Biological Report 90(19)
December 1990

Synthesis of Soil–Plant Correspondence Data From Twelve Wetland Studies Throughout the United States

Fish and Wildlife Service
U.S. Department of the Interior

Biological Report

This publication series of the Fish and Wildlife Service comprises reports on the results of research, developments in technology, and ecological surveys and inventories of effects of land-use changes on fishery and wildlife resources. They may include proceedings of workshops, technical conferences, or symposia; and interpretive bibliographies.

Copies of this publication may be obtained from the Publications Unit, U.S. Fish and Wildlife Service, 1849 C Street, N.W., Mail Stop 130—ARLSQ, Washington, DC 20240, or may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.

ISSN 0895-1926

This publication may be cited as:

Segelquist, C. A., W. L. Slauson, M. L. Scott, and G. T. Auble. 1990. **Synthesis of Soil-Plant Correspondence Data From Twelve Wetland Studies Throughout the United States.** U.S. Fish Wildl. Serv., *Biol. Rep.* 90(19). 24 pp.

Biological Report 90(19)
December 1990

Synthesis of Soil–Plant Correspondence Data FromTwelve Wetland Studies Throughout the United States

By

C. A. Segelquist, W. L. Slauson, M. L. Scott, and G. T. Auble

U.S. Department of the Interior
Fish and Wildlife Service
Washington, D.C. 20240

Contents

Synthesis of Soil–Plant Correspondence Data From Twelve Wetland Studies Throughout the United States

by

Charles A. Segelquist

U.S. Fish and Wildlife Service
National Ecology Research Center
4512 McMurry Avenue
Fort Collins, Colorado 80525

William L. Slauson

TGS Technology, Inc.
4512 McMurry Avenue
Fort Collins, Colorado 80525

and

Michael L. Scott and Gregor T. Auble

U.S. Fish and Wildlife Service
National Ecology Research Center
4512 McMurry Avenue
Fort Collins, Colorado 80525

Abstract. This report synthesizes the information collected for the U.S. Fish and Wildlife Service in a series of 12 studies designed to describe the relation between soils and vegetation in wetlands located in 11 States throughout the United States. Results of the study demonstrated almost complete agreement between hydric soils and hydrophytic vegetation. However, agreement between nonhydric soils and nonhydric vegetation was not as high because most nonhydric soils lay adjacent to the wetland boundary. There was some evidence that various vegetation layers describe the hydrophytic nature of the vegetation differently than others. Herbaceous species seem to reflect current hydrologic conditions while trees may reflect past hydrologic conditions. Wetland indicator categories for some plants listed in the Fish and Wildlife Service national list of plant species that occur in wetlands may need to be reevaluated as additional data become available. Similarly, soils listed in the Soil Conservation Service hydric soils of the United States list should always be verified in the field prior to assigning them to a hydric category. While wetland hydrology is the critical factor determining wetlands, the use of soils and vegetation are frequently adequate for designating wetland conditions.

Key words: Hydric soils, hydrophytic vegetation, wetland ecology, wetland delineation.

The National Ecology Research Center of the U.S. Fish and Wildlife Service (FWS) planned and funded a series of 12 studies from 1984 through 1989 to document relations between hydric soils and hydrophytic vegetation in and near selected wetlands throughout the United States. The results of these studies are synthesized in this report. This research was conducted as part of a larger effort to develop and test procedures to delineate wetlands as defined by Cowardin et al. (1979) using the parameters of hydrophytic vegetation, hydric soils, and wetland hydrology.

Prior to 1989 the U.S. Army Corps of Engineers (Environmental Laboratory 1987), the Environmental Protection Agency (Sipple 1988), and the Soil Conservation Service (USDA 1987) developed independent procedures that variously described use of soils, vegetation, and hydrology for wetland delineation. The Federal manual for identifying and delineating jurisdictional wetlands (Federal Interagency Committee for Wetland Delineation 1989) now mandates standard procedures for using all three parameters—soils, vegetation, and hydrology—for wetland delineation.

However, problems are still encountered by regulatory personnel in delineating wetland boundaries because of poor correspondence among the multiple attributes that define wetlands. According to the Fish and Wildlife Service wetlands classification system (Cowardin et al. 1979):

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

The classification system also states that:

> The upland limit of wetland is designated as (1) the boundary between land with hydrophytic cover and land with predominantly mesophytic or xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time each year and land that is not.

This definition relies on three attributes of wetlands, but distinct boundaries seldom occur along gradients for individual attributes and boundaries in one attribute may not correspond with others. According to Tiner (1989) the one feature that must always be present for an area to be a wetland is wetland hydrology. An area has wetland hydrology when it is saturated to the surface or inundated at some time during an average rainfall year as defined by the Federal Interagency Committee for Wetland Delineation (1989); usually, an area saturated for a week or more during the growing season develops the anaerobic conditions necessary for meeting the wetland hydrology criteria. However, because hydrology is generally difficult to measure, hydric soils and hydrophytic vegetation are often used as surrogates for determining wetland hydrology and delineating wetland boundaries.

Hydrophytic plants or hydrophytes are defined as any plants growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content (Cowardin et al. 1979). The U.S. Soil Conservation Service (SCS) describes hydric soils as soils developed under conditions sufficiently wet to support the growth and regeneration of hydrophytic vegetation (SCS 1987). Thus, hydric soils and hydrophytic vegetation reflect wetland hydrology, but often not perfectly.

The SCS published a list of hydric soils of the United States in 1985 (SCS 1985) and revised the list in 1987 (SCS 1987). The 1987 list, hereafter referred to as the Soils List, describes hydric soils criteria in detail and identifies named soil series or phases of series that satisfy the hydric criteria. A list of plant species that occur in U.S. wetlands, hereafter referred to as the Plant List, was first published in 1986 (Reed 1986) and updated in 1988 (Reed 1988). The Plant List classifies plant species based on their frequencies of occurrence in wetlands.

A number of wetland designation procedures were evaluated by Wentworth and Johnson (1986) to assist the FWS and SCS in the development of a wetland delineation procedure. A weighted average procedure developed by Wentworth and Johnson (1986) uses the Plant List to identify wetland vegetation. The procedure is based on averages of species indices, weighted by importance values (Wentworth and Johnson 1986; Wentworth et al. 1988). Species indices are derived from the Plant List and used to calculate weighted average values or scores for plant communities sampled across moisture gradients. The weighted average values calculated in this manner represent the wetland character of the vegetation on a simple numerical scale. The use of weighted averages to characterize environmental relationships of vegetation has an extensive history in plant community ecology (Curtis and McIntosh 1951). Another procedure tested by Wentworth and Johnson (1986) is based on unweighted averages of species indices.

The objectives of the 12 soil–plant correlation studies on which this analysis is based were to evaluate the relation between hydric and nonhydric soils and hydrophytic and nonhydrophytic vegetation for selected wetlands and to test the weighted average and index average procedures of Wentworth and Johnson (1986). Before the studies were completed, revised versions of the Soils List and Plant List were published. Thus, the first six studies were based on earlier versions of the lists and the later studies used the revised lists.

Accomplishing the objectives described for these 12 studies required examination of the presence or absence of hydrophytic and nonhydrophytic plants on hydric and nonhydric soils and the relation of hydric soils and hydrophytic vegetation to the hydrology of the wetlands selected for study. Studies were conducted throughout the United States based on a prioritized list of wetland types developed by the regional wetland coordinators of the FWS (Table 1). Wetlands selected for study were often the ones that were considered to be most difficult to delineate or most important as fish and wildlife habitat.

Procedures

Literature Review

Each study began with a review of all available published and unpublished information useful for accomplishing study objectives. The review focused on the interrelations among vegetation communities, soils, and the hydrology of the wetlands selected for study. If sufficient data were already available to analyze the relations between soils and vegetation, such analyses were accomplished without further field investigations. The Alaska study

Table 1. *Sites where soil—plant correlation studies were conducted and reference to the published report for each study.*

Site	Reference
1. Prairie pothole wetlands in South Dakota	Hubbard et al. 1988
2. Forested wetlands in northern Florida	Best et al. 1990
3. Sandhill and rainwater basin wetlands in Nebraska	Erickson and Leslie 1987
4. Riparian wetlands of the Gila and San Francisco rivers in New Mexico	Dick-Peddie et al. 1987
5. Riparian wetlands on the Carson River and nearby emergent wetlands in Lyon County, Nevada	Nachlinger 1988
6. Riparian wetlands in the Sacramento Valley of northern California	Baad 1988
7. Pocosin wetlands in North Carolina	Christensen et al. 1988
8. Diked former tideland wetlands along San Francisco Bay in California	Eicher 1988
9. Tussock tundra wetlands in the northern foothills of the Brooks Range in Alaska	Walker et al. 1989
10. Pitcher plant bogs and wetlands in southern Mississippi	Erickson and Leslie 1989
11. Forested wetlands in Rhode Island	Allen et al. 1989
12. Floodplain wetlands of the Connecticut River Valley in Massachusetts	Veneman and Tiner 1990

was based on available data (Walker et al. 1989), the Rhode Island study was an extension of an ongoing research project (Allen et al. 1989), and Christensen et al. (1988) analyzed existing data for wetlands in North Carolina and other southeastern States in addition to collecting new data from the pocosins on the Croatan National Forest. All other studies involved collection and analysis of new field data.

Selection of Wetland Study Areas

The basic wetland unit selected for study consisted of a broadly defined wetland complex: an area consisting of wetlands, transition lands, and adjacent uplands; within a limited geographic range and with similar characteristic associations of vegetation and soils. Wetland complexes were identified by regional wetland coordinators from various Fish and Wildlife Service regional offices and prioritized by the Washington office of the FWS Ecological Services division. Twelve study sites were located in 11 States (Fig. 1).

To facilitate sampling, wetlands selected for study were, where possible, located in areas where wetland or soil maps were available. However, such maps were not available for study areas in Nevada, New Mexico, Alaska, and parts of South Dakota.

A major consideration in final wetland site selection was accessibility. Also important was selection of study areas relatively undisturbed by human activities so that vegetation, soils, and hydrologic conditions were as natural as possible. However, in every case except Alaska, wetlands had been altered to some extent by drainage, grazing, forestry, flooding, farming, or other activities.

Sampling Design

The standard sampling design ensured inclusion of multiple locations of each soil within the perceived wetland zone, all transition zone soils, and at least one adjacent soil with nonhydric characteristics. However, sampling procedure as well as

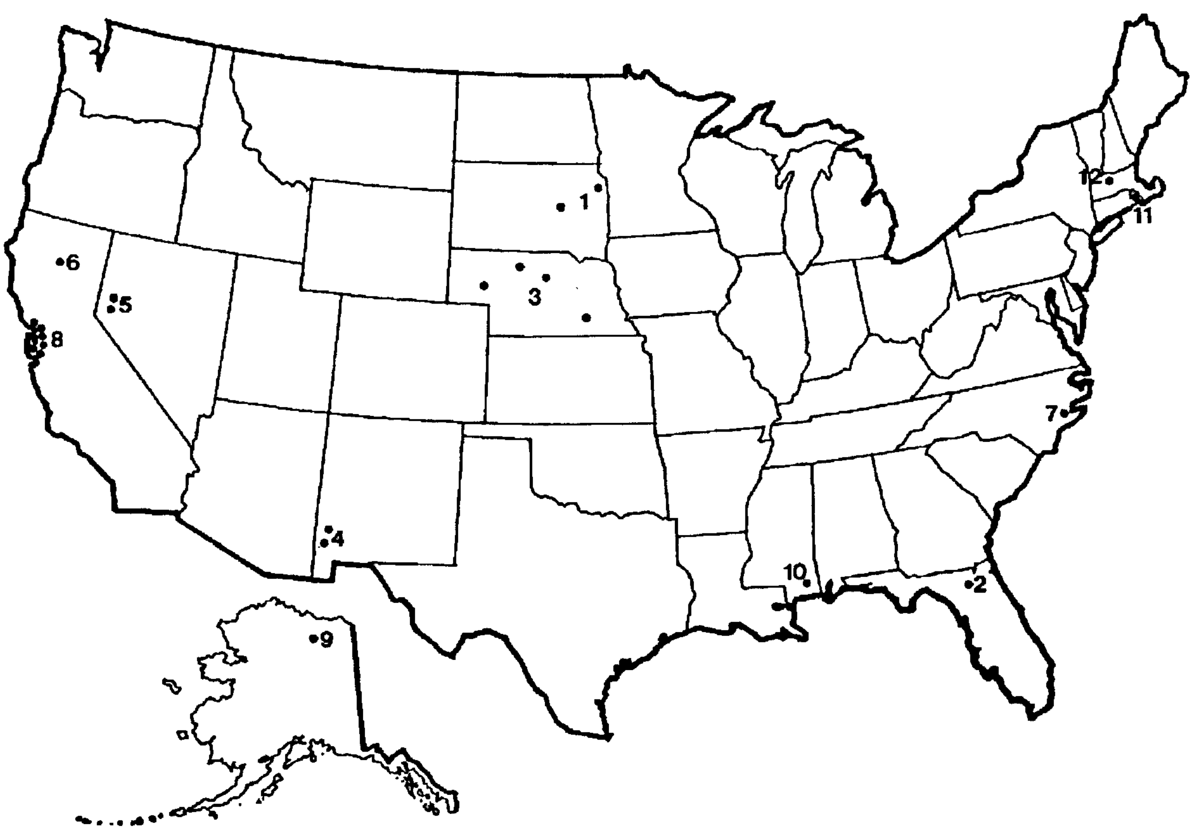


Fig. 1. Locations of the 12 soil–plant correlation sites.

analytical treatment of the data varied as indicated by original reports for each study (Table 1). Sample sites selected for study were randomly located, to the extent possible, using soil maps where wetland boundaries had been approximated or wetland maps where soils had been delineated. In areas where maps were not available, sites were established after field reconnaissance. Poorly represented soils often were not sampled.

Soil Sampling Procedures

Soils selected for study were identified and verified on-site by soil scientists from the Soil Conservation Service, U.S. Forest Service, or universities. Standard soil survey procedures (Soil Survey Staff 1951) were followed for this determination. Boundaries of soils were verified to avoid transitions between adjacent soils and to ensure that vegetation sample plots were located on the expected soil types.

Hydrologic Determinations

Hydric status of many soils also was verified by on-site determinations. Various hydrologic parameters (depth to groundwater, water table fluctuations, soil moisture, and duration of flooding) were examined for soils in Massachusetts, Rhode Island, South Dakota, Nevada, North Carolina, New Mexico, and Alaska. In all other studies, investigators attempted to evaluate hydrology through other means such as analysis of soils information or elevational gradients in relation to groundwater or flooding. Thus, independent evidence of the hydric nature of all soils was verified to some extent and the probability is high that a soil designated as hydric in this synthesis report meets the criteria for hydric soils (SCS 1987).

In the original studies (Table 1) and in the analysis of herbaceous data for selected studies by Scott et al. (1989), the presence or absence of soils on the Soils Lists was taken as the principal evidence that a soil was hydric. However, because independent evidence of the hydric nature of all soils was used for this synthesis, some differences occur between results in this report and those described in some of the original studies and in Scott et al. (1989).

Vegetation Sampling Procedures

Vegetation measurements for each soil included assessment of all vegetation layers—trees, shrubs, and ground cover—where such layers were present. Standard specifications were used for vegetation sampling (Table 2); however, some differences in sampling procedures were required to meet individual study objectives. Where the standard vegetation sampling scheme was modified, changes were discussed with and approved by the Project Officer at the National Ecology Research Center. Studies based on existing data or ongoing research did not meet these specifications, but did approximate most of the established criteria.

Table 2. *Specifications for sampling vegetation on the 12 study sites.*

Definition of vegetation layer	Importance value measured for each species	Size of quadrat (m^2)	Number of random quadrats per replication (soil)
Trees, all stems > 7.5 cm dbh	Diameter at breast height (dbh) on all stems	100	5
Tall shrubs, woody species < 7.5 cm dbh, >1.3 m tall	Number of main leaders	4	5
Short shrubs, all woody species >0.5 m and <1.3 m tall	Number of individual plants (clumps) emerging from ground	4	5
Herbaceous, all woody species < 0.5 m tall and *all* herbaceous species regardless of height	Percent cover in 0–6 Daubenmire (1968) classes	0.5	10

The shrub layer quadrats were located within the larger tree quadrats for each soil sampled. The herbaceous layer was typically measured by two quadrats placed within each tree quadrat. Percent cover by species was estimated by Daubenmire (1968) cover classes for all vegetation in the herbaceous layer (Table 3).

Table 3. *Cover estimated by Daubenmire (1968) cover classes with the midpoints of class ranges used for calculations.*

Cover class	Class range	Midpoint of range
1	0–5	2.5
2	6–25	15.0
3	26–50	37.5
4	51–75	62.5
5	76–95	85.0
6	96–100	98.0

Data Analysis

Because the primary objective of these studies was to show the relation of wetland plants to hydric soils, vegetation composition by wetland indicator classes was determined for each vegetation layer. There were some variations in the way data were analyzed among individual studies; however, for this synthesis, all data were reanalyzed using standard procedures, except when noted. Wetland plant classes were based on the indicator status in the Plant List (i.e., obligate wetland, facultative-wetland, facultative, facultative-upland, and obligate upland).

For each quadrat, or plot, within each vegetation layer a weighted average (*WA*) score was calculated by the equation given by Wentworth and Johnson (1986):

$$W_j = \left(\sum_{i=1}^{P} I_{ij} E_i \right) / \left(\sum_{i=1}^{P} I_{ij} \right)$$

where

W_j = weighted average for plot j
I_{ij} = "importance" value for species i in plot j
E_i = ecological index for species i
P = number of species in plot.

Index averages also were calculated from presence/absence information. Calculations were made according to the following formula, also from Wentworth and Johnson (1986):

$$I_j = \left(\sum_{i=1}^{p} E_i \right) / p$$

where

I_j = index average for sample plot j
E_i = ecological index for species i
p = number of species in sample plot j.

Importance was estimated by percent cover for the herbaceous layer, density for the two shrub layers, and basal area for trees. The ecological index (E) was obtained from the Plant List (Reed 1988) by assuming numerical values for the following categories and ignoring + and – modifiers:

1 = Obligate
2 = Facultative-wetland
3 = Facultative
4 = Facultative-upland
5 = Upland[1]

Standard analysis for each of the original studies included calculations of weighted average (*WA*) and index average (*IA*) scores for each vegetation layer. The range, mean, standard deviation, and standard error of the mean were calculated for both scores for each soil in most studies.

In this synthesis we calculated a number of different values or scores to accomplish certain comparisons. (1) We calculated mean weighted average (mean *WA*), median weighted average (median *WA*), and median index average (median *IA*) values for the herbaceous layer for each soil using plant species indicator values from Reed (1988) to compare these three methods for describing the hydrophytic nature of herbaceous vegetation nationwide. (2) For the six studies completed before the 1988 Plant List was published, we calculated median *WA* plot scores for the herbaceous layer using plant species indicator values from Reed (1986) and compared the results to similar values computed using Reed (1988) to determine the extent of the change using the revised list. (3) We also calculated median *WA* scores using wetland indicator values from Reed (1988) for each vegetation layer individually and for all layers combined for each soil sampled, except for Alaska and Rhode

[1] Most species that were not on the list were upland species; however, 59 species were considered to be hydrophytes—for these species, the principal investigators assigned a "provisional indicator status."

Island, where original field data were not available. The weighted average score for all layers combined was computed as the arithmetic mean of all layers present on a soil.

We used median *WA* plot values for most analyses rather than mean *WA* to describe the hydric nature of vegetation associations because the Lilliefors and Bartlett test showed that weighted average scores are generally not normally distributed and have unequal variances at the levels tested in this study (Scott et al. 1989). Therefore, the median of the weighted average plot scores is a better measure of the central tendency of vegetation plots within a soil. For each of the preceding analyses, weighted average or index average scores less than 3.00 were considered to represent hydrophytic vegetation and scores of 3.00 or more indicated upland vegetation.

We also conducted graphic analyses of median *WA* values for all vegetation layers combined to show the full range of variation in the hydrophytic nature of vegetation associations by soils. Grouped, notched box plots (McGill et al. 1978; Velleman and Hoaglin 1981) were used to depict the distribution of weighted average plot scores for each soil. These box plots display the distribution of data by quartiles (Fig. 2). The first and third quartiles are marked by the lines forming the narrow sides of the box. The length of the box is called the interquartile range (*IQR*) and includes the middle 50% of the data. The median or second quartile is marked by the vertical line near the middle of the box. The horizontal lines extend beyond the box to the extreme data values, or to a point 1.5 times the *IQR* below the first and above the third quartile. The remaining, outlying data points are indicated individually (Velleman and Hoaglin 1981). Box plots illustrate position, range, scale, and skewness of the distribution. In addition, the approximate 95% confidence interval (CI) about the median is shown by the notch in the box. The notch spans the median by the amount 1.58 $(IQR)n^{0.5}$ above and below the median, where *IQR* is the interquartile range and *n* is the sample size (McGill et al. 1978; Velleman and Hoaglin 1981).

In these graphic analyses, vegetation associations are placed in one of three categories based on the distribution of weighted average scores of the plots sampled in a soil. Any vegetation association with a 95% CI that includes 3.00 is classified as intermediate between hydrophytic and upland. Vegetation is classified as hydrophytic or nonhydrophytic, respectively, if the 95% CI is completely below or above 3.00. This is different from the method of Wentworth and Johnson (1986) and Wentworth et al. (1988) where intermediate vegetation includes any vegetation association with mean scores in the range of 2.50–3.50 and it differs from the method of the Federal Interagency Committee for Wetland Delineation (1989) that divides soils and vegetation into wetlands and nonwetlands at 3.00. However, these analyses more accurately address the range of conditions that occur in nature and more of the variability inherent in the data collected in the field.

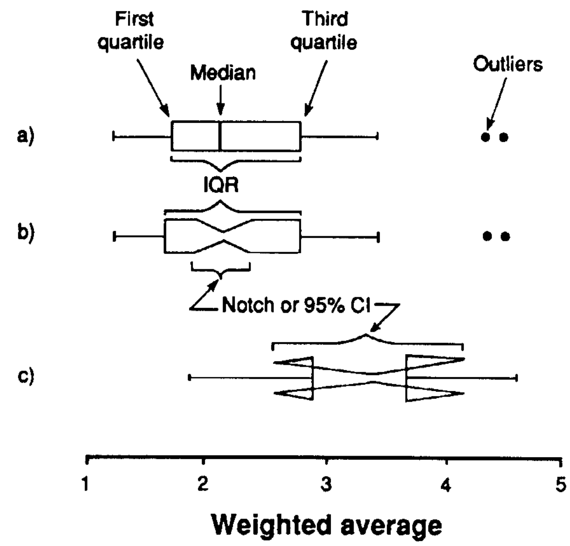


Fig. 2. Sample box plots showing the data range and quartiles for a variable measured on a weighted average scale of 1 to 5. The box plots in (a) and (b) are for the same data, but (b) shows the notch indicating the approximate 95% confidence interval (CI) about the median. Box plot (c) shows another data distribution where the notch exceeds the interquartile range (IQR). The box is extended so that the complete notch is visible.

Results and Discussion

Soils from a variety of wetland habitats and adjacent uplands were sampled from the study sites (Table 4). Of the 116 soils sampled in the 12 studies, 77 were hydric soils and 39 were nonhydric soils (Table 4). Each soil did not represent a different series, but each soil identified was recognized as distinct from all other soils sampled at each study area.

Table 4. *Location, habitat description, soil identification, drainage class, soil subgroup, and hydric status for soils sampled from 12 study sites.*

Location	Habitat description	Soil identification	SCS drainage class	Subgroup	Hydric status[a]
California					
Butte Sink	Riparian emergent wetlands, sinks, table marshes, and adjacent uplands	Capay silty clay	MWD	Typic Chromoxerert	H
		Clear Lake clay old field, flooded	PD	Typic Pelloxerert	H
		tule marsh	PD	Typic Pelloxerert	H
		depressions	PD	Typic Pelloxerert	H
		mounds	PD	Typic Pelloxerert	H
		Galt clay flooded	MWD	Typic Chromoxerert	H,
		Live Oak–Galt,			
		swale	MWD	Typic Chromoxerert	H
		upland	MWD	Typic Chromoxerert	N
		Olashes sandy loam,			
		flooded	WD	Mollic Haploxeralf	N
		well-drained	WD	Mollic Haploxeralf	N
		Palls–Stohlman			
		stony sandy loam	WD	Mollic Haploxeralf	N
		Shanghai silt loam	SPD	Aquic Xerofluvents	N
		Columbia fine sandy loam	SPD	Aquic Xerofluvent	N
San Francisco Bay tidelands	Coastal emergent tidelands and diked former tidelands and adjacent uplands	Novato clay	VPD	Typic Hydraquents	H
		Reyes clay	SPD	Sulfic Fluvaquents	H
		Joice muck	VPD	Typic Medisaprists	H
		Omni silty clay loam	PD	Fluvaquentic Haplaquolls	H
		Pescadero clay	PD	Aquic Natrixeralfs	H
		Alviso silty clay loam	PD	Tropic Fluvaquents	H
		Antioch loam	MWD	Typic Natrixeralfs	N
		Rincon clay	WD	Mollic Haploxeralfs	N
		Ballard gravelly loam	WD	Typic Argixerolls	N
		Vallecitos gravelly loam	WD	Lithic Ruptic-Xerochreptic Haploseralfs	N
Nevada					
Carson River riparian lands	Riparian emergent wetlands, sparsely wooded riparian areas, and adjacent uplands	East Fork	SPD	Fluvaquentic Haploxerolls	H
		Sagouspe	SPD	Aquic Xerofluvents	H
		Fallon	SPD	Aquic Xerofluvents	H
		Dia	PD	Fluvaquentic Haploxerolls	H
		Diathod	FP	Fluvaquentic Haploxerolls	H
		Fallon–drained	SPD	Aquic Xerofluvents	N
		Patna	SED	Typic Haplagids	N
		Isolde	ED	Typic Torripsamments	N
Fernley Marsh	Saline depressional wetlands and adjacent upland	Unnamed NV-1	VPD	Terric Medafibrists	H
		Unnamed NV-2	VPD	Typic Haplaquents	H
		Umberland	SPD	Aeric Halaquepts	H
		Parran	SPD	Typic Salorthids	H
		Swingler	MWD	Typic Torriorthents	N
		Osobb	WD	Typic Durorthids	N

Table 4. *Continued.*

Location	Habitat description	Soil identification	SCS drainage cls	Subgroup	Hydric status[a]
New Mexico					
Gila River riparian lands	Riparian woodlands and adjacent upland	Swale	VPD	Typic Fluvaquent	H
		Sandbar	PD	Aquic Ustifluvent	H
		Lower terrace	WD	Typic Ustifluvent	N
		Upper terrace	WD	Fluventic Ustochrepts	N
San Francisco River riparian lands	Riparian woodlands and adjacent uplands	Swale	VPD	Typic Fluvaquent	H
		Sandbar	PD	Aquic Ustifluvent	H
		Lower terrace	WD	Typic Ustifluvent	N
		Upper terrace	WD	Fluventic Ustochrepts	N
South Dakota					
Beadle County potholes	Prairie potholes and adjacent uplands	Worthing	VPD	Typic Argiaquolls	H
		Tetonka	PD	Argiaquic Argialbolls	H
		Hoven	PD	Typic Natraquolls	H
		Hand	WD	Typic Haplustrolls	N
Deuel County Potholes	Prairie potholes and adjacent uplands	Southam	WPD	Cumulic Haplaquolls	H
		Parnell	PD	Typic Argiaquolls	H
		Vallers	PD	Typic Calciaquolls	H
		Flom	PD	Typic Haplaquolls	N
		Svea	MWD	Pachic Udic Haploborolls	N
		Barnes	WD	Udic Haploborolls	N
Nebraska					
Rainwater	Basin Depressional emergent wetlands and adjacent uplands	Massie	VPD	Typic Argialbolls	H
		Fillmore	PD	Typic Argialbolls	H
		Scott	VPD	Typic Argialbolls	H
		Butler	SPD	Abruptic Argialbolls	N
Sandhills	Seasonal to semipermanent depressional emergent wetlands and adjacent sandhill prairie grasslands	Marlake	PD	Mollic Fluvaquents	H
		Hoffland	PD	Typic Calciaquolls	H
		Loup	PD	Typic Haplaquolls	H
		Tryon	PD	Typic Psammaquents	H
		Els	PD	Aquic Ustipsamments	N
		Ipage	MWD	Aquic Ustipsamments	N
		Valentine	ED	Typic Ustidsamments	N
Mississippi					
Pitcher plant bogs	Pitcher plant bogs, wet prairies, and adjacent pine woodlands	Atmore	PD	Plinthic Paleaquults	H
		Croatan	VPD	Terric Medisaprists	H
		Hyde	VPD	Typic Umbraquults	H
		Plummer	PD	Grossarenic Paleaquults	H
		Harleston	MWD	Aquic Paleudults	N
North Carolina					
Pocosins	Shrub–bog emergent wetlands	Bayboro, flatwood	VPD	Umbric Paleaquult	H
		Croatan,			
		low pocosin	PD	Terric Medisaprist	H
		high pocosin	PD	Terric Medisaprist	H
		gum swamp	PD	Terric Medisaprist	H
		bay forest	PD	Terric Medisaprist	H
		lake shore swamp	PD	Terric Medisaprist	H

Table 4. *Continued.*

Location	Habitat description	Soil identification	SCS drainage cls	Subgroup	Hydric status[a]
North Carolina (continued)		Dare,			
		low pocosin	VPD	Typic Medisaprist	H
		medium pocosin	VPD	Typic Medisaprist	H
		gum swamp	VPD	Typic Medisaprist	H
		lake shore swamp	VPD	Typic Medisaprist	H
		Dorovan, gum swamp	VPD	Typic Medisaprist	H
		Leaf, flatwood	PD	Typic Albaquult	H
		Lenoir, flat-wood	SPD	Aeric Paleaquult	H
		Pantego, flat-wood	VPD	Umbric Paleaquult	H
		Onslow, savannah	MWD	Spodic Paleudult	N
Rhode Island					
red maple swamp	Forested red maple swamps and adjacent forested uplands	Carlisle	VPD	Typic Medisaprists	H
		Adrian	VPD	Terric Medisaprists	H
		Scarboro	VPD	Histic Humaquept	H
		Walpole	PD	Aeric Haplaquepts	H
		Wareham	PD–SPD	Humaqueptic Psammaquents	H
		Deerfield	SPD–MWD	Aquic Udipsamments	N
		Sudbury	MWD	Aquic Udipsamments	N
Florida					
Forested wetlands		Croatan	VPD	Terric Medisaprists	H
		Surrency	VPD	Arenic Umbric Paleaquults	H
		Mascotte			
		managed	PD	Ultic Haplaquods	H
		unmanaged	PD	Ultic Haplaquods	H
		Sapelo			
		managed	PD	Ultic Haplaquods	H
		unmanaged	PD	Ultic Haplaquods	H
		Ocilla	SPD	Aquic Arenic Paleudults	N
		Albany	SPD	Grossarenic Paleudults	N
Massachusetts					
		Saco	VPD	Typic Fluvaquent	H
		Rippowam	PD	Aeric Fluvaquent	H
		Limerick	PD-SPD	Aeric Fluvaquent	H
		Winooski	MWD	Aquic Udifluvent	H
		Pootatuck	MWD	Aeric Fluvaquent	N
		Hadley	WD	Typic Udifluvent	N
		Limerick	SPD	Aeric Fluvaquent	N
		Winooski	MWD	Aquic Udifluvent	N
Alaska					
Arctic foothills of the Brooks Range	Arctic tundra	Soils Unnamed	Perma-frost	Pergelic Cryofibrist	H
				Pergelic Cryohemist	H
				Hemic Pergelic Sphagnofibrist	H
				Histic Pergelic Cryaquept	H
				Pergelic Cryaquept	H
				Pergelic Cryorthent	N
				Pergelic Cryochrept	N

Comparison of Methods for Calculating Hydrophytic Status of Vegetation

The herbaceous layer was the only class of vegetation common to all soils; thus, comparison of methods for calculating the hydrophytic nature of vegetation were based on analyses of this layer. Data were available for 102 of the 116 soils suitable for calculating weighted average and index average values (Table 5). Depending on which method was used—median *WA*, mean *WA*, or median *IA*—*results varied enough among vegetation associations to change categories from hydrophytic to nonhydrophytic or vice versa for eight soils: Alviso; Umberland; Parran; Hoven; Scott; Mascotte, managed and unmanaged; and Sapelo, managed. However, the percent agreement or correspondence between hydric soils and hydrophytic vegetation and between nonhydric soils and nonhydrophytic vegetation (Table 6) suggested little difference among the three methods used to estimate the hydrophytic nature of vegetation. Mean WA* values as used by Wentworth and Johnson (1986) and median *WA* values as calculated by Scott et al. (1989) required rather exhaustive quantitative measurements of species importance to calculate the hydrophytic nature of vegetation and consequently required extensive sampling. However, simply enumerating the presence or absence of herbaceous species on a systematic basis and calculating median *IA* scores resulted in scores between soils and vegetation very similar to median *WA* scores.

Table 5. *Comparison of mean weighted average, median weighted averages, and median index averages for the herbaceous layer for soils sampled at 12 study sites. All values computed using Reed (1988).*

State, locality, and soil[a]	Mean weighted average	Median weighted average	Median index average
California			
Butte Sink			
*Capay silty clay	2.15	2.52	2.27
*Clear Lake clay, old field flooded	1.92	1.93	2.15
*Clear Lake clay, tule marsh	1.88	1.78	2.13
*Clear Lake clay, depressions	1.21	1.19	1.33
*Clear Lake clay, mounds	2.21	1.96	2.47
*Galt clay, flooded	2.78	2.87	2.92
*Live Oak–Galt, swale	2.40	2.33	2.67
Live Oak–Galt, upland	4.20	4.32	3.59
Olashes sandy loam, flooded	3.62	3.62	3.75
Olashes sandy loam, well-drained	4.50	4.52	4.44
Palls–Stohlman stony sandy loam	4.55	4.54	4.50
Shanghai silt loam	3.21	3.26	3.14
Columbia fine sandy loam	3.37	3.50	3.15
San Francisco Bay			
*Novato	1.22	1.00	1.00
*Reyes	1.01	1.00	1.00
*Joice	1.23	1.15	1.33
*Omni	1.53	1.48	2.00
*Pescadero	2.59	2.58	2.67
*Alviso	2.81	2.99	3.00
Antioch	4.10	3.99	4.00
Rincon	2.95	2.93	2.54
Ballard	4.31	4.50	4.18
Vallecitos	4.74	4.94	4.73
Nevada			
Carson River			
*East Fork	1.01	1.00	1.00
*Sagouspe	1.40	1.28	1.50
*Fallon	1.81	1.48	2.00
*Dia	2.35	2.49	2.13
*Diathod	2.54	2.67	2.25
Fallon, drained	3.14	3.00	3.00
Patna	3.80	4.00	4.00
Isolde	4.98	5.00	5.00
Fernley Marsh			
*Unnamed NV-1	1.24	1.00	1.00
*Unnamed NV-2	1.71	1.24	2.00
*Umberland	2.41	3.00	3.00
*Parran	2.47	3.00	3.00

Table 5. *Continued.*

State, locality, and soil[a]	Mean weighted average	Median weighted average	Median index average
Nevada (continued)			
Swingler	5.00	5.00	5.00
Osobb	5.00	5.00	5.00
New Mexico			
Gila River			
*Swale	2.51	2.32	2.50
*Sandbar	3.51	3.74	3.67
Lower terrace	4.13	4.43	4.00
Upper terrace	4.66	4.81	4.75
San Francisco River			
*Swale	2.28	2.23	2.60
*Sandbar	3.50	3.94	3.63
Lower terrace	4.01	4.00	4.00
Upper terrace	4.01	4.29	4.40
South Dakota			
Beadle County			
*Worthing	1.09	1.05	1.45
*Tetonka	2.33	2.39	2.75
*Hoven	3.02	3.06	2.93
Hand	4.76	4.78	4.29
Devel County			
*Southam	1.00	1.00	1.00
*Parnell	1.42	1.35	1.49
*Vallers	2.73	2.84	2.84
Flom	3.89	3.97	3.81
Svea	4.09	4.08	4.23
Barnes	4.18	4.18	4.30
Nebraska			
Rainwater Basin			
*Massie	1.41	1.16	1.33
*Fillmore	2.38	2.64	2.41
*Scott	3.00	3.04	2.83
Butler	3.18	3.16	3.20
Sandhills			
*Marlake	1.35	1.24	1.33
*Hoffland	2.61	2.49	2.44
*Loup	2.28	2.12	2.37
*Tryon	2.73	2.83	2.74
Els	3.78	3.92	3.81
Ipage	3.50	3.61	3.34
Valentine	4.42	4.33	4.25
Mississippi			
Sandhill Crane Refuge			
*Atmore	1.64	1.66	1.71
*Croatan	1.46	1.48	1.60
*Hyde	1.97	1.95	2.00
*Plummer	1.82	1.76	1.82
Harleston	2.40	2.23	2.06
North Carolina			
Pocosins			
*Bayboro, flatwood	2.00	2.00	2.00
*Croatan, low pocosin	1.79	1.79	1.75
*Croatan, high pocosin	1.88	1.89	1.85
*Croatan, gum swamp	2.18	2.03	2.27
*Croatan, bay forest	2.00	2.00	2.00
*Croatan, lake shore swamp	2.25	2.33	2.00
*Dare,low pocosin	1.91	1.92	1.90
*Dare, medium pocosin	1.81	1.84	1.72
*Dare, gum swamp	2.10	2.01	2.20
*Dare, lake shore swamp	1.93	2.00	2.00
*Dorovan, gum swamp	2.11	2.08	2.20
*Leaf, flatwood	2.03	2.00	2.00
*Lenoir, flatwood	2.01	2.00	2.00
*Pantego, flatwood	2.24	2.27	2.35
Onslow, savannah	2.67	2.70	2.69
Rhode Island			
Red Maple Swamps			
*Carlisle	1.81	Data not available	Data not available
*Adrian	2.00	Data not available	Data not available
*Scarboro	2.06	Data not available	Data not available
*Walpole	2.95	Data not available	Data not available
*Wareham	2.74	Data not available	Data not available
Deerfield	3.17	Data not available	Data not available
Sudbury	3.32	Data not available	Data not available
Florida			
Forested wetlands			
*Croatan	1.43	1.27	1.60
*Surrency	1.82	1.88	2.00

Table 5. *Continued.*

State, locality, and soil[a]	Mean weighted average	Median weighted average	Median index average
Florida (continued)			
*Mascotte, managed	2.99	2.96	3.00
*Mascotte, unmanaged	2.69	2.69	3.00
*Sapelo, managed	3.24	3.29	3.39
*Sapelo, unmanaged	2.79	3.00	3.00
Ocilla	3.02	3.00	3.00
Albany	3.44	3.47	3.45
Massachusetts			
Connecticut River			
*Saco	2.51	2.00	2.00
*Rippowam	2.07	2.00	2.00
*Limerick	2.00	2.00	2.00
*Winooski	2.03	2.02	2.25
Pootatuck	3.00	3.04	3.25
Hadley	3.61	3.63	3.55
Limerick	2.00	2.00	2.00
Winooski	3.54	3.84	3.66
Alaska			
Acidic tussock tundra		Data not available	
*Pergelic cryofibrist	1.0		
*Pergelic cryohemist	1.9		
*Hemic pergelic sphagnofibrist	2.2		
*Histic pergelic cryaquept	2.3		
*Pergelic cryaquept	2.9		
Pergelic cryorthent	3.8		
Pergelic cryochrept	3.8		

[a] Hydric soils are identified by an asterisk.

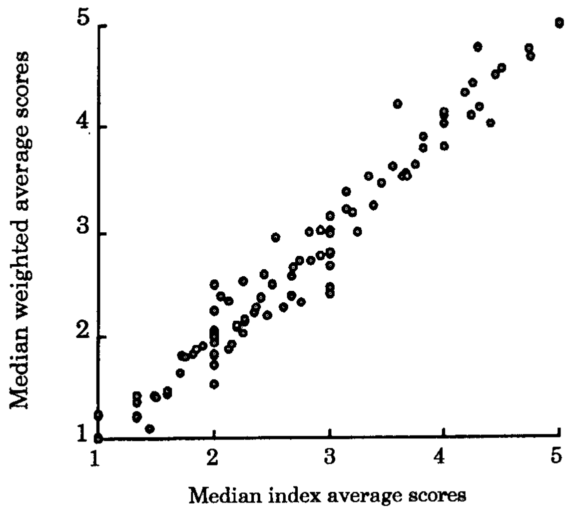
We emphasize that most of the upland soils examined in these studies fell in the transition zone between well-defined wetlands and uplands where the distinction between soils and vegetation are difficult to determine. If we had sampled farther into the upland, and had sampled hydric and nonhydric soils in proportion to their abundance in the landscape, the agreement between soils and vegetation certainly would have been much higher.

Graphic comparisons of relations between median *IA* and *WA* values and between median and mean *WA* values indicated strong agreement among these measures for predicting the hydrophytic nature of the herbaceous vegetation layer (Fig. 3). No one measure appeared to define the hydric soil-hydrophytic vegetation or the nonhydric soil-nonhydrophytic vegetation association better than any other measure.

Table 6. *Comparison of the percent agreement or correspondence between hydric soils and hydrophytic vegetation and nonhydric soils and nonhydric vegetation for the herbaceous layer based on three techniques. Data for Alaska and Rhode Island were available only for computing mean weighted average values.*

Soil and vegetation associations	Percent agreement		
	Mean weighted average	Median weighted average	Median index average
Hydric soils: hyrophytic vegetation	93 (92)[a]	88	87
Nonhydric soils: nonhydrophytic vegetation	89 (90)[a]	89	86
Total	91 (92)[a]	88	86

[a] Includes Alaska and Rhode Island.



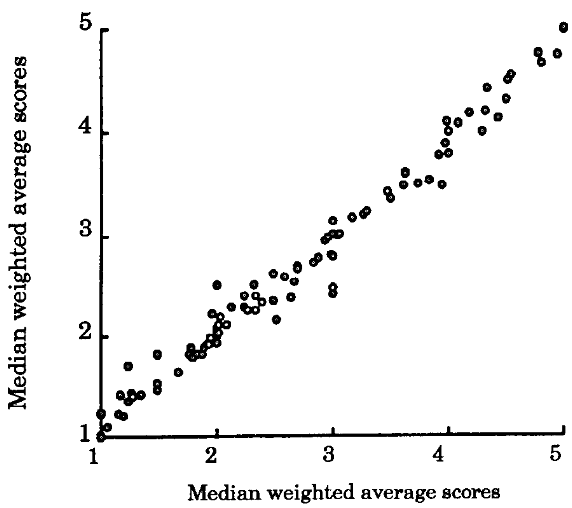


Fig. 3. Relation between index average and weighted average median values and between median and mean weighted averages for the herbaceous layer for all soils sampled.

Comparison of Results Using 1986 and 1988 Plant Lists

The first six studies initiated (Dick-Peddie et al. 1987; Erickson and Leslie 1987; Baad 1988; Christensen et al. 1988; Hubbard et al. 1988; Nachlinger 1988) were completed before publication of the most recent Plant List (Reed 1988) was published; thus, analyses in the original publications were based on the earlier Plant List (Reed 1986). Some readers of the original studies were concerned that the results of those studies might have incorrectly described the association between soils and vegetation because they were based on the earlier version of the Plant List. Accordingly, plant indicator status values were updated to conform to the 1988 Plant List and median *WA* values for the herbaceous layer for these six studies were compared to similar calculations based on plant species indicator values from the 1986 Plant List. Results indicated that weighted average vegetation scores changed categories for only two soils as a result of updating the indicator status of herbaceous species and reanalyzing the data. The values that changed were for Umberland and Parran soils in the Fernley Marsh in Nevada, where median *WA* scores changed from 2.00 to 3.00 from 1986 to 1988. Other values changed slightly, but not enough to move from one hydrophytic category to another.

The reason for the changes in *WA* scores for Umberland and Parran soils in Nevada, according to J. L. Nachlinger (Nevada Protection Planner, The Nature Conservancy, Reno, Nevada, personal communication) was because inland saltgrass (*Distichlis spicata* var. *stricta* [Torr.] Scribn.) was transferred from the facultative-wetland indicator category in the earlier Plant List (Reed 1986) to the facultative category in the later Plant List (Reed 1988), and black greasewood (*Sarcobatus vermicultus* [Hook.] Torr.) was transferred from the facultative to facultative-upland category in the 1988 Plant List. Nachlinger feels that both of these changes may be inappropriate for these species in that region. She indicated that a reasonable amount of literature suggested that black greasewood occurs where the water table is high. In fact, she suggests that growth habits of black greasewood may be more like those of iodine bush (*Allenrolfea occidentalis* [S. Wats.] Kuntze), a facultative-wetland species (Reed 1986, 1988) that occurs on similarly wet, but more alkaline soils, than they are like growth habits of facultative species or facultative upland species growing in the same area. Nachlinger believes that this situation underscores the need to conduct further research into vegetation associations on saline soils in this region and to further evaluate the assignment of wetland indicator categories for these species and perhaps others.

Comparison of Vegetation Layers For Determining Affiliation of Soils and Vegetation

Only six studies (Dick-Peddie et al. 1987; Erickson and Leslie 1987; Christensen et al. 1988; Allen et al. 1989; Best et al. 1990; Veneman and Tiner 1990) contained data for multiple vegetation layers useful for comparing the association of vegetation layers to soils. Large cottonwood trees (*Populus fremontii* S. Wats.) were relatively abundant on several of the soils sampled along the Carson River in Nevada (Nachlinger 1988), but they were spaced so widely apart that they were never encountered on sample plots. This suggests that canopy cover may be a more useful criterion than diameter at breast height for measuring influence of trees where they are widely dispersed.

Data for the Rhode Island study were collected in a manner suitable for comparison to other studies only for the herbaceous, short-shrub, and tall-shrub layers; thus, analyses of the associations of soils and vegetation layer do not include the tree layer or all layers combined for Rhode Island. In addition, median *WA* scores could not be computed for Rhode Island data; thus, comparisons for those data were based on the mean *WA* values computed by Allen et al. (1989). Considerable variation was observed among median *WA* values by vegetation layers for given soils (Table 7). In New Mexico, for example, the herbaceous vegetation layer on the lower terrace soils along the Gila and San Francisco rivers was dominated by species with indicator values of 4.00 or above, while the tree layer had values of 2.22 or above. This might indicate the effect of temporal changes in hydrologic, climatic, or other environmental conditions related to establishment of long-lived species such as cottonwood trees, which reflect past conditions, versus short-lived herbaceous vegetation. However, this also might indicate that the indicator status of some plant species in Reed (1988) have been assigned incorrectly for that region.

Differences in scores among vegetation layers for certain soils in Florida and Rhode Island also were great enough to affect the designation of the hydrophytic status of vegetation, and the authors of the respective studies, Best et al. (1990) and Allen et al. (1989), discussed the possible reasons for these differences in their respective reports. Best et al. (1990) suggested that wetland indicator categories for some species may need to be adjusted on a regional basis. Specifically, they indicated that slash pine (*Pinus elliottii* Engelm.) and ink-berry (*Ilex glabra* [L.] Gray) may be more appropriately assigned to facultative rather than facultative-wetland categories. Allen et al. (1989) found that differences in scores between vegetation layers had little to do with improper indicator assignment of wetland species, but felt that herbs were more sensitive to the moisture gradient while shrubs were more broadly adapted and distributed. However, Allen et al. (1989) suggested that ink-berry and swamp azalea (*Rhododendron viscosum* [L.] Torr.) might have been assigned to lower wetland-indicator categories than appropriate, and thus changed the indicator status of swamp azalea from obligate to facultative-wetland prior to analyzing the results of their study.

The correspondence between hydric soils and hydrophytic vegetation was superior to comparable values between nonhydric soils and nonhydrophytic vegetation for each layer of vegetation and for all layers combined (Table 8). This is probably because the hydric soils were more uniformly saturated during some part of the growing season, whereas nonhydric soils included soils with various degrees of saturation because they were located in the wetland–upland transition zone. However, the most significant aspect of this analysis is the superior agreement between nonhydrophytic herbaceous vegetation and nonhydric soils as compared to other vegetation layers. This substantiates similar observations by Allen et al. (1989) for Rhode Island and suggests that herbs may be the best indicators of wetness in the transition zone.

Moisture gradients were more abrupt in the western United States than in the East. This is evidenced by the rapid increase in weighted average values for all vegetation layers combined from swales to the upper terrace soils in New Mexico (Table 7), where soil moisture conditions grade markedly from hydric to xeric across the relatively narrow floodplain, as compared to the much more gradual increases in scores in most of the eastern states where moisture gradients are not as steep. Similar results also were observed in western areas where only the herbaceous layer was present (Table 5).

Lack of agreement between nonhydric soils and nonhydrophytic shrub and tree layers seems to indicate that some woody species have considerably lower wetland indicator values than herbaceous species growing on the same soil. This may indicate that the woody species became established during previous periods of higher moisture

Table 7. *Comparison of median weighted average values for tree, shrub, herbaceous, and all layers combined for soils sampled from 12 study sites. All values computed using Reed (1988).*

State, locality, and soils[a]	Median weighted average values				
	Herbaceous	Short shrub	Tall shrub	Tree	Combined
New Mexico					
Gila River					
*Swale	2.32	1.77	1.21	—[b]	2.06
*Sandbar	3.73	1.66	2.00	2.00	2.26
Lower terrace	4.43	2.61	2.00	2.00	3.00
Upper terrace	4.80	4.03	5.00	5.00	4.67
San Francisco River					
*Swale	2.22	2.00	—	—	2.17
*Sandbar	3.93	1.00	1.04	2.00	2.00
Lower terrace	4.00	2.00	1.91	2.00	2.87
Upper terrace	4.28	4.00	4.00	4.21	4.01
Mississippi					
Sandhill Crane Refuge					
*Atmore	1.65	2.00	—	—	1.65
*Crotan	1.47	2.00	2.00	1.05	1.35
*Hyde	1.93	2.00	—	2.00	2.01
*Plummer	1.86	2.00	2.00	4.00	2.01
Harleston	2.18	2.00	2.00	2.00	2.05
North Carolina					
Pocosins					
*Bayboro, flatwood	2.00	2.00[c]	—	2.00	2.00
*Croatan,					
low pocosin	1.79	2.00	—	2.00	1.96
high pocosin	1.87	2.00	—	2.00	1.90
gum swamp	2.03	2.50	—	2.98	2.66
bay forest	2.00	2.00	—	2.00	2.00
lake shore swamp	2.33	2.00	—	2.00	2.13
*Dare,					
low pocosin	1.92	2.00	—	2.00	1.96
medium pocosin	1.84	2.00	—	2.00	1.92
gum swamp	2.01	2.00	—	2.98	2.42
lake shore swamp	2.00	2.00	—	2.13	2.06
*Dorovan,					
gum swamp	2.08	2.00	—	2.88	2.36
*Leaf, flatwood	2.00	2.11	—	2.00	2.04
*Lenoir, flatwood	2.00	2.00	—	2.14	2.06
*Pantego, flatwood	2.27	2.08	—	3.00	2.43
Onslow, savannah	2.70	—	—	4.00	3.34
Rhode Island[d]					
Red maple swamps					
*Carlisle	1.81	2.98	2.74		
*Adrian	2.00	2.99	2.97		
*Scarboro	2.06	2.78	2.59		
*Walpole	2.95	2.91	3.00		
*Wareham	2.74	2.87	2.72		
Deerfield	3.17	2.99	2.66		
Sudbury	3.32	2.24	2.00		
Florida					
Forested wetland					
*Croatan	1.26	2.00	2.00	1.69	1.62
*Surrency	1.87	2.00	2.00	1.04	1.74
*Mascotte,					
managed	2.95	2.76	2.00	2.00	2.47
unmanaged	2.68	2.22	2.00	2.00	2.31
*Sapelo,					
managed	3.28	2.65	2.00	2.00	2.64
unmanaged	3.00	2.89	2.00	3.63	2.77
Ocilla	3.00	2.41	3.00	2.37	2.68
Albany	3.46	2.91	3.00	2.15	2.93
Massachusetts					
Connecticut River					
*Saco	2.00	2.00	2.20	2.01	2.10
*Rippowam	2.00	2.07	—	2.00	2.06
*Limerick	2.00	2.00	2.00	2.00	2.02
*Winooski	2.02	2.00	2.00	3.38	2.13
Pootatuck	3.04	3.11	3.25	4.00	3.49
Hadley	3.63	3.96	3.50	3.72	3.64
Limerick	2.00	2.00	2.00	2.00	2.00
Winooski	3.84	3.62	3.00	3.56	3.43

[a] Asterisk indicates hydric soil.
[b] Layer not present.
[c] Tall and short shrubs were combined into the short shrub layer in North Carolina.
[d] The Rhode Island analyses are based on mean weighted average values; data for the tree layer were not collected in a manner suitable for predicting importance values by soils or, consequently, all layers combined.

availability, whereas the more herbaceous layer reflects response to current, drier, conditions. On the other hand, some woody species may simply have been assigned lower wetland indicator values by the developers of the plant list.

Graphic Analyses of Median Weighted Average (WA) Scores

The preceding discussions have focused on results of efforts to divide soils and vegetation into

Table 8. *Comparison of percent agreement or correspondence between hydric soils and hydrophytic vegetation and between nonhydric soils and nonhydric vegetation, by vegetation layers, for soils sampled throughout the United States (based on data from Table 7).*

Soil and vegetation associations	Percent agreement				All layers combined
	Herbaceous	Short shrubs	Tall shrubs	Trees	
Hydric soils: hydrophytic vegetation	89	100	100	90	100
Nonhydric soils: nonhydric vegetation	85	50	53	50	58
Total	86	86	79	78	86

two categories: hydric and nonhydric. However, in nature, few distinct boundaries are observed among plant communities or soil types along the moisture gradient or, for that matter, any other environmental gradient. Interaction within and among hydrologic, edaphic, and vegetation conditions along moisture gradients practically ensure that soils and plants cannot be divided distinctly into hydric and nonhydric categories. Graphic analyses for median weighted average (*WA*) scores for all layers combined indicate how median *WA* scores varied among the soils sampled in this study.

Scott et al. (1989) discussed the distribution of median *WA* values for many of these same soils; however, their analyses were based only on values for the herbaceous layer whereas the present analyses are based on values for all vegetation layers combined. According to Allen et al. (1989), the herbaceous layer may be more sensitive to moisture gradients. However, all layers are used in the method agreed upon by the Federal Interagency Committee for Wetland Delineation (1989)—an evaluation that may be more appropriate, but not necessarily more accurate. Some vegetation and soil associations were combined and analyzed differently in Scott et al. (1989) and in our study. Values for Marlake, Tryon, and Loup soils in Nebraska were computed and analyzed based on geographic locations in Scott et al. (1989), but in the present study, data for these soils were combined for all geographic locations because we did not have independent confirmation of their hydric nature. Data for Florida (Best et al. 1990), Massachusetts (Veneman and Tiner 1990), and the Central Valley of California (Baad 1988) also were added to the analyses of Scott et al. (1989). Median *WA* scores for Alaska (Walker et al. 1989) and Rhode Island (Allen et al. 1989) were not available; thus, results of these two studies were not included in this analysis.

Hydric Soils

Previous analyses have shown the strong association between hydric soils and weighted average median values below 3.00; however, distribution of median *WA* values for all layers combined for hydric soils clearly shows that such values do not always unequivocally differentiate vegetation into hydrophytic and nonhydrophytic categories (Fig. 4).

Two hydric soils, Umberland and Parran, with intermediate values (Fig. 4) were sampled in Nevada by Nachlinger (1988). The Umberland soil is on the hydric Soils List. The Parran soil is not on the Soils List, but both soils had hydric characteristics at the sites sampled (Nachlinger 1988). Vegetation associations on both soils had median value weighted averages of 3.00 (Table 7). Iodine bush, a facultative-wetland species, and seaside arrow grass (*Triglochin maritimum* L.), an obligate wetland species, were present on both soils, but the dominant vegetation on each soil was inland saltgrass, a facultative species. Inland saltgrass, iodine bush, and seaside arrow grass are all extremely salt tolerant and limited to moist conditions or areas with accessible groundwater (Nachlinger 1988). Yet inland saltgrass, with its intermediate index value, together with species such as black greasewood and barley (*Hordeum jubatum* L.), both facultative-upland species, were present in sufficient quantities to elevate the weighted-average value of the vegetation association to the intermediate range. Earlier we discussed the effect of changing the indicator category of inland saltgrass from facultative-wetland to facultative and of changing black greasewood from facultative to facultative-upland, and Nachlinger's

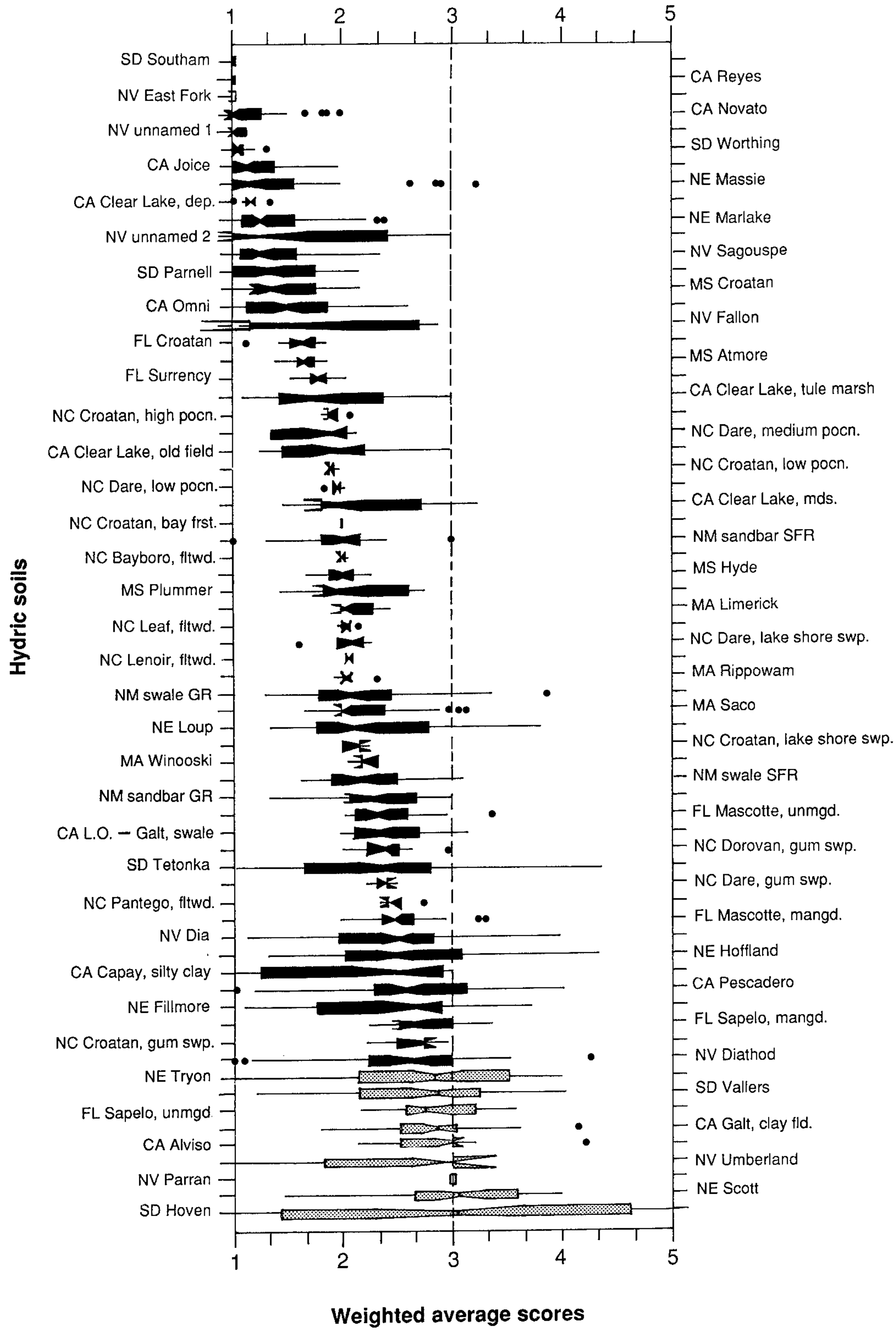


Fig. 4. *Box* plots showing distribution of median weighted average (*WA*) scores, for all vegetation layers combined, for hydric soils sampled at the 12 study sites. *Black boxes* = hydrophytic vegetation; *shaded boxes* = intermediate vegetation.

opinion (personal communication) that these changes may have been inappropriate. This suggests that wetland indicator assignments for the plants growing on these hydric saline soils probably need to be reevaluated based on the results of more detailed field studies.

Three other Nevada soils—Dia, East Fork, and Saqouspe, located on the floodplain of the Carson River—were not on the Soils List, but all had hydric characteristics as a result of raised water tables and inundation associated with the nearby Lahonton Reservoir. These soils had median *WA* values that clearly reflect their hydric condition (Fig. 4).

The Hoven and Vallers soils in South Dakota both met the criteria for hydric soils, yet had vegetation that represents the intermediate condition. Hubbard et al. (1988) suggested that this condition reflects the need for a critical evaluation of the indicator status for prairie plants in the Plant List as well as plants not on the list that occur on hydric soils. Hubbard et al. (1988) listed 10 plant species that they believed were classified incorrectly on the soils they sampled. All of these plants occurred on the Vallers or Hoven soils.

The hydric Scott soil in Nebraska was dominated by Japanese brome (*Bromus japonicus* Thunb.), a facultative-upland species, and naked-spike ragweed (*Ambrosia artemisiifolia* L.), a facultative species. Kentucky bluegrass (*Poa pratensis* L.), spreading bentgrass (*Agrostis stolonifera* L.), and fox-tail barley (*Hordeum jubatum* L.), facultative-upland, facultative, and facultative-wetland species, respectively, were the next most abundant species (Erickson and Leslie 1987). By far the majority of species sampled on the Scott soil reflected intermediate conditions. Median *WA* values for the Tryon soil in Nebraska varied from below 3.00 to over 3.00 among geographic regions (Scott et al. 1989), suggesting that it probably has hydric and nonhydric phases. In the absence of confirming hydrologic information the Tryon soil was not divided into distinct phases in this analysis; however, its position in the intermediate range (Fig. 4) indicates that detailed examination of its hydrology is probably required for properly assigning this soil throughout its range in Nebraska.

In California, the hydric Alviso soil, median *WA* score 2.99, was considered by Eicher (1988) to be disturbed. The sample site had been diked for at least 40 years and grazed by cattle until 1979. In 1983 the site was seeded with barley for waterfowl food. When sampling was conducted during summer 1987, the site was dominated by three facultative species—Mediterranean barley (*Hordeum geniculatum* All.), perennial ryegrass (*Lolium perenne* L.), and prickly lettuce (*Lactuca serriola* L.)—and one facultative-wetland species—alkali heath (*Frankenia grandifolia* Cham. & Schlecht.). Alkali heath is a native species that normally occurs in high salt marshes of central and southern California. The species tolerates some types of disturbance better than other native species, but it is not considered an indicator of disturbance (A. L. Eicher, Biological Consultant, Arcata, California, personal communication). However, Mediterranean barley, perennial ryegrass, and prickly lettuce are each indicative of disturbed conditions and their presence elevated weighted average scores.

Vegetation on the hydric Galt clay, flooded soil in the Sacramento River Valley of northern California had a median *WA* score of 2.87 (Table 5), but its variability was such that it fell in the range of intermediate vegetation (Fig. 4). This soil is located in the historic floodplain of Butte Creek; however, the area has been subjected to extensive land and water alteration (Baad 1988). The area was leveed, cleared, and farmed for several years. Now wetlands are being reestablished for waterfowl management. Galt clay soils lie in basins and will probably redevelop distinct hydrophytic vegetation as flooding regimes are restored.

The hydric unmanaged Sapelo soil is described by Best et al. (1990) as a transitional-hydric soil. It has a spodic (humus-rich) horizon within a meter of the surface, which impedes infiltration. The water table is generally less than 40 cm below the soil surface during rainy periods, and usually deeper than 76 cm during drier months (SCS 1984). This soil supports plants with weighted average values near the upper limits of the hydric category; however, they are still in the intermediate range. The managed Sapelo soil has values nearly the same as the unmanaged soil, but they did not fall into the intermediate range. Best et al. (1990) sampled several soils in managed (subjected to annual prescribed burning) and unmanaged conditions. They found no significant difference in weighted average values between managed and unmanaged soils.

Scott et al. (1989) suggested that Tryon, Scott, Vallers, Hoven, and Alviso soils were characterized by median *WA* values in the intermediate range because they were the uppermost hydric soils in the gradient from hydric to xeric conditions. This seems to apply to the unmanaged Sapelo as well. Each of these soils were located adjacent to nonhydric soils and in some instances the adjacent nonhydric soils also had values in the intermediate range. Disturbance seems to be the principal reason that the Galt soil in California was dominated by species in the intermediate range.

Nonhydric Soils

As discussed previously, the proportion of soils with noncorresponding weighted average values among the nonhydric soils was higher than among the hydric soils (Fig. 5). Because most nonhydric soils sampled were adjacent to the hydric soils or to the wetland boundary, this was expected. However, most nonhydric soils had higher values than adjacent hydric soils suggesting that the median *WA* procedure correctly differentiated among soils across the moisture gradient.

The Olashes sandy loam, flooded soil sampled in the Central Valley of California (Baad 1988) had a median *WA* value well above 3.00. This soil is classified as a hydric soil in its undisturbed condition, but the soil sampled was located in an area where flood control practices have all but eliminated wetland hydrology or the possibility that this soil will ever again meet those conditions (Baad 1988). Thus, this particular Olashes soil is nonhydric based on its current hydrologic characteristics even though it is on the Soils List. The Columbia fine sandy loam and Shanghai silt loam soils are two riparian soils also on the Soils List, but both have been drained to the extent that they no longer meet hydric soils criteria (Baad 1988). The values for each of these three soils corroborate their nonhydric condition.

The nonhydric Limerick soil in Massachusetts had values of approximately 2.00. However, based on detailed analysis, the Limerick soil demon-

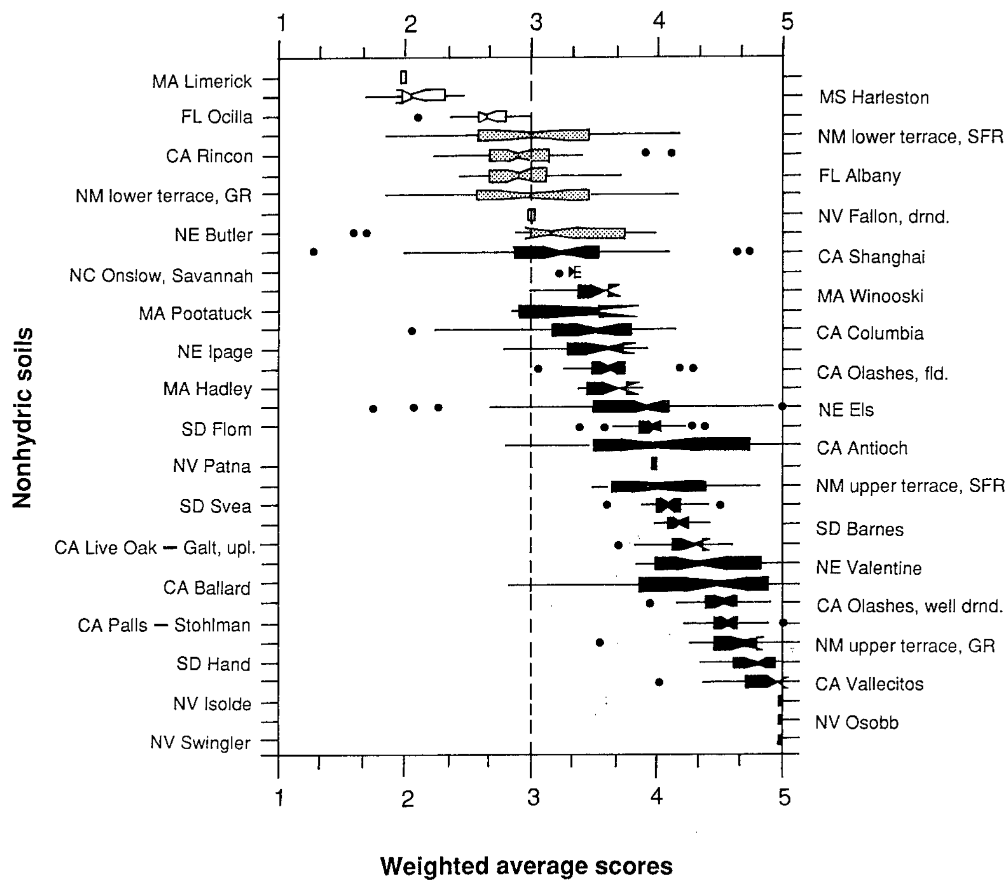


Fig. 5. *Box* plots showing distribution of median weighted average (*WA*) scores, for all vegetation layers combined, for nonhydric soils sampled at the 12 study sites. *Open boxes* = hydrophytic vegetation; *shaded boxes* = intermediate vegetation; *black boxes* = nonhydrophytic vegetation.

strated weak mottling, faintness of contrast (mottle vs. matrix), an elevated position on fingerlike ridges, a somewhat poorly drained nature, brief duration of flooding, excessive depth of water table, and evidence of rapid aeration following flooding, indicating that these sites were nonhydric. The species richness of vegetation on the nonhydric Limerick was the lowest for all soils sampled in Massachusetts by Veneman and Tiner (1990) suggesting that the frequency and magnitude of flooding with its scouring action and deposition created an environment that favored the establishment of hydrophytic vegetation or selected against nonhydrophytic vegetation despite its nonhydric soils. Veneman and Tiner (1990) also suggested that the woodnettle (*Laportea canadensis* L.) and ostrich fern (*Matteuccia struthiopteris* [L.] Todaro.), both facultative-wetland species, might better be considered facultative species. Thus, Veneman and Tiner (1990) concluded that the range in morphological characteristics for some floodplain soils (e.g., Limerick and Winooski) need to be better defined to effectively represent hydric and nonhydric conditions.

The nonhydric Ocilla and Albany soils in north-central Florida both had median *WA* values indicative of hydrophytic vegetation. Best et al. (1990) suggested that two facultative-wetland species—slash pine and ink-berry, dominant tree and shrub species, respectively, for these two soils—may have wetland index values too low for this area. Allen et al. (1989) also observed that inkberry may have been assigned a lower value than it should have been. Slash pine is a native species formerly confined to ponds or pond margins where soil moisture or standing water provided protection from fire (Fowells 1965). However, it has been extensively planted throughout the south on drier sites. Best et al. (1990) suggested that the widespread use of slash pine in timber management may preclude its usefulness in defining wetland conditions in the South.

The Harleston soil in Mississippi was considered a nonhydric soil; however, its vegetation was dominated by species with wetland index values less than 3.00 (Fig. 5). This discrepancy was discussed by Scott et al. (1989). They suggested that the soil meet hydric criteria at times; however, hydrophytic species at this site also included slash pine, the species that Best et al. (1990) suggested may have been assigned to a lower indicator category than justified by its growth characteristics. Thus, in this case, soils and vegetation may both need further investigation to determine their proper status.

The Flom soil in South Dakota was classified as a hydric soil by the Soils List and was listed with the hydric soils in Scott et al. (1989), but the Flom soil sampled did not meet the hydric soil criteria based on an assessment of water regimes (Hubbard et al. 1988). Consequently, Flom is listed as a nonhydric soil in this synthesis report. Including Flom among the nonhydric soils brings it into agreement with its weighted average vegetation score (Fig. 5).

The Fallon soil in Nevada was sampled in the nominal and the nondrained phase. The nondrained phase is hydric and supports wetland vegetation (Fig. 4). The nominal phase is nonhydric, but also supports some hydrophytic vegetation as its intermediate value demonstrates (Fig.5). This particular site is located near the Carson River and has apparently become drained in fairly recent times as the river has degraded. As time progresses, this site may become increasingly xeric and this should be reflected in the vegetation.

The lower terrace soils on the Gila and San Francisco rivers in New Mexico were designated hydric by Dick-Peddie et al. (1987) based on a soil survey by the U.S. Forest Service, but the data for this soil do not support the hydric criteria described in the Soils List because the depth to water (as determined during the growing season) is excessive, from 150 to 200 cm (59 to 79 inches), and flooding, while common, is described as brief. Thus, the soil was classified as nonhydric in Scott et al. (1989) and in this report (Fig. 5). However, the median *WA* values are equivocal for the different vegetation layers (Table 7). The herbaceous layer for both soils was dominated by upland species, but tree and shrub layers were dominated by hydrophytes. These vegetation differences probably correspond to hydrologic patterns of stream movement and their effects on sediment deposition and evolution of the adjacent riparian floodplain. Trees and shrubs may have become established on sandbars or stream edges under hydric conditions and, as the stream migrated laterally and deposition continued to occur, these lower terrace soils became less hydric. The younger, shallow-rooted herbaceous vegetation layer has now become established on these drier soils, while the older trees and shrubs, whose deep roots reach the water table, still reflect the more hydric condition that prevailed when they were established. However, even on the sandbars of the Gila and San Francisco rivers, *WA* values of the herbaceous layer are much higher than corresponding values for trees and shrubs. This suggests that some upland species, such as opportunistic weedy annuals, may have become established on sandbars because flooding has been too brief to create anaerobic conditions or that indicator assignments in the Plant List may need to be reevaluated for some herbaceous species in this Region.

Recommendations and Conclusions

The Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation 1989) requires the examination of soils, vegetation, and hydrology for determining wetland boundaries. The result of the studies synthesized in this report provides strong support for that requirement. However, because wetland hydrology is often difficult to measure, soils and vegetation are frequently the parameters used for boundary determination. Given that vegetation and soils must be sampled in all cases, and are often the only parameters measured, several important findings derive from this synthesis.

Widely-spaced trees should be sampled by estimating canopy cover if they are not encountered on sample plots when estimating density or basal area. Trees also reflect long-term environmental conditions. Trees may have become established when conditions at the site were either wetter or drier than they are at present.

Wetland-indicator categories assigned to plant species in the Plant List (Reed 1988) are generally good indicators of their hydrophytic nature; however, indicator categories for some species may need to be reevaluated based on field studies. The judgment of a qualified plant ecologist or taxonomist may be essential to verify the indicator category of uncommon species or to recommend the need for further study.

Mean weighted average, median weighted average, and median index average were equally good estimators of the hydrophytic nature of the herbaceous layer at scores less than 3.00, based on percent agreement or correspondence with 67 hydric soils. Agreement for these three procedures ranged from 87 to 93 percent. However, 100 percent agreement was observed between hydric soils and median weighted average scores (mean *WA* scores were used for 5 hydric soils in Rhode Island) below 3.00 for all vegetation layers combined for 37 hydric soils that had multiple vegetation layers.

Scores of 3.00 or above for mean weighted average, median weighted average, and median index average were good estimators of nonhydrophytic vegetation for the herbaceous layer, based on agreements ranging from 86 to 89 percent for 35 nonhydric soils. However, only 58 percent agreement was recorded between nonhydric soils and median weighted average scores of 3.00 or above, for all vegetation layers combined, for 13 nonhydric soils that had multiple vegetation layers. The 85 percent agreement observed between nonhydric soils and median weighted average scores, based on vegetation in the herbaceous layer alone, suggests that in some areas species (principally herbs) in the herbaceous layer may be better indicators of wetness than trees or shrubs. Short-lived herbs may reflect current moisture conditions, but opportunistic weedy species may confound results in the herbaceous layer and should be considered with caution.

Field verification of hydric criteria is essential for confirmation of hydric soils in the Soils List (SCS 1987). Conversely, moist soils not on the list should be examined to verify that they lack hydric criteria. Soils with hydric criteria are considered hydric regardless of their occurrence on the Soils List.

Wetland hydrology should be the primary criterion for determining hydric soils. However, secondary criteria often must be used because hydrologic data may be difficult or impossible to obtain. However, neither soils nor vegetation are always separated distinctly into wetland and nonwetland categories, and hydrology changes gradually across the wetland boundary. Division of soils, vegetation, and hydrology into wetland and upland categories is a perception of man, not a reality of nature. However, regulatory agencies are required to delineate wetlands for jurisdictional purposes. Quantified vegetation associations can help to delineate these boundaries, but in problem cases, close examination of soils and groundwater hydrology will be required for final delineation. Soil characteristics are generally considered reliable indicators of long-term hydrology, while vegetation is considered more responsive to short-term hydrologic conditions. However, transitional areas that do not fit neatly into one category or the other will require detailed assessment of hydrologic conditions and, ultimately, subjective judgment to determine whether they should be considered wetlands or nonwetlands for jurisdictional purposes.

Acknowledgments

This synthesis of information on the relations among soils and vegetation for selected wetlands throughout the United States would not have been possible without the cooperation and dedication of the following principal investigators and their assistants who conducted individual field studies: W. A. Dick-Peddie, J. V. Hardesty, E. Muldavin, and B. Sallach, New Mexico State University, Las Cruces; N. E. Erickson and D. M. Leslie, Jr., Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, Stillwater; J. L. Nachlinger, Desert Research Institute, Reno, Nevada; A. L. Eicher, Biological Consultant, Arcata, California; D. E. Hubbard, J. B. Millar, and D. D. Malo, South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Brookings; M. I. Baad, California State University, Sacramento; N. L. Christensen, R. B. Wilbur, and J. S. McLean, Duke University, Durham, North Carolina; S. D. Allen, F. C. Golet, A. F. Davis, and T. E. Sokoloski, University of Rhode Island, Kingston; M. D. Walker, D. A. Walker, and K. R. Everett, Walker Geobotanical Surveys, Lafayette, Colorado; G. R. Best, D. S. Segal, and C. Wolfe, University of Florida, Gainesville; P. L. M. Veneman, University of Massachusetts, Amherst; and R. W. Tiner, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts.

In addition J. L. Nachlinger, P. L. M. Veneman, A. L. Eicher, W. A. Dick-Peddie, M. D. Walker, M. F. Baad, N. E. Erickson, R. W. Tiner, and F. C. Golet provided comments on the preliminary draft of this report. S. J. Brady, U.S. Soil Conservation Service; W. S. Sipple, U.S. Environmental Protection Agency; and T. R. Wentworth, North Carolina State University also reviewed and provided useful comments on this synthesis.

B. M. Teels, U.S. Soil Conservation Service, W. O. Wilen and P. B. Reed, U.S. Fish and Wildlife Service, and a host of individuals, far too numerous to name—including the Regional Wetland Coordinators of the U.S. Fish and Wildlife Service, soil scientists with the U.S. Soil Conservation Service and the U.S. Forest Service, and those individuals who reviewed the study plan and the results of the individual studies—deserve special credit for their support and assistance. Finally, L. S. Ischinger, Section Leader, Inland Freshwater Ecology Section, National Ecology Research Center, U.S. Fish and Wildlife Service, provided technical direction and supervisory guidance for this project from beginning to end, and reviewed all reports and publications resulting from the project.

References

Allen, S. D., F. C. Golet, A. F. Davis, and T. E. Sokoloski. 1989. Soil–vegetation correlations in transition zones of Rhode Island red maple swamps. U.S. Fish Wildl. Serv., Biol. Rep. 89(8). 47 pp.

Baad, M. F. 1988. Soil–vegetation correlations within the riparian zone of Butte Sink in the Sacramento Valley of northern California. U.S. Fish Wildl. Serv., Biol. Rep. 88(25). 48 pp.

Best, G. R., D. Segal, and C. Wolfe. 1990. Soil–vegetation correlations in selected wetlands and uplands of north-central Florida. U.S. Fish Wildl. Serv., Biol. Rep. 90(9). 48 pp.

Christensen, N. L., R. B. Wilbur, and J. S. McLean. 1988. Soil–vegetation correlations in the pocosins of Croatan National Forest. U.S. Fish Wildl. Serv., Biol. Rep. 88(28). 97 pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv., FWS/OBS-79/31. 131 pp.

Curtis, J. T., and R. P. McIntosh. 1951. An upland forest continuum in the prairie forest border region of Wisconsin. Ecology 32:476–496.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row, New York. 300 pp.

Dick-Peddie, W. A., J. V. Hardesty, E. Muldavin, and B. Sallach. 1987. Soil–vegetation correlations on the riparian zones of the Gila and San Francisco rivers in New Mexico. U.S. Fish Wildl. Serv., Biol. Rep. 87(9). 29 pp.

Eicher, A. L. 1988. Soil–plant correlations in wetlands and adjacent uplands of the San Francisco Bay estuary, California. U.S. Fish Wildl. Serv., Biol. Rep. 88(21). 35 pp.

Environmental Laboratory. 1987. Corps of Engineer's wetlands delineation manual. U.S. Army Eng. Waterways Exp. Stn., Vicksburg, Miss.,Tech. Rep. Y-87-1. 169 pp.

Erickson, N. E., and D. M. Leslie, Jr. 1987. Soil–vegetation correlations in the Sandhills and Rainwater Basin wetlands of Nebraska. U.S. Fish Wildl. Serv., Biol. Rep. 87(11). 72 pp.

Erickson, N. E., and D. M. Leslie, Jr. 1989. Soil–vegetation correlations in coastal Mississippi wetlands. U.S. Fish Wildl. Serv., Biol. Rep. 89(3). 47 pp.

Federal Interagency Committee for Wetland Delineation. 1989. Federal manual for identifying and delineating jurisdictional wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S.

Fish and Wildlife Service, and U.S. Soil Conservation Service, Washington, D.C. 76 pp. + appendices.

Fowells, H. A. 1965. Silvics of forest trees of the United States. U.S. For. Serv., Agric. Handbook 271. 761 pp.

Hubbard, D. E., J. B. Millar, D. D. Malo, and K. F. Higgins. 1988. Soil–vegetation correlations in prairie potholes of Beadle and Deuel counties, South Dakota. U.S. Fish Wildl. Serv., Biol. Rep. 88(22). 97 pp.

McGill, R., J. W. Tukey, and W. A. Larsen. 1978. Variations of box plots. Am. Statistician 32:12–16.

Nachlinger, J. L. 1988. Soil–vegetation correlations in riparian and emergent wetlands, Lyon County, Nevada. U.S. Fish Wildl. Serv., Biol. Rep. 88(17). 39 pp.

Reed, P. B., Jr. 1986. Wetland plants of the United States of America. U.S. Fish Wildl. Serv., WELUT-86/W17.01. 121 pp.

Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: 1988 national summary. U.S. Fish Wildl. Serv., Biol. Rep. 88(24). 244 pp.

Scott, M. L., W. L. Slauson, C. A. Segelquist, and G. T. Auble. 1989. Correspondence between vegetation and soils in wetlands and nearby uplands. Wetlands 9:41–60.

Sipple, W. S. 1988. Wetland identification and delineation manual, Vols. I and II. U.S. Environmental Protection Agency, Office of Wetlands Protection, Washington, D.C. Vol. I, 30 pp.; Vol. II, 40 pp.

Soil Conservation Service. 1984. Soil survey of Columbia County, Florida. U.S. Soil Conservation Service, Washington, D.C.

Soil Conservation Service. 1985. Hydric soils of the United States. U.S. Soil Conservation Service, Washington, D.C. np.

Soil Conservation Service. 1987. Hydric soils of the United States. U.S. Soil Conservation Service, Washington, D.C. np.

Soil Survey Staff. 1951. U.S.D.A. Soil Surv. Handb. 18. 173 pp.

Tiner, R. W., Jr. 1989. A clarification of the U.S. Fish and Wildlife Service's wetland definition. Nat. Wetlands Newsl. 11(3):6–7.

U.S. Department of Agriculture. 1987. Highly erodible land and wetland conservation (7 CFR Part 12). Fed. Register 52:35200–35208.

Velleman, P. F., and D. C. Hoaglin. 1981. Applications, basics, and computing of exploratory data analysis. Duxbury Press, Boston. 354 pp.

Veneman, P. L. M., and R. W. Tiner. 1990. Soil–vegetation correlations in the Connecticut River floodplain of western Massachusetts. U.S. Fish Wildl. Serv., Biol. Rep. 90(6). 51 pp.

Walker, M. D., D. A. Walker, and K. R. Everett. 1989. Wetland soils and vegetation, Arctic Foothills, Alaska. U.S. Fish Wildl. Serv., Biol. Rep. 89(7). 89 pp.

Wentworth, T. R., and G. P. Johnson. 1986. Use of vegetation in the designation of wetlands, final report. U.S. Fish and Wildlife Service, St. Petersburg, Fla. 107 pp.

Wentworth, T. R., G. P. Johnson, and R. L. Kologiski. 1988. Designation of wetlands by weighted averages of vegetation data: a preliminary evaluation. Water Resour. Bull. 24:389–396.

TAKE PRIDE

in America

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Departmnet also has a major responsibility for American Indian reservation communities and for people who live in island territories under U. S. administration.