NOTE / NOTE

A carbon-based method for estimating the wetness of forest surface soil horizons

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Abstract: The degree of wetness in forest surface soils has an effect on chemical and biological processes but is not easily measured. The high spatial variability in carbon (C) concentration creates high variability in water-holding capacity, and gravimetric water content is not informative. Local hydrology can create patchiness in soil moisture, with saturated soils often found near well-drained ones. When sampling to measure such factors as nitrification potential, it would be advantageous to have a simple metric that reflects the relative wetness of the soil. The relationship between C concentration (range 51.5–520.8 $g \cdot kg^{-1}$) and gravimetric water content was found to be linear for a set of 113 H- and A-horizon samples assumed to be at field capacity. The wetness ratio is defined as the actual water content of a sample divided by the water content predicted by the least squares regression equation based on C concentration (soil water content ($kg \cdot kg^{-1}$) = 0.080 + 0.0057 soil C concentration ($g \cdot kg^{-1}$)). Soil moisture retention curves were developed for a small number of samples in the range of 0 to about –10 kPa and showed that the equation predicted that water would be held at relatively high potential. In samples taken from 10 watersheds in the northeastern USA, wetness ratios between 1.25 and 3.1 were associated with soils identified in the field as ranging from wet to boglike. A median ratio of 0.49 was found in a watershed sampled after an extended dry period. At the Sleepers River Research Watershed, high wetness ratios were associated with a high soil calcium concentration, presumably from enriched groundwater. The ratio should be a useful measurement in watershed studies.

Résumé : Le degré d'humidité des sols de surface en forêt a un effet sur les processus chimiques et biologiques mais il n'est pas facilement mesuré. La forte variabilité spatiale de la concentration de carbone (C) entraîne une grande variation de la capacité de rétention d'eau et le contenu en eau libre ne procure pas d'information. Les conditions hydrologiques locales peuvent entraîner des variations spatiales dans l'humidité du sol de telle sorte qu'on retrouve souvent des sols saturés près de sols bien drainés. Lorsqu'on échantillonne pour prendre des mesures telles que la capacité de nitrification, il serait avantageux d'avoir une mesure simple qui reflète l'humidité relative du sol. Nos observations ont montré que la relation entre C (étendue de 51,5 à 520,8 $g \cdot kg^{-1}$) et le contenu en eau libre était linéaire pour un ensemble de 113 échantillons des horizons H et A qu'on a présumé être à la capacité au champ. Le rapport d'humidité est défini comme le contenu réel en eau d'un échantillon divisé par le contenu en eau prédit par une équation de régression des moindres carrés basée sur C (eau du sol ($kg \cdot kg^{-1}$) = 0,080 + 0,0057 C du sol ($g \cdot kg^{-1}$)). Des courbes de rétention d'humidité du sol ont été développées pour un petit nombre d'échantillons dans la gamme de 0 à environ –10 kPa et ont montré que l'équation a prédit le contenu en eau retenue à un potentiel relativement élevé. Dans les échantillons prélevés dans 10 bassins du nord-est des États-Unis, des rapports d'humidité de 1,25 à 3,1 étaient associés à des sols qualifiés sur le terrain d'humide à quasi marécageux. Un rapport médian de 0,49 a été mesuré dans un bassin échantillonné après une longue période de sécheresse. Dans le bassin de recherche de la rivière Sleepers, des rapports d'humidité élevés étaient associés à un contenu élevé en calcium provenant vraisemblablement d'une eau du sol enrichie. Le rapport devrait être une mesure utile dans l'étude des bassins versants.

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Introduction

When destructively sampling forest soils for chemical analyses, such as nitrogen (N)-transformation rates, it would be advantageous to be able to easily and quantitatively estimate the relative wetness of the soil. Volumetric water content and soil water potential are difficult to measure, especially in small disturbed samples. Gravimetric water content can easily be determined but forest surface horizons have high spatial variability in carbon (C) content, and water content is difficult to relate to water potential. Forest soil bulk density has been found to correlate with C content (Curtis and Post 1964; Federer 1983; Federer et al. 1993; Huntington et al. 1989; Prévost 2004) and an H horizon

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with 400 g C·kg^{-1} will have a much lower dry mass per unit volume (and usually a much higher water content) than an A horizon with 100 g C·kg^{-1}. A higher C content is associated with not only lower bulk density but also greater pore space and water-holding capacity. There have been a number of investigations into the utility of soil C or soil organic matter as a predictor of soil moisture retention characteristics, although most have not examined forest soils with a high C content (e.g., Emerson 1995; Olness and Archer 2005; Vereecken et al. 1989). It might be possible to predict wetness, or water content relative to a norm, in forest surface horizons from soil C content because of the wide range often found.

Dry soils may limit the mobility of micro- and mesofauna (Gorres et al. 1999; Neher et al. 1999), whereas overly wet soils may limit oxygen diffusion and aerobic reactions such as nitrification. Numerous studies have shown variations in soil moisture to be related to N-transformation rates (e.g., Devito et al. 1999; Evans et al. 1998; Gilliam et al. 2001). In the field, it is relatively easy to observe either complete saturation or extremely dry conditions (highly organic soils are often powdery and initially hydrophobic when rewetting is attempted). Determining the difference in degree of wetness between these two conditions can be subjective. The present study was undertaken to develop a more quantitative method for estimating relative wetness.

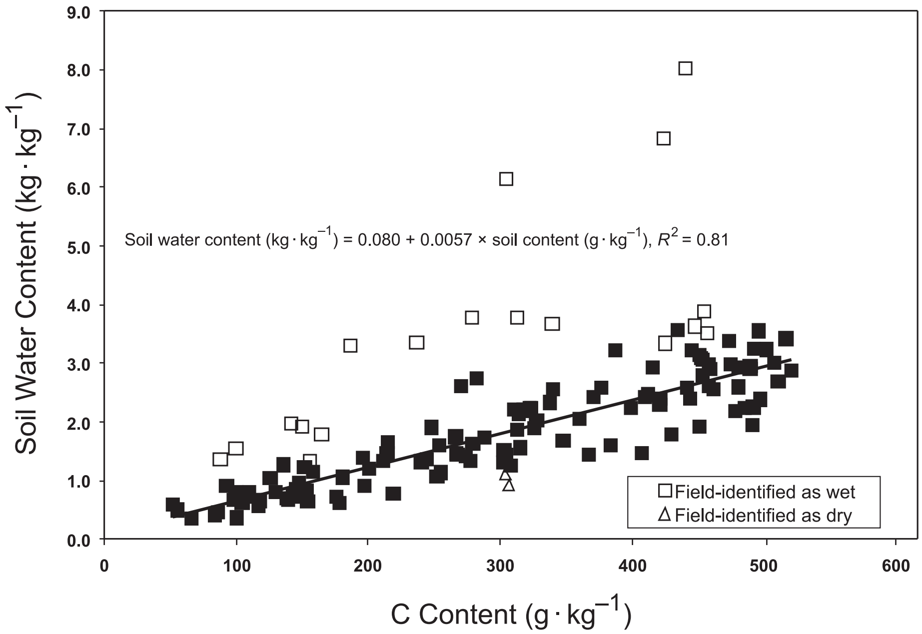
Materials and methods

Soil samples were obtained as part of a regional study of nitrification rates. In May 2002, 30 H- and A-horizon samples were taken from two subwatersheds of Buck Creek in the southwestern Adirondacks (Lawrence 2002; Ross et al. 2004); in June 2002, 39 samples were obtained from watersheds W9-A and W9-C of the Sleepers River Research Watershed (Shanley et al. 2002); in October 2002, 30 samples were taken from watershed W-7 at the Hubbard Brook Experimental Forest in New Hampshire; and in June 2003, 34 H- and A-horizon horizon samples were taken from a 121 ha watershed just outside the Lye Brook Wilderness Area in southeastern Vermont. Field notes were taken, to record any unusual characteristics at each sampling point; if the site was obviously wet or dry, the observation was usually recorded. Samples (~500 mL) were taken from the first horizon below the F layer that was at least 2 cm thick (usually an H layer). If horizon depth was greater than 10 cm, only the upper portion was sampled. The soil was mixed and stored in a sealed polyethylene bag at about 10 °C until subsampled for dry mass. The packed contents of two 5 mL spoons were weighed into an aluminum dish, air-dried for at least 10 days, and then held for 2 h in an 80 °C forced-air oven. After cooling in a desiccator, samples were weighed and the water content was calculated in kilograms of water per kilogram of dry soil. Samples were run in duplicate and the procedure was repeated if the results were not within 5% of each other. For C-content determination, the same samples were ground with a mortar and pestle to pass through a 125 µm mesh sieve so that small reproducible subsamples could be weighed. The ground samples were stored at 55 °C and weighed, after cooling in a desiccator, into tin capsules for C and N analysis by means of an elemental analyzer (CE440, Exeter Analytical, Chelmsford, Mass.). These 133 samples were used to develop a relationship between C content and wetness. The wetness ratio was calculated as the water content in the field divided by that predicted from this relationship.

Similar procedures were performed on an additional 635 samples taken between the fall of 2001 and the spring of 2004. These samples were obtained from the research sites described above and from three additional sites: the Cone Pond Research Watershed in New Hampshire (Bailey et al. 1996), the Winnisook watershed in New York's Catskill Mountains (Johnson et al. 2000), and two subwatersheds of Brush Brook in central Vermont (Ross et al. 1994). Each site was visited between 2 and 4 times and samples were taken along established transects or grids. New samples were obtained by either extending the transects or sampling in new locations between previous points. To obtain an estimate of exchangeable calcium (Ca), a subset of 622 samples (all soils sampled after the spring of 2002 with sufficient quantity remaining) were extracted with NH_4–acetate (1.25 mol·L^{-1} acetate), pH 4.8, at a 5:1 (*v*:*v*) solution:soil ratio. Air-dried samples sieved through 2 mm mesh were used and the soil concentration was calculated using the dry mass of the soil volume used. Ca content was determined by means of inductively coupled plasma-atomic emission spectrophotometry (ICP-AES) using standard procedures and an internal laboratory soil reference sample as quality control. Net nitrification potential rates were determined using the 1 day method of Ross et al. (2006). Duplicate subsamples were extracted in the field with 2 mol·L^{-1} KCl and additional subsamples were extracted 1 day later in the laboratory after incubation at 10 °C. This method has been found to give higher rates than longer incubations in either intact cores or composite samples, but the results of all methods were well correlated (Ross et al. 2004, 2006).

Six soil cores (7.6 cm in diameter and 2.54 cm thick) for measuring water potential were obtained from the lower area of the Brush Brook watershed on 23 November 2004, after a rewetting period (14 mm of rain during the previous 4 days reported at Underhill, Vt.) following a somewhat dry period (4 mm of rain from 8 through 18 November) (USDA Natural Resources Conservation Service 2006*a*). An additional four cores were taken on 16 August 2006 during a period of continued moist conditions (a total of 36 mm of rain on 12 of the previous 14 days) (USDA Natural Resources Conservation Service 2006*a*). The L and H horizons were carefully peeled off the H or A horizon and the cores inserted while cutting around the edge with a sharp knife. A coarse filter (non-gauze milk filter, KenAG Corp., Ashland, Ohio) was taped to the bottom of each core, and the cores were then sealed in polyethylene bags and kept chilled until analysis. After weighing to determine field moisture, cores were placed in funnels with a ceramic-frit base and an attached water column (plastic tubing and a 50 mL burette). A pack of coarse sand (50 g) was placed between the ceramic base and the core to ensure good contact. Separate moisture-retention measurements were made on the sand only and subtracted from the core + sand measurements. Starting with saturated sand and a burette filled to 0.0 mL, water was forced into the core, to achieve saturation, by elevating the burette. After equilibration, the burette was lowered and readings were

Fig. 1. Relationship between C content and gravimetric soil water content in H- and A-horizon samples from four forested watersheds in the northeastern USA (Buck Creek, N.Y.; Sleepers River Research Watershed W9; an unnamed watershed near the Lye Brook Wilderness Area, Vt.; and the Hubbard Brook Experimental Forest W-7, N.H.).



taken at approximately –0.5, –1, –2, –4, and –8 kPa (5–80 cm of hanging water). Equilibration time increased from 1 to 64 h as the pressure decreased. After these measurements were made, the cores were oven-dried and weighed and the C content was determined as described above.

Simple regression analysis and analysis of variance were performed using SAS® version 9.1 (SAS Institute Inc. Cary, N.C.). Proc reg was used for linear regression, with the normality and homogeneous distribution of the residuals confirmed graphically. The general linear model (proc glm) was used to test differences between sampling dates. The distributions of both the wetness ratios and the gravimetric water contents were skewed because of some high values, and analysis of variance was performed on log-transformed data. The Student–Newman–Keuls procedure was used to compare one sampling date with the others.

Results and discussion

The 133 samples used to develop the relationship had C contents ranging from 51.5 to 520.8 $g \cdot kg^{-1}$ (mean 302.2 $g \cdot kg^{-1}$) and water contents ranging from 0.38 to 8.04 $kg \cdot kg^{-1}$ dry soil (median 1.90 $kg \cdot kg^{-1}$). The water content of these high-C-content surface horizons is often greater than their dry mass. We assumed that most of the soils were at or near field capacity because of the combination of low temperatures, relatively high elevation, and recent precipitation (i.e., local climate). For example, the samples from Lye Brook Wilderness Area were taken on 20 June 2003; a nearby weather station (<1 km away) in Sunderland, Vermont, reported precipitation of 98 mm and an average temperature of 11.5 °C for the previous 30 days (USDA Natural Resources Conservation Service 2006*a*). However, from field observation, it was known that 20 of the initial 133 samples were either very wet or very dry. Dry conditions were noted on a hummock and a gravelly slope on two samples taken in October at Hubbard Brook Experimental Forest watershed W-7. The wet soils were found in areas near seeps, shallow groundwater, or wetlands. That is, they were wet because of the local hydrology. A simple linear regression was performed on the 113 samples not identified in the field as either wet or dry (Fig. 1). The estimated slope (0.0057) was significantly different from zero ($p < 0.0001$) but the estimated intercept (0.080) was not ($p = 0.37$). A simple conversion factor of 0.0059 can be derived by forcing the regression through zero. To obtain a wetness ratio that was independent of C content, the actual moisture content was divided by the value predicted from the least squares regression equation.

The wet soils (as observed in the field) eliminated from the regression had wetness ratios between 1.3 and 3.1. When data ($n = 635$) from other dates and other sampling sites not included in the original regression analysis were used, wet soils (field notes indicated wetter than normal conditions) had wetness ratios between 1.25 and 2.85. The overall average for all 635 samples was 1.10, with a median of 1.00. Sampling sites with wetness ratios above 2.0 often had standing water ≤10 cm deep. One of the samples with the highest ratio, 2.85, had 340 g $C \cdot kg^{-1}$ and standing water 6 cm deep. These 635 samples were similar to those used to develop the regression, ranging in C content from 49.6 to 532.1 $g \cdot kg^{-1}$ (mean 299.1 $g \cdot kg^{-1}$) and in water content from 0.17 to 7.56 $kg \cdot kg^{-1}$ dry soil (median 1.81 $kg \cdot kg^{-1}$).

Soils were classified under the USDA system as either Inceptisols or Spodosols (Table 1). All were coarse-textured, and based on field observations, the mineral horizons were usually estimated to be sandy loams. No particle-size analysis was performed in the current study but typical profiles of the series listed in Table 1 have been determined to be sandy loams, loams, and silt loams (USDA Natural Resources Conservation Service 2006*b*). Two Mundal series soil

Table 1. Major soil series found at each watershed and their USDA classification.

Watershed	Major soil series/complexes*	Classification (USDA system)
Brush Brook	Houghtonville, Stratton–Glebe	Coarse-loamy to loamy-skeletal Haplorthods and Humicryods
Buck Creek	Tunbridge–Lyman, Rawsonville–Hogback	Coarse-loamy to loamy Haplorthods and Haplohumods
Cone Pond Research Watershed	Peru, Tunbridge, Lyman	Coarse-loamy to loamy Haplorthods
Hubbard Brook Experimental Forest W-7	Peru, Tunbridge, Lyman	Coarse-loamy to loamy Haplorthods
Lye Brook Wilderness Area	Mundal, Wilmington	Coarse-loamy Haplorthods, loamy Endoaquods
Sleepers River Research Watershed W9	Vershire–Dummerston, Cabot, Buckland	Coarse-loamy to loamy Udepts and Aquepts
Winnisook	Lackawanna, Arnot, Oquaga	Coarse-loamy to loamy-skeletal Udepts

*Sources are as follows: Brush Brook (Ross et al. 1994); Buck Creek and Lye (USDA Natural Resources Conservation Service 2006*c*); Cone Pond Research Watershed (Bailey et al. 1996); Hubbard Brook Experimental Forest (USDA, unpublished mapping); Sleepers River Research Watershed (Shanley et al. 2002); Winnisook (Johnson et al. 2000).

Table 2. Soil moisture retention data and characteristics of 10 H- and A-horizon cores taken from the Brush Brook watershed.

			Field soil moisture:			Measured soil moisture:		Water potential	
Core No.	C content ($g\cdot kg^{-1}$)	Bulk density ($Mg\cdot m^{-3}$)	by volume ($m^3\cdot m^{-3}$)	by mass ($kg\cdot kg^{-1}$)	Calculated soil moisture by mass ($kg\cdot kg^{-1}$)*	at –7 kPa ($kg\cdot kg^{-1}$)	at saturation ($kg\cdot kg^{-1}$)	Wetness ratio 1.5 (kPa)	Wetness ratio 2.0 (kPa)
1-1	467	0.12	0.32	2.63	2.83	2.40	7.13	–1.4	–0.6
1-2	476	0.16	0.48	2.97	2.89	2.60	5.78	–1.1	–0.1
1-3	404	0.17	0.49	2.88	2.46	2.60	5.01	–0.9	–0.1
1-4	411	0.18	0.59	3.31	2.50	2.90	5.06	–2.0	–0.2
1-5	217	0.29	0.45	1.55	1.33	1.30	2.96	–1.6	–0.6
1-6	154	0.35	0.41	1.15	0.94	1.15	2.25	–2.0	–0.5
2-1	343	0.21	0.56	2.64	2.05	2.58	4.28	–1.8	–0.2
2-2	423	0.19	0.61	3.27	2.50	3.07	4.82	–1.1	0.0
2-3	437	0.17	0.55	3.33	2.58	2.78	5.64	–1.0	–0.2
2-4	272	0.29	0.59	2.04	1.64	1.98	3.17	–0.9	–0.1

Note: Cores were sampled on two different dates (series 1 on 23 November 2004 and series 2 on 15 August 2006).

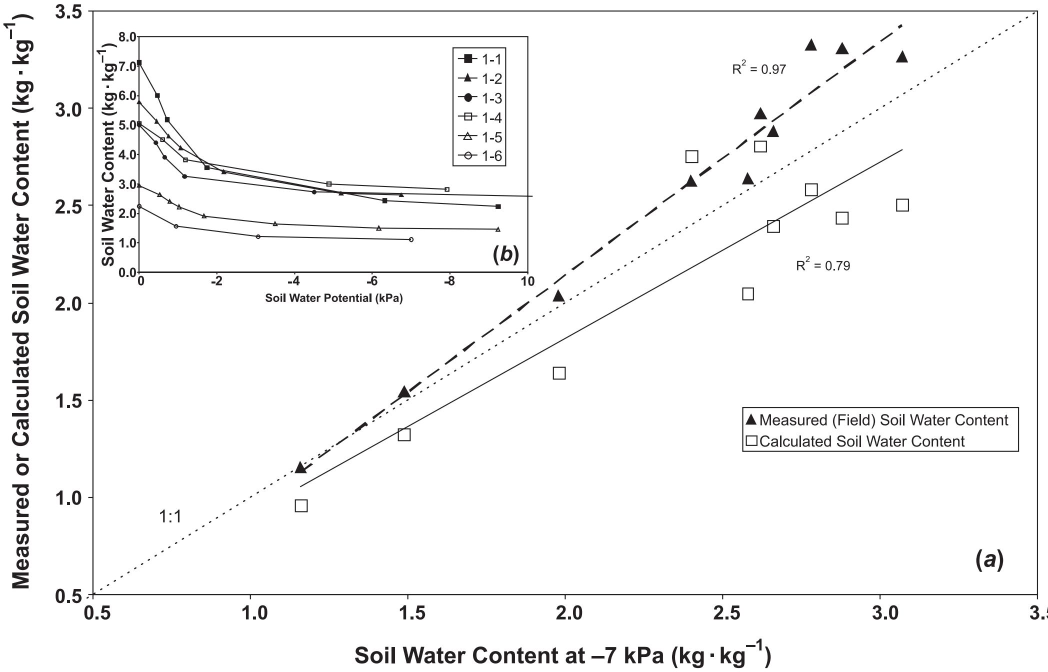
*Calculated from soil C content using the least squares regression equation shown in Fig. 1.

profiles have been thoroughly described just outside of the Lye Brook Wilderness Area watershed (USDA Natural Resources Conservation Service 2006*a*). One profile (00VT003002) had an A horizon with a sand, silt, and clay content of 611, 335, and 54 $g\cdot kg^{-1}$, respectively. The other profile (00VT003001) did not have an A horizon, but the upper B horizon had a sand, silt, and clay content of 533, 426, and 41 $g\cdot kg^{-1}$, respectively. These low clay contents are probably typical of most of the study soils and help explain the near-zero intercept found for the relationship between water content and C content (Fig. 1). A higher clay content should yield a higher intercept because of the influence of clay on soil structure, and possibly change the slope. Emerson (1995) compiled data from eight studies of agricultural soils having a relatively low range of C contents (~5 to 40 $g\cdot kg^{-1}$) but a clay content as high as 410 $g\cdot kg^{-1}$. He found the slope of the relationship between soil water content ($kg\cdot kg^{-1}$) at field capacity (defined as –10 kPa) and C content ($g\cdot kg^{-1}$) to range between 0.0026 and 0.013, with an average slope of 0.0053 (close to the 0.0057 found in the present study). Working with soils having a range of C contents similar to those reported in the studies analyzed by Emerson (1995) (in fact using data from some of the same studies), Olness and Archer (2005) modeled the change in available water capacity (defined as that held between –33 and –1500 kPa) versus C content and found a variable effect of clay content. More work is needed to fully understand the interaction between clay and C contents in determining soil water holding capacity.

Relationship to water potential

To determine if the equation relating C content to water content had a physical basis, soil water retention curves in the range near field capacity were developed for 10 surface horizon samples. Field capacity is usually defined as the water content of a soil 2–3 days after rewetting and is assumed to be –10 kPa for coarse-textured soils and –33 kPa for those with a finer texture (Hillel 1998). A value for forest organic horizons is not commonly given. On one of the two sampling dates, the soils examined had field water contents near those predicted by the regression equation (Table 2); on the second sampling date the soil was wetter in the field, presumably because of rain just prior to sampling. When the water-retention data were used, water content at –7 kPa (the lowest potential measured for some of the cores) was in relatively good agreement with that predicted by the C content (Fig. 2*a*). Because the slopes of the water-retention curves are shallow between –3 and –8 kPa, it is not possible to unequivocally assign a value for field capacity. Field soil moisture was somewhat higher than that measured at –7 kPa, while the predicted soil moisture (from the linear regression) was somewhat lower (Fig. 2*a*). It ap-

Fig. 2. (*a*) Soil water content at –7 kPa for 10 cores versus both the soil water content found in the field (measured) and that calculated from the soil C content and the least squares regression equation shown in Fig. 1. (*b*) Soil moisture retention curves between 0 and about –10 kPa for the six cores taken on 23 November 2004.



pears that field capacity was slightly higher than –10 kPa and that, for this small set of samples, water contents predicted by the equation were accurate. The soil water potential at calculated wetness ratios of 1.5 and 2.0 was determined by interpolation from the water-retention curves (Fig. 2*b*). Potentials were close to zero, ranging between –2.0 and 0.0 kPa (Table 2). Any soils with such ratios would be wet because of restricted drainage or local hydrology, unless they were sampled shortly after a rain or snowmelt event.

The bulk densities measured in these 10 samples (average 0.21 Mg·m^{-3}) were in close agreement with values predicted using the equations of either Huntington et al. (1989) (0.19 Mg·m^{-3}) or Federer (1983) (0.18 Mg·m^{-3}). Prévost (2004) found that these equations did not accurately predict bulk density in soils from northern Quebec following mechanical site preparation. It is likely that the wetness ratios would also be different following such soil treatment and may only be useful for relatively undisturbed sites.

Application of the wetness ratio

The wetness ratio may be applied in a variety of situations. One use would be for estimating the moisture status of a watershed or research site at a given point in time without installing and calibrating moisture sensors. If sampling is performed on different dates, the wetness ratio can be used to determine if moisture conditions were or were not similar. We have found examples of both dry and wet conditions when sampling different watershed soils to measure N transformation, which is known to be limited by both extremes in moisture conditions. Relating the gravimetric water content to these processes is irrelevant if its relationship to soil C content is not known. The two subwatersheds at Brush Brook were sampled on 10 September 2002 after a warm, dry period (17 mm of rain was recorded during the previous 25 days in nearby Underhill, Vt.) and had a mean wetness ratio of 0.64, significantly lower than that on the three other sampling dates (Table 3). The mean C and gravimetric water contents were also lower during this sampling than on two of the other dates (because different transect points were sampled), but the wetness ratio provides a metric of soil moisture status independent of the differences in C content caused by variability in sampling. Wetter than normal conditions preceded the sampling on 25 May 2004 at Lye Brook Wilderness Area, and this was also reflected in the wetness ratio (Table 3), although it was only significantly higher than that obtained from the 30 September 2003 sampling. There were no significant differences between any of the dates in either C content or gravimetric water content. Thus, the wetness ratio can reveal a difference when the other metrics cannot.

The differences in wetness ratio appeared to affect net nitrification potential rates at Brush Brook but not at Lye Brook Wilderness Area (Table 3). The dry conditions at Brush Brook in the fall of 2002 were associated with the lowest rates, although they were only significantly different from those on one other sampling date. The 1 day rates (Ross et al. 2006) may not be as sensitive to moisture differences as longer incubations. Another complicating factor in using the wetness ratio as a predictor of nitrification rates is that some very wet soils were found in and near enriched seeps that were apparently not oxygen-deficient (see below). Nitrification rates in these samples were among the highest measured, probably because of the combination of high pH and low C/N ratio. Other very wet sites in the same watersheds were "waterlogged" and likely oxygen-deficient, having no measurable nitrate. Thus, soils with high wetness ratios were at the two extremes of net nitrification potential rates.

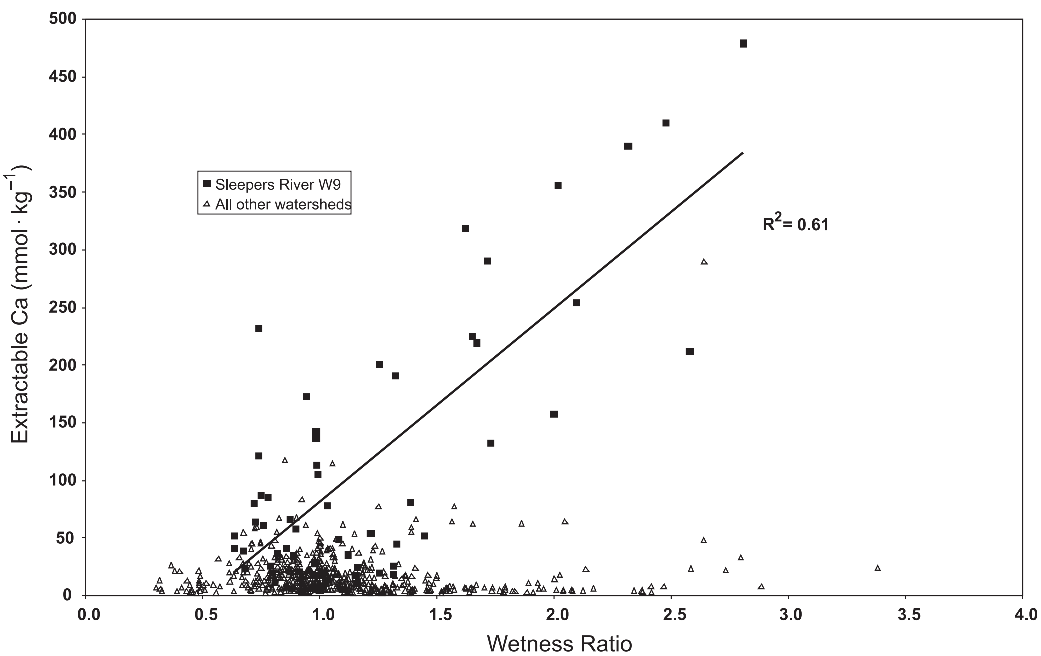
Table 3. Mean and median wetness ratios, gravimetric water contents, C contents, and net nitrification potential rates for H and A horizons on four sampling dates at two watersheds.

		Wetness ratio		Water content ($kg \cdot kg^{-1}$)		C content ($g \cdot kg^{-1}$)		
Sampling date	No. of samples	Mean	Median	Mean	Median	Mean	Median	One day nitrification rate* ($\mu mol \cdot h^{-1} \cdot kg^{-1}$)
Brush Brook								
11 Oct. 2001	44	1.03a	0.98	1.65a	1.44	270.3a	272.7	16.9ab
30 May 2002	41	1.12a	1.03	1.87a	1.79	285.6a	276.5	18.2ab
10 Sept. 2002	41	0.64b	0.49	0.84b	0.64	202.8b	183.9	14.4b
12 May 2004	41	1.13a	1.04	1.45a	1.22	218.5b	200.5	25.7a
Lye Brook Wilderness Area								
22 Oct. 2002	34	1.34ab	1.18	2.50a	2.47	323.5a	366.3	11.9a
24 June 2003	34	1.44ab	1.20	2.69a	2.62	337.6a	333.4	14.2a
30 Sept. 2003	30	1.28b	1.15	2.27a	2.02	312.6a	325.5	9.0a
25 May 2004	32	1.51a	1.48	2.40a	2.14	270.1a	225.9	12.5a

Note: Sampling on 10 September 2002 followed a long, dry spell and that on 25 May 2004 followed heavy precipitation. Within each watershed, means followed by a different letter are significantly different ($p < 0.05$). Statistical analyses of wetness ratios and water contents were performed on log-transformed data.

*Based on measurements taken in the field and after 1 day of incubation in the laboratory (Ross et al. 2006). Rates for Brush Brook represent only one subwatershed (20 samples per date) because of missing data from the other subwatershed.

Fig. 3. Wetness ratios versus extractable Ca (NH_4-acetate, pH 4.8). Soils with high wetness ratios at the Sleepers River Research Watershed had high concentrations of extractable Ca, presumably from upwelling of enriched waters.



A further application was found in a nutrient-cycling study in the Sleepers River Research Watershed. The vegetation in watershed W9 is northern hardwood with a high percentage of sugar maple (*Acer saccharum* Marsh.). The soils are underlain with calcite-bearing bedrock (Shanley et al. 2002) and not generally as acidic as soils found in other typical northern hardwood sites. Numerous seeps throughout the watershed bring high-pH, Ca-enriched waters up towards the soil surface. This soil Ca enrichment is reflected by the wetness ratio (Fig. 3). The highest soil Ca concentrations were found in soils with the highest wetness ratios. With the exception of one sample from an enriched seep at Brush Brook, wet soils from other sites did not have high Ca concentrations, reflecting the lack of a Ca source.

It is likely that this metric has other uses because it clearly defines the moisture status of forest soil surface horizons. It may not be applicable to disturbed sites, and whether it will work well on different soils outside the humid northeast is not known. However, testing its suitability should be relatively easy and different equations could be developed.

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