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Indicators of Saturation in Albic Horizons of New Hampshire and Maine

Karen Dudley and Elizabeth A. Rochette¹

Abstract

Field soil scientists rely heavily on color variations, such as redoximorphic features, as tools to determine water table levels in soils. Redoximorphic features are reliable water table indicators in many soil types, but Aquods are excluded. However, eluviation processes in Aquods create leached, albic horizons that may contain indicators of water table influences. Polychromatic (color variegation) features have been considered redoximorphic features in albic horizons, but soil scientists of the Northeast have noted that polychromatic features are also observed in well-drained and moderately well-drained Spodosols. Therefore, the objective of this study was to determine whether variegated color patterns of albic horizons in Spodosols are indicators of saturation. Albic color patterns at 12 sites with various average saturation durations (ASD) (i.e., wetness) were examined. The relationships between ASD and three indices, Value, Aquods, and POD (Schaetzl and Mokma, 1988) Indices, were investigated. The Value Index indicates color deviation from pure gray. The Aquods Index is the product of the Value Index and surface plus albic horizon thicknesses. The POD Index is a measure of the degree of podzolization. A strong correlation was observed between ASD and the Aquods Index, while correlations between the ASD and the Value and POD indices were moderate to slight. The Aquods Index provides a basis for further research on water table fluctuations in albic horizons.

Many land development permits and regulations in the northeastern USA require that the depth to water table determination be based on soil conditions (New Hampshire Department of Environmental Services, 1991; United States Army Corps of Engineers, 1987). Field soil scientists must use guidelines that have been adopted by regulators to determine depth to the water table with the use of soil features. However, these guidelines occasionally require refinement.

Field soil scientists in the Northeast have questioned using the polychromatic feature (S8) of the National Indicators (USDA-NRCS, 2002) because they have noted that polychromatic features in albic horizons also exist in well and moderately well drained Spodosols. Furthermore, redoximorphic features within the albic horizon can be difficult to discern.

In this study we examined the color patterns and thickness of twelve albic horizons of Spodosols in New Hampshire and Maine and compared them

¹ K. Dudley, Soil Scientist, USDA-NRCS, Unit 312, The Concord Center, 10 Ferry Street, Concord, NH 03301-5081 (email: karen.dudley@nh.usda.gov); E.A. Rochette, Washington State Department of Ecology, 3100 Port of Benton Blvd, MS-HO-57, Richland, WA 99354.

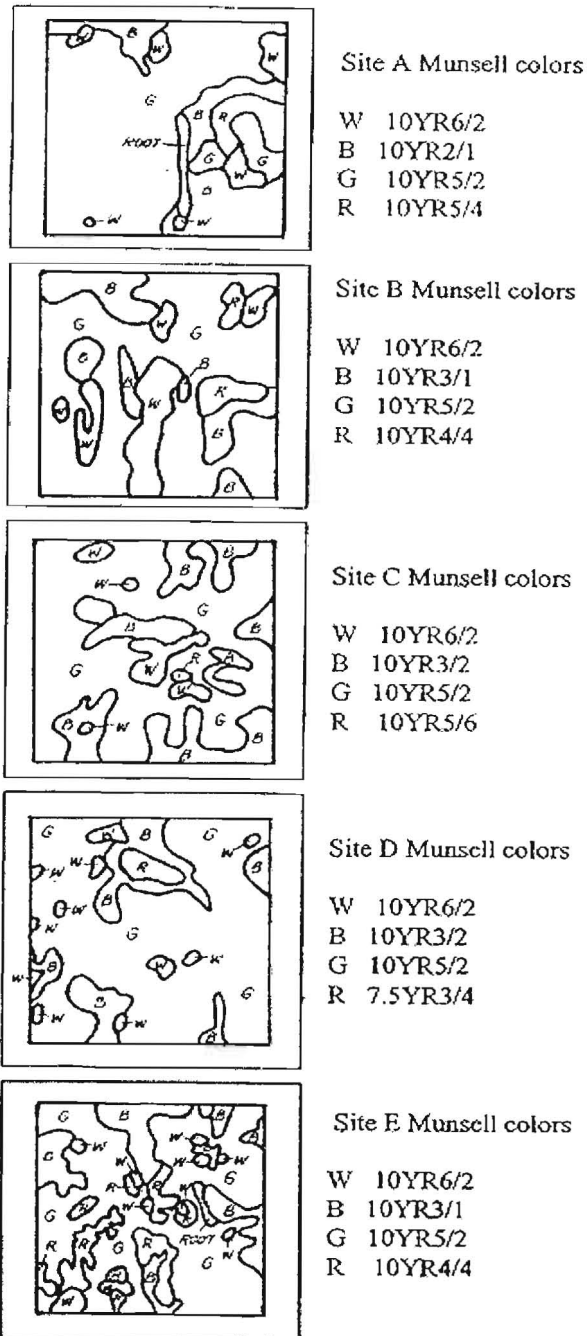


Fig. 2. Example of albic horizon site maps, Adams site (Adams Series), Fryeburg, ME. Areas labeled B, W, G, and R represent areas of black, white, gray, and red, respectively.

average yearly fluctuations is to normalize all sites in terms of duration. The ASD was calculated from the water table data taken at the sites.

Calculation of Color Indices

The Value Index represents color variegation in the albic horizon and is calculated for each site using the albic maps:

$$\text{Value Index} = \frac{4.5 - [(\% \text{ area}_W \times W) + (\% \text{ area}_G \times G) + (\% \text{ area}_B \times B)]}{100\%}$$

where 4.5 is the calculated number of "pure gray" and is the midpoint between Munsell values 7 and 2, %area_W is the percent area with a Munsell value 7 or 6, W is the Munsell value 7 or 6, %area_G is percent area with a Munsell value 5 or 4, G is Munsell value 5 or 4, %area_B is percent area with a Munsell value 3 or 2, B is Munsell value 3 or 2. The Aquods Index is calculated as follows:

$$\text{Aquods Index} = [(\Sigma O \text{ and } A \text{ thickness}) + E] \times \text{Value Index}$$

where O is O horizon thickness (cm), A is A horizon thickness (cm), E is Albic horizon thickness (cm).

Schaetzl and Mokma (1988) created the POD Index as a measure of the degree of podzolization in Spodosols. The POD index is a measure of the color differences between the albic and spodic horizons, based on field data:

$$\text{POD Index} = \Sigma \Delta V \times 2^{\Delta H}$$

where ΔV is the value difference between the E and B subhorizons, ΔH is the number of Munsell pages different in hue, Σ indicates that the summation occurs over all B horizons.

The POD Index was calculated using colors of the albic and spodic horizons from the site pedon descriptions at each site. The POD index was also combined with the thickness of the O and E horizons at each site (the Value Index was replaced with the POD index) to test for correlation and is termed the POD*(O+E) Index.

Finally, in an effort to develop a simple field technique that can be used easily and quickly to test for degree of saturation in the albic horizon, grab samples of the albic horizons were collected after each map was made. The grab sample was mixed together in the hand and the Munsell Value (V) and Chroma (C) were determined and average Values and Chroma for each site (5 plots) were calculated. Ratios of Value to Chroma (V/C) were calculated to test for a correlation between these mixed E horizon colors and ASD.

Results and Discussion

All study sites received rainfall within 10% of the 30-yr average with the exception of two sites. These two sites are somewhat excessively drained

Table 1. Average saturation duration (ASD) values of sites. ASD calculated by dividing the percent time the albic horizon is saturated by the average yearly fluctuations into the E horizon.

Site	Avg. yearly fluctuations	% time E is saturated	No. of years of data	ASD
Adams	0	0	3	0
Croghan	0	0	3	0
Oxford	0	0	3	0
Swamp	0	0	10	0
Spring	0	0	11	0
County	0.2	1	11	5.5
Bethlehem	3.4	28	7	8.3
Lancaster	2.1	38	8	17.9
Dummer	3.8	69	5	18.2
Joppa	2.4	62	5.5	26.2
Franconia	2.3	72	7	30.9
Bremen	1.7	61	3	36.6

and moderately well drained, so there is a negligible effect on the calculated ASD (Table 1) of the E horizons at these sites because the water table never reached into the E horizon.

One of the main goals of this study was to determine an easily attainable field indicator of wetness of the albic horizon. Spearman's Rank approach provides a measure of intensity of association between two variables, and these correlations were examined to explore relationships between pairs of variables. The mixed color V/C index was investigated for this purpose, but it did not correlate with ASD, $R = 0.091$ (Table 2). The albic horizon tended to lose its variegation after mixing in this test. Therefore, mixed colors should not be used in the determination of albic horizon wetness.

In contrast to correlations between the mixed colors and ASD, several of the indices correlated well with ASD. Spearman's Rank correlation values (Table 2) for ASD vs. E horizon thickness and ASD vs. O horizon thickness were high (0.77 and 0.72, respectively). These results support conclusions of other studies (Hyde and Ford, 1989; Zampella, 1994) that the E and

Table 2. Spearman's Rank Correlation results of field albic map data. R value of 1 and low p value represents a strong correlation.

Data compared	Spearman's Rank	p level
ASD vs. E horizon thickness	0.767	0.003
ASD vs. O horizon thickness	0.723	0.008
ASD vs. Value Index (w/o spodic)	0.563	0.072
ASD vs. Aquods Index	0.912	0.000069
ASD vs. POD Index	0.459	0.134
ASD vs. (O + E) x POD Index	0.792	0.002
ASD vs. Mixed albic color (average V/C)	0.091	0.777
ASD vs. O + E thickness	0.768	0.004
E horizon thickness vs. O horizon thickness	0.811	0.001
E horizon thickness vs. POD Index	0.473	0.121

O horizons become thicker with longer average saturation durations. The Value Index vs. ASD correlation results indicate that, generally, the wetter albic horizons at these sites trend away from "pure" gray ($R = 0.56$, p level of 0.07). The albic horizon colors trend toward more white or black colors as saturation duration increases.

The Aquods Index is a combination of the two highly correlating factors (O + E horizon thickness) and one generally correlating factor (Value Index). This suggests that the Aquods Index correlated highly with ASD (Spearman's Rank = 0.92, $p < 0.01$; Fig. 3).

The POD*(O+E) Index was well correlated with the ASD, resulting in a Spearman's Rank $R = 0.79$. This R was comparable to that of the E thickness vs. ASD and O horizon thickness vs. ASD alone ($R = 0.77$ and $R = 0.72$, respectively). The POD value alone correlates slightly with ASD ($R = 0.46$, p level of 0.13).

The Value Index, E horizon thickness, and O horizon thickness, when combined, are good indicators of saturation amounts in the albic horizon of Spodosols. The Value Index incorporates Munsell color values and the fraction of the map area over which each Munsell value was observed into one number for each site. The Value Index is the deviation of color value from that of pure gray. Low Value Indices indicate an albic horizon close in color to "pure" gray, while high Value Indices indicate colors that are either whiter or blacker than pure gray. Generally, wetter sites had higher Value Indices than drier sites, leading to the conclusion that wetter albic horizons at these sites are "whiter" or "blackier" than those at drier sites.

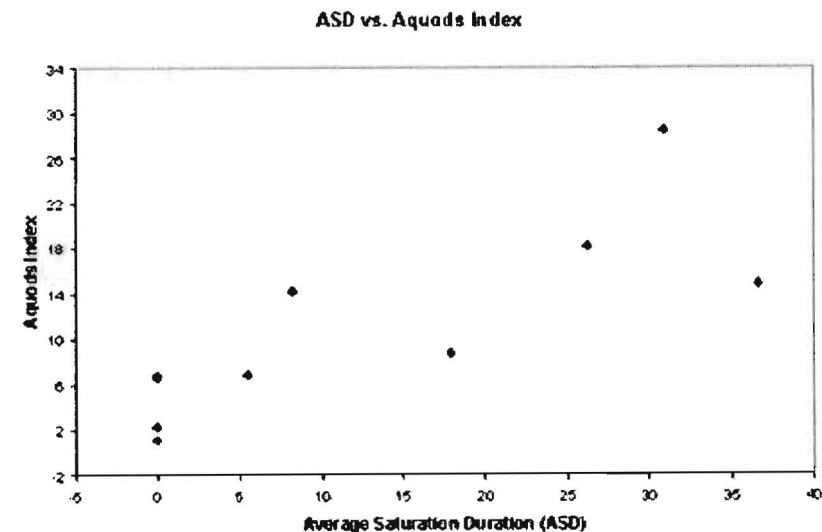


Fig. 3. Aquods Index as a function as average saturation duration (ASD). Spearman's Rank Correlation, $R = 0.92$, $p = 0.000069$, $n = 11$.

The POD Index correlates slightly with ASD and was calculated for a single described pedon at each site. The POD Index may have had a stronger correlation with ASD if all five albic map sites per site were examined (i.e., five pedons worth of spodic and albic data examined instead of the one pedon description).

The E horizon thickness correlated well with ASD and O horizon thickness and had an observable correlation with the POD index (Table 2). It can be concluded that the E horizon morphology is a very important result of Aquods development and warrants greater consideration in hydric soil determination in Spodosols. The strong correlation of the E horizon thickness with the O horizon thickness (Table 2) indicates that with or without a water table, the E and O horizons may develop at the same rate (the ratio of horizon thickness may be different but the rate of development is the same). This also suggests that E horizon thickness is dependent on the amount of organic matter above it. Many researchers have noted that the albic horizon increases in thickness as saturation increases (Garman et al., 1981; Hunkler and Schaetzl, 1996; Stanley and Ciolkosz, 1981; Harris and Hollien, 2000).

The Value Index and the O and E horizon thicknesses are highly correlated with the ASD. These parameters are all components of the Aquods Index. Therefore, it is not surprising that the Aquods Index correlation to the ASD is very strong ($R = 0.912$, $p = <0.01$).

Conclusions

The objective of this study was to determine whether variegated color patterns in albic horizons can be reliably used as indicators of saturation. It can be concluded that albic horizon colors alone cannot be a strong indicator of saturation, but when combined with surface features, a strong correlation to wetness is noted. The Aquods Index supplies a basis for future studies involving color and thickness features in Aquods and it enhances the ability of soil scientists to understand the color features of albic horizons.

This study indicates that albic horizons are comprised of more than one color, and when describing albic horizons, scientists should look for variegated colors and note the percentage and colors. The color variations within albic horizons of Spodosols are worthy of greater attention. Additionally, redoximorphic features currently used to assess the water table in albic horizons warrant reinterpretation.

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Note Editor Mike Wilson's new email:
mike.wilson@lin.usda.gov