Relationships of Site Characteristics to Vegetation in Canyon Grasslands of West Central Idaho and Adjacent Areas

E.W. TISDALE AND MARY BRAMBLE-BRODAHL

Abstract

The relation of vegetation types to soil and other site characteristics was examined for 57 sample plots representing the Pacific Northwest Bunchgrass Region. Three series characterized by *Carex* spp., *Festuca idahoensis*, and *Agropyron spicatum* respectively, and 5 habitat types comprised the vegetation units. These were compared to their associated soil taxa (soil families) and to a group of individual soil and other site characteristics. Relationship to soil taxa was relatively weak, with several soil families associated with each of 4 of the habitat types. Strong relationship of vegetation types to 13 individual soil and site factors was shown by means of stepwise discriminant analysis. Reclassification by these site factors resulted in 92% concurrence with habitat types and even higher agreement with vegetation series. Site factors showing the highest degree of relationship with vegetation units were: elevation, radiation index, color (value), and organic matter of the "A" horizon, and lime depth. This method of relating individual site factors to vegetation provides a powerful tool for testing the validity of ecosystems recognized by vegetation, and should be useful also in categorizing sites where plant cover has been disturbed.

The grasslands of the Snake and Salmon River valleys in Idaho and adjacent parts of eastern Oregon and Washington constitute a distinctive section of the Pacific Northwest Bunchgrass Region. These grasslands occur mainly on steep canyon slopes and are closely related to the so-called Palouse grasslands of the Columbia Plateau in northeastern Oregon, eastern Washington, and northwestern Idaho.

A brief description of this canyon area and a preliminary classification of its grassland has been published (Tisdale 1979). Due to a combination of rugged topography, dry climate, and stony soils, most of the grassland remains uncultivated. Despite the influence of heavy use by livestock over much of the area, many examples of relatively undisturbed vegetation remain. From a study of such relict areas, Tisdale (1979) recognized 2 vegetation series and 5 habitat types which constitute most of the grassland vegetation of the area. The *Festuca idahoensis* series includes 3 habitat types: *Festuca idahoensis/Koeleria cristata, Festuca idahoensis/Agropyron spicatum,* and *Festuca idahoensis/Symphoricarpos albus.* The other group, occupying drier sites, is the *Agropyron spicatum* series which includes *Agropyron spicatum/Poa sandbergii* and the *Agropyron spicatum/Opuntia polyacantha* habitat types.

Subsequent studies indicated the existence of a third vegetational series characterized by the co-dominance of *Carex hoodii, C. geyeri,* and other upland *Carex* species. One habitat type, *Carex hoodii/Festuca idahoensis,* has been recognized to date. This type is restricted to the highest elevations of the grasslands, and has not been previously described in the literature. In addition to the dominance of *Carex,* it is characterized by the common occurrence of *Bromus carinatus, Danthonia intermedia, Poa nervosa, Antennaria anaphaloides,* and *Eriogonum flavum,* species often associated with subalpine areas and rare or lacking in grasslands of lower elevation. Data from this habitat type are included in the present study.

The classification approach used here recognizes the "series" as a group of communities characterized by a single dominant climax species. The habitat type is considered to be the "aggregate of all areas that support or can support the same primary climax" (Daubenmire 1970). The habitat type (h.t.) has relatively uniform biotic and abiotic structure and is the primary unit of ecosystem classification. It is recognized by means of its vegetation, but is characterized also by distinctive habitat features.

Following preliminary classification of the vegetation, a second objective was to determine the relationship of habitat factors to the plant communities. We desired to know whether these vegetational groups represented recognizable ecosystems when considered on the basis of site characteristics only.

Methods

The habitat data were confined to topographic and edaphic factors, since climatic records for the study area are too sparse to be of value in a detailed analysis. Topographic information included records of elevation, slope, and aspect. Soil data included type of parent material, depth and stoniness of profile; texture, color, organic matter, structure and pH of the principal horizons; presence and depth of lime accumulation; and amount of surface gravel and stone. The soils were also classified into taxonomic units according to the USDA system (USDA 1975). Classification was made only to soil family, since soil survey information was not sufficient to provide classification to the series level for many soils of the study area. A radiation index, based upon latitude, aspect and slope (Frank and Lee 1966), was calculated for all sites.

The kinds of information listed above were available for 74 sample plots representing 6 habitat types. One of these, the *Festuca idahoensis/Symphoricarpos occidentalis* h.t. which occurs marginally in the study area, was represented by only 3 samples and was dropped from the analyses.

Two approaches appeared feasible for investigating vegetation-site relationships with the data available. One was to make a direct comparison of vegetation and soil taxonomic units, the other was to determine the relationship of individual site factors to units of vegetation. The rationale for the first approach is that climax vegetation and soils are considered to be the products of the same set of formative factors (Jenny 1958), hence, some degrees of relationship at the taxonomic level might be expected.

Authors are professor emeritus, Dept. of Range Resources, and consultant on range and statistics, Dept. of Plant and Soil Science, Univ. of Idaho, Moscow 83843.

The authors are grateful to the Forest, Wildlife and Range Experiment Station, University of Idaho, for use of facilities and for partial financial support for this study. Particular thanks are due to Dr. Minoru Hironaka, professor of range resources, for his continued interest and support, to Dr. M.A. Fosberg, professor of soil science, who identified most of the soils, and to Dr. Kirk Steinhorst, associate professor of agricultural applied statistics, for his advice on the statistical analyses.

Manuscript received July 23, 1982.

The second alternative involved examination of the data for individual site characteristics in order to determine their relationship to vegetation units. Graphing of such data, and consideration of group mean values and their variability, indicated that a number of site characters had some degree of relationship to vegetation.

Although marked differences in several of these site factors were evident between some of the habitat types, no one factor was dominant among all of them, and the data showed high variability within and considerable overlap of site values among vegetation units. These results indicated that a multivariate analysis was needed to explore the relationships further.

Of the several methods available, stepwise linear discriminant analysis appeared most suitable for our purposes. Discriminant analysis has been successfully used by several workers studying vegetation and vegetation-site relationships (Mathews 1979, Bunting 1978, Pyott 1971).

Stepwise linear discriminant analysis consists of stepwise multivariate analysis of variance (stepwise MANOVA) for selection of variables, followed by canonical analysis. In our data, classes were defined by habitat types.

The initial discriminant analysis of our data followed the procedure described in SPSS (Nie et al. 1975). The results were then checked by the discriminant analysis procedure described in SAS (Helwig and Council 1979).

For the stepwise linear discriminant analysis (SPSS) procedure, the selection of variables, the calculation of Fisher's Linear Discriminant Functions, and the canonical analysis were performed on the 57 sites (of the 71) which had complete data for 16 site variables. The variables submitted to the program were: depth of the solum, organic matter of the A and the B_1 horizons, color value and chroma of the A horizon, pH of the A, texture of the A (percent silt, percent sand, percent clay), depth of the A and depth of the B_1, percent of the surface covered by coarse fragments, percent coarse fragments (stoniness) in the profile, depth of the $CaCo_3$, radiation index, and elevation. Thirteen of these variables were selected in the initial stepwise multivariate analysis of variance portion of the program.

The discriminant analysis and reclassification of the original sites were then performed using the 13 selected variables.

The linear discriminant (SPSS) procedure assumes approximate equality of within group variances. The SAS procedure was used to test this assumption and to provide an alternate (quadratic) discriminant analysis if unequal group variance was detected. The latter being the case, the SAS quadratic procedure was then used to confirm the linear discriminant results. This method requires that the number of variables in the model be about half the number of sites sampled. The limiting factor in this case was the *Carex/Festuca* h.t. with 9 sites. To meet this restriction we chose 5 variables based on their weights in the first standardized function of the linear analysis (Table 2). These variables were: elevation, radiation index, organic matter and color (value) and pH of the "A" horizon. In a second analysis, logarithmic transformations of pH and organic matter were made to improve normalcy of distribution. Reclassification success was used to evaluate the effectiveness of the 5 variables in the model.

Results

Soil Types and Vegetation

Comparison of soil taxa with vegetation showed great variability in the degree of relationship. The closest correspondence was found for the *Carex Festuca* h.t., which was associated in all cases with a single soil family described as loamy skeletal mixed Typic Cryumbrept. Association with soil taxa was much looser for all other habitat types. The *Festuca/Koeleria* h.t. occurred with 2 soil orders (Mollisols and Inceptisols), although the majority of sites occurred within the former. At the Great Group level, both Argixerolls and Haploxerolls were represented, with a total of 6 soil families within these groups. Nearly as much variability was found in soils of *Festuca/Agropyron* h.t.; all were Mollisols, but 5 soil families occurred. The *Agropyron/Poa* h.t. occurred only in Mollisols, but with 6 soil families included. The *Agropyron/Opuntia* h.t. showed wider variability with Entisols as well as Mollisols at Order level, and 9 soil families included. Two of the latter were Xerorthents, the others divided among Haploxerolls and Argixerolls.

In addition to the occurrence of several soil families for all but 1 of the 5 habitat types, 3 soil families occurred in more than 1 type. Loamy skeletal mixed mesic Ultic Argixerolls were found in the *Agropyron/Opuntia, Agropyron/Poa, Festuca/Agropyron* and *Festuca/Koeleria* habitat types, although in 1 site only for the latter 2 types. Lithic Ultic Argixerolls were found in both the *Agropyron/Opuntia* and *Festuca Agropyron* habitat types and Pachic Ultic Argixerolls occurred in both the *Festuca/Agropyron* and *Festuca/Koeleria* habitat types, although more commonly in the latter type. Some of this overlap might be removed at soil series level, but classification to this category was not available.

These results are not surprising in light of the findings of others who have studied comparable vegetation and soils. Daubenmire (1970) found little relationship between vegetation and soil taxa in grassland and shrub-grass communities of Washington. The *Agropyron/Poa* h.t. occurred with 4 soil families (6 if the "lithic phase" of the *Agropyron/Poa* is included). His *Festuca/Symphoricarpos* h.t. was found with 7 soil families. Conversely, 1 soil series, Ritzville silt loam, supported 5 shrub-grass or grassland habitat types. Hironaka and Fosberg (1979) found 2-5 soil families associated with most habitat types in sagebrush-grass vegetation of southern Idaho. Hugie et al. (1973) concluded from their study of shrub-grass vegetation and soils in the Intermountain Region that "soil classification appeared to be most compatible with vegetation at the soil subgroup level."

Individual Site Factors and Vegetation

Results of analysis by the SPSS procedure for determining the relative influence of individual site factors are summarized in Tables 1-4. The value of the various functions in accounting for the variance among habitat types is shown in Table 1.

Table 1. Eigenvalue and percent of variance accounted for in 4 canonical discriminant functions involving 13 site factors.

Function	Eigenvalue	Variance	Cumulative variance
1	18.30324	85.40	85.40
2	2.14858	10.03	95.43
3	0.75304	3.51	98.94
4	0.22627	1.06	100.00

The data indicate that almost all the influence of the site factors is expressed in functions 1 and 2. This result is pertinent to evaluation of the discriminant function coefficients for the 13 site factors shown in Table 2. These coefficients reflect the magnitude and

Table 2. Standardized canonical discriminant function coefficients (1 + 2) for 13 site factors.

Site Factor	Function 1	Function 2
Solum depth	–0.30889	–0.80339
Depth "B"	–0.09850	0.50535
Lime depth	0.69604	–0.37557
Color (value)	0.89325	0.35938
Color (chroma)	–0.21241	–0.28159
Organic M. "A"	0.72272	–0.50285
Organic M. "B"	–0.53390	0.41550
PH "A"	0.58504	–0.52075
Sand "A"	–0.12554	0.67661
Silt "A"	–0.42171	0.21147
Radiation index	0.97959	0.71423
Elevation	-1.56080	0.21027
Gravel (surface)	0.41521	–0.53258

direction (positive or negative) of the distribution of each dependent variable in that function.

The apparent influence of different site factors evidently varies considerably both within and between functions. Since the data of Function 1 account for 85% of the total variability, those variables counting most heavily in it may be considered the principal habitat factors reflecting the vegetation pattern. These are, in order of magnitude, elevation, radiation index, color (value) and organic matter of the "A" horizon, lime depth, pH of "A" horizon, organic matter of "B", horizon, percent silt in "A" horizon, surface gravel and depth of solum. In Function 2 some of these factors show as less influential, while depth of "B" horizon and percent sand in the "A" horizon become relatively important.

Table 3. Canonical discriminant functions evaluated at group means (group) centroids).

Habitat Type	Function 1	Function 2
Agropyron/Opuntia	5.49837	1.05871
Agropyron/Poa	2.39029	0.57747
Festuca/Agropyron	0.43533	-1.72166
Festuca/Koeleria	-2.25274	-1.44966
Carex/Festuca	-7.21427	2.05309

Other valuable information is provided by the discriminant functions evaluated at group means as shown in Table 3. These data show the relative positioning (ordination) of the 5 types by habitat factors. The arrangement in Function 1 shows a gradient from the values associated with the most xeric community *(Agropyron/Opuntia)* to the most mesic *(Carex/Festuca)*. The data in Function 2 show particularly well the affinities within and the separation among the vegetation units at series level. The ultimate test of the analysis, however, is the degree to which the the data from the habitat factors predict the groupings established by vegetation alone. The results of this test are summarized in Table 4.

The data indicate a high degree of concurrence between the group designations by habitat factors and by vegetation, with an overall agreement of 92%. Where differences in site grouping occurred, it was mainly within the series. A subsequent test, using stepwise discriminant analysis and grouping the sites by series rather than habitat types, resulted in agreement of 94, 100, and 100 % for the *Agropyron, Festuca* and *Carex* series, respectively.

A feature of the discriminant data, not shown in Table 4, is that the classification of each site by habitat factors is given in terms of a highest and a second highest group, each with a specific probability rating. This provision of first and second choice with probability ratings is useful in assessing the status of sites which are marginal in regard to their classification. An example occurs in the 4 sites with full habitat information which were classified differently by vegetation versus habitat. In 2 of these cases, the habitat data show relatively low probabilities (0.5164 and 0.5447) for "first choice" in the analysis, while the "second choice" agrees with the vegetation classification with a probability only slightly lower (0.4688 and 0.4553). The vegetational composition of each of these sites falls in the outer range of its class, and the habitat data reflect the same marginal situation. The probability rating for most sites, where classification by vegetation and habitat factors concurred, was in the range of 0.7500 to 1.000.

There were indications in the results of this "all group" analysis (Table 4) that differences between the *Carex/Festuca* h.t. and the other types were greater than those among the latter. The 2 habitat types of the *Agropyron* series seemed particularly similar. The analysis by series gave a high degree of separation (98%) at that level. The *Agropyron* and *Festuca* series also showed a high degree of concurrence (91 and 100% respectively), for site factors and habitat types.

Analysis by the SAS procedure showed that in all cases the hypothesis of equal inter-group variance matrices was rejected, and quadratic discriminent analysis was performed. The results obtained from this analysis are shown in Table 5.

The results show 86% of the sites were classified to concur with the habitat types, and 97% in the "correct" vegetational series. It is evident that the SAS procedure, using only 5 major variables, provided only slightly less agreement overall among vegetation and site factor groupings than did the SPSS procedure using 13 variables. The degree of concurrence was noticeably poorer only in the case of the *Agropyron/Poa* h.t., which was distinguished from the *Agropyron/Opuntia* h.t. in just 66% of the cases. When log transformations for 2 of the 5 variables, pH and organic matter of the "A" horizon were used to improve the normality in distribution, agreement of the vegetation and site classification was improved overall to 93% In the case of the *Agropyron* series, concurrence was increased to 93.7% and 81.2% for the *Agropyron/Opuntia* and *Agropyron/Poa* habitat types, respectively. This still left agreement for the latter lower than for any of the other 4 types. Addition of some of the 8 variables omitted in this test might have resulted in better separation of this type. Direct comparison of group means and their variability suggests that such factors as solum depth, organic matter of the "B" horizon, percent sand in the "A" horizon and percent surface gravel may have value in distin-

Table 4. Results of classifying habitat types by 13 site factors using SpSS discriminant analysis.

	Number of cases	Predicted Group Membership (%)				
		AG/OP	AG/POA	FEST/AG	FEST/KO	CAR/FEST
Agropyron/Opuntia	12	91.7	8.3	0	0	0
Agropyron/Poa	13	15.4	84.6	0	0	0
Festuca/Agropyron	9	0	11.0	89	0	0
Festuca/Koeleria	16	0	0	0	100	0
Carex/Festuca	9	0	0	0		100

Table 5. Results of classifying habitat types by 5 site factors using SAS discriminant analysis.

Group	Predicted Group				
	AG/OP	AG/POA	FEST/AG	FEST/KO	CAR/FEST
Agropyron/Opuntia	88	12	0	0	0
Agropyron/Poa	31.3	62.5	6.2	0	0
Festuca/Agropyron	0	9.1	90.9	0	0
Festuca/Koeleria	0	0	5.5	94.5	0
Carex/Festuca	0	0	0	0	100

guishing between the 2 *Agropyron* habitat types.

Discussions and Conclusions

The apparent lack of strong relationship between most vegetation and soil taxonomic units must be considered in light of the current state of the art and the limitations of the current study. The classification of plant communities was made primarily on the basis of species presence, followed by consideration of frequency and cover data. The soil taxa are determined on the basis of a large number of factors, many of which may not critically affect botanical composition.

The current soil classification appears to recognize finer divisions in the grassland ecosystems under study than does the system of vegetation classification. This may be inherent in the systems, but the fact that the soils classification represents a concerted national effort over several decades is also pertinent. No comparable effort to develop a standard system for the classification of vegetation has been made, at least on this continent. As a consequence, we may have recognized only the broader ecosystem units as reflected in botanical composition, and missed finer subdivisions that might correlate more closely with soil families.

Even in the present situation, certain relationships of soil and vegetation taxa are evident. In the *Agropyron spicatum/Opuntia polycantha* h.t., 50% of the sites had Xerolls with lithic profiles, while another 12.5% were Lithic Orthents. Only 1 lithic profile was found in the *Agropyron spicatum/Poa sandbergii* h.t., where Ultic or Calcic Argixerolls occupied 43% of the sites and Calcic Haploxerolls another 25%. The *Festuca idahoensis/Koeleria cristata* h.t. contained 45% Pachic Ultic or Ultic Argixerolls and 40% Pachic Ultic Haploxerolls, reflecting the depth of mollic epipedon and degree of leaching associated with this more mesic community.

Future studies should include close examination of currently recognized vegetation units which are associated with several soil taxa. Similarly, consideration should be given to recognizing certain groups of soil taxa as essentially equivalent with respect to vegetation. The process of resolving apparent differences calls for joint soil-vegetation studies on a more intensive scale than has generally be practiced in the past.

The effort to relate individual site factors to vegetation units at both series and habitat type levels was highly successful. This was accomplished by multivariate analysis in the form of stepwise discriminant analysis. The method tended to maximize differences "between" groups and to minimize the considerable variability "within" which characterized our data. The analysis confirmed the validity of groups recognized by vegetation only. It also showed the value of the series concept as a basic group in the classification hierarchy, by giving higher agreement with site factors at this level than for habitat types.

The SAS analytical procedure was helpful in corroborating the results obtained with the SPSS approach. It also was attractive in providing a high degree of vegetation-site correlation with use of only a few site factors. It must be remembered, however, that the selection of these 5 site factors was possible only after their relative importance had been shown by the SPSS procedure. Even with the SPSS system, the value of the analysis was definitely affected by number of sites, and the results support the value of obtaining relatively large numbers of samples for this type of study, in order to cope with the great natural variability encountered in both vegetation and site factors.

The rating of site variables provided by the SPSS procedure supports the hypothesis of a topo-edaphic pattern in the distribution of the canyon grassland vegetation. In the case of the 6 leading factors, elevation and radiation index may be considered as representing the topographic influence most directly, while the soil influence is reflected primarily in organic matter, color and pH of the "A" horizon, and in lime depth.

The advantages of this approach for situations such as presented in the current study include the ability to use soil and other site data determined directly on the sample plots. These data can be obtained concurrently with sampling the vegetation and are not dependent on the prior existence of soil survey or local meteorological data.

The results of this analysis of site factors support the idea that vegetation units independently determined can define ecosystems. The method also offers promise for the study of seral vegetation. Except on sites where severe accelerated erosion has occurred, it seems likely that the site factors used in this study would be affected little by the livestock grazing which has altered the vegetation during the past century.

Literature Cited

Bunting, S.C. 1978. The vegetation of the Guadalupe Mountains. Ph.D. Thesis, Texas Tech. Univ.

Daubenmire, R.F. 1970. Steppe vegetation of Washington. Washington Agr. Exp. Sta. Tech Bull. 62.

Frank, E.C., and R. Lee. 1966. Potential solar beam irradiation of slopes. USDA Forest Serv. Res. Pap. RM-18.

Hironaka, M., and M.A. Fosberg. 1979. Non-forest habitat types of southern Idaho. Interim Rep. Univ. Idaho F.W.R. Exp. Sta. (Processed).

Hugie, V.K., E.W. Williams, H.B. Passey, and D.E. Ball. 1973. Soil-vegetation climatic relationships. USDA Soil Conserv. Serv. Rep. (Processed).

Helwig, J.T., and K.A. Council (eds.). 1979. SAS users guide. SAS Institute Inc. Raleigh, N.C.

Jenny, H. 1958. Role of the plant factor in the pedogenic functions. Ecology 39:5-16.

Mathews, J.A. 1979. A study of the variability of some successional and climax plant assemblage-types using multiple discriminant analysis. J. Ecol. 67:255-271.

Nie, N.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner, and D.H. Brent. 1975. Statistical package for the social sciences. 2nd Ed. McGraw Hill Co.

Norusis, M.J. 1979. SPSS statistical algorithms Release 8.0, SPSS Inc. Chicago.

Pyott, W. 1971. Numerical classification of range vegetation and statistical analysis of its ecology. Ph.D. Thesis, Oregon State Univ. Corvallis.

Tisdale, E.W. 1979. A preliminary classification of Snake River Canyon grasslands in Idaho. Univ. of Idaho, FWR Exp. Sta. Note No. 32.

USDA Soil Conservation Service. 1975. Soil taxonomy. Agriculture Handbook No. 436. U.S. Gov. Printing Office, Washington D.C.