME (Husch et al. 1972), as shown in Table 3.

Agreement with NTCHS is high (≥ 82%) for all four methods. Correlation between NTCHS is very strong for the LMFV method and RSMR and strong for SDC and ASMR. The RME is greatest for the LMFV method. Overall ranking of similarity to NTCHS is LMFV, RSMR, SDC, and ASMR.

Trends in the Sample Data

Some trends in the sample data are suggested from Figure 4. The LMFV method had the fewest false positives. RSMR had the most false positives. SDC had slightly more false negatives than it had false positives. ASMR showed the greatest number of false negatives.

	% AGREEMENT WITH NTCHS	PHI COEFFICIENT*	RME (95% CONFIDENCE LEVEL)
LMFV	96	+0.91	92
ASMR	82	+0.62	73
RSMR	87	+0.72	79
SDC	84	+0.67	75

*All Phi coefficients are significant at alpha < .01.

Table 3. Four alternative methods for classifying hydric soils compared to NTCHS. "% agreement" is the % of classifications (hydric or non-hydric) in the sample data that agreed with NTCHS. The phi coefficient (also known as "mean square contingency coefficient") is a correlation coefficient (measuring degree of association between NTCHS and each other method and potentially ranging from -1 to +1), and the RME is a statistical estimate of the minimum % agreement at the 95% confidence level.

Hydric soil classifications by the LMFV showed the greatest similarity to NTCHS. Agreement was high over a range of different soils, including most disturbed soils. Disagreement occurred in two disturbed soil profiles. Those two soils were classified as hydric by LMFV but non-hydric according to NTCHS (i.e., were false positives). Both soils were severely disturbed and almost met NTCHS thresholds. LMFV did not classify any soils as non-hydric that were hydric according to NTCHS (i.e., did not produce any false negatives).

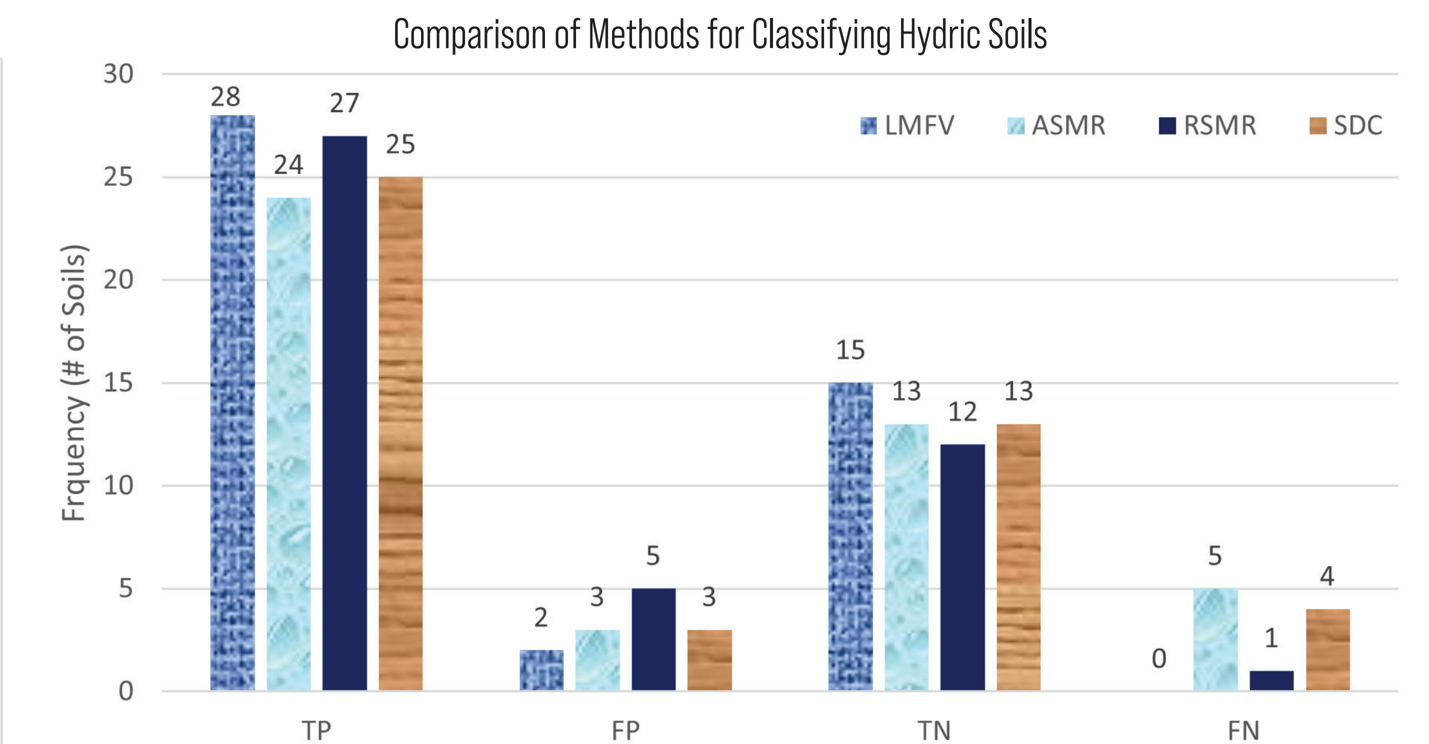

Figure 4. Four methods of classifying hydric soil compared to NTCHS hydric soil indicators (USDA 2018). "True" means classification matched with NTCHS ; "false" means they did not match. TP = true positives, the number of soils classified as hydric that match (as hydric) with NTCHS; FP = false positive, soils classified as hydric but classified as non-hydric by NTCHS; TN = true negative, the number of non-hydric soils matching as non-hydric with NTCHS; FN = false negative, the number of soils classified as non-hydric but classified as hydric by NTCHS.

Classification Objectives and Accuracy of Hydric Soil Identification

Since there is no universal standard of what constitutes a hydric soil, our data cannot show, in an absolute sense, which method of hydric soil classification is most accurate. Nevertheless, we think that NTCHS is a valid standard for relative comparison. Additional verification to compare methods more thoroughly would require longer term research using water table monitoring wells or Indicator of Reduction in Soils films in the mineral soils to record reduction rates.

LMFV, RSMR, ASMR, and SDC classifications all have been used to identify hydric soils in the Lower Mainland-Fraser Valley region. As might be expected, classifications that are focused on soil characteristics and that include detailed, quantitative soil criteria, such as the LMFV method, produce results most similar to those of NTCHS, a classification based solely on soil characteristics.

LMFV, like NTCHS criteria, is based on relatively detailed descriptions of soil morphology—for example, specific values of soil layer depths and thickness and Munsell colors. It has been developed with the specific purpose of identifying hydric soils in the Lower Mainland-Fraser Valley region in order to facilitate wetland identification and delineation.

RSMR, as mentioned above, considers soil, site, local hydrological, and vegetation characteristics (Green and Klinka 1994). Many important soil criteria are included but detailed criteria, such as depth thresholds and Munsell soil colours, are not included. ASMR was initially created to facilitate comparison of soil moisture among BEC ecosystem taxa in different regional climates and was later incorporated into British Columbia's wetland classification (MacKenzie and Moran 2004). It is useful for classifying wetland taxa but lacks detailed, specific hydric soil criteria.

Soil moisture regimes were created with the intention of showing the relative amount of plant-available water, not the degree of anaerobiosis in soil. Best results from RSMR or ASMR hydric soil assessment require an accurate assessment of vegetation. The plant community must be described in sufficient detail to compare to vegetation tables or indicator species groups. The reference plant communities and indicator species groups are based on data from mid-seral to climax stage communities. Those communities are typically absent from Lower Mainland-Fraser Valley sites. Another obstacle is that hydric soil assessments sometimes must be done outside of the growing season when some species may be difficult to identify and species abundance challenging to estimate accurately (Standish and Alards-Tomalin 2022).

Unlike RSMR and ASMR, SDC criteria are focused on site and soil features and do not utilize vegetation. They were intended to show soil wetness limitations for agricultural crops (Tiner 2017). Assessment criteria include important site and soil features such as slope, soil texture and structure, gleying, and soil taxa (Agriculture Canada Expert Committee on Soil Survey 1983). However, as with RSMR and ASMR, criteria are mainly qualitative and are relatively sensitive to individual interpretation.

SUMMARY AND CONCLUSIONS

Several alternatives have been used over the past decades for classifying hydric soils in the Lower Mainland-Fraser Valley. The USDA hydric soil indicators for Land Resource Region A (USDA 2018 and referred to in this paper as NTCHS) have been widely used in the USA and parts of Canada. Alternatives include a hydric soil classification based on Canadian pedological and wetland ecosystem criteria, referred to in this paper as LMFV. Others are RSMR, ASMR, and SDC. Forty-five Lower Mainland-Fraser Valley soils were sampled and classified as hydric or non-hydric for each of the five methods. Hydric soils according to NTCHS were compared to the other four methods. LMFV had the greatest similarity to NTCHS. Results for the other three methods, in order of decreasing similarity to NTCHS, are: RSMR, SDC, and ASMR.

We chose to compare to NTCHS because it is well-known, has been in use and evolving over three decades, and seems to apply well enough to Lower Mainland-Fraser Valley soils. For each of the four methods, (LMFV, RSMR, ASMR, and SDC), results were expressed as percentage agreement within the sample, correlation (phi coefficient), and RME.

Some observations are:

- All methods can produce more or less comparable results with respect to NTCHS (there was 82% or more agreement within the sample).
- Greatest agreement with NTCHS (96%) was for LMFV. LMFV also had the strongest correlation (+0.91) and RME (92%).
- Disagreement between NTCHS and LMFV occurred with only two soils; both were highly disturbed and were marginally hydric for LMFV versus marginally non-hydric for NTCHS. Soils with disturbed profiles or altered hydrology are a challenge regardless of which hydric soil classification is used (Tiner 2017; USACE 2010).
- NTCHS and LMFV are both methods based largely on soil morphology and are most similar in their results. SMRs include vegetation criteria and were intended primarily to address plant-available water and its potential effect on vegetation. SDCs are intended to classify soils with respect to wetness limitations for growing crops.
- RSMR produced the most false positives (non-hydric soils misidentified as hydric soils); LMFV produced the least.
- ASMR produced the most false negatives (hydric soils misidentified as non-hydric soils), followed by soil drainage class. LMFV did not produce any false negatives.
- The authors prefer use of NTCHS or LMFV because it is specifically focused on relatively detailed hydric soil features. We speculate that it should result in less statistical noise compared to SMRs or SDC (all of which require relatively more subjective judgment).

We cannot say which hydric soil identification method is most accurate because there is no absolute standard for comparison. NTCHS is recognized as highly credible and has been used in the Lower Mainland-Fraser Valley region and other places in British Columbia. Advantages of LMFV method are that it is concise, region-specific, and easily relatable to Canadian pedological soil classification as well as BEC and WREC.

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