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SOIL AND PLANT CORRELATIONS IN A SOLONETZIC GRASSLAND

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On the Great Hungarian Plain, the correlation between soil variables and plant data was studied in a heterogeneous solonetzic grassland. A 21-m transect was sampled to identify the basic features of the soil-plant correlations. The abrupt change from nonsaline meadow to salt-affected grassland vegetation was explained by the sharp increase in the sodium concentration of the groundwater. Two 50-m transects were sampled, and the relationship between soil variables and plant data was used to predict soil variables. The observed data of the 50-m long transects were divided into two groups of plants, one used for the multiple regression equations and the other used as a check. When comparing the efficiency of various groups of variables for estimation, plant cover data was only half as precise as the soil data.

Vegetation of solonetz soils relates closely to the soil properties because the abiotic effects—the extreme conditions of water availability, sodicity, salinity, and alkalinity—are very strong (Waisel 1972). Consequently the general theory of plant indication provides a good basis for studying the realization of plant indication in the solonetzic environment. Juhász-Nagy states (Juhász-Nagy 1984) that every vegetation cover has indicative power of the environment, but the value of indication must be defined in every particular case. Therefore, we use data on vegetation for prediction of soil properties.

The study of correlation between soil properties of solonetzic grasslands and vegetation has significance in soil mapping. The much sought relationship of *observed data=f(soil)* can be replaced by two relationships of *observed data=f(vegetation)* and *vegetation=f(soil)*. The practical significance of this correlation is that soil properties can be estimated quantitatively by observing the plant cover alone. Up to now, four different approaches have been used for estimating soil properties on the basis of seminatural vegetation of the solonetzic grasslands. The simplest way is when the presence or cover of one species indicates a limit or a range of some soil property (Magyar 1928), which is the traditional case of the use of indicator species. When plant associations are used for estimation, a range of values for several soil properties, e.g., a soil type, is attributed to the different vegetation categories (Bodrogközy 1965). The third method is proposed by Petrova (1988) who estimated ranges of salinity and sodicity based on the categories of occurrence of the plants. If several species are taken into consideration, her estimation becomes more reliable. The fourth is a new, not fully explored method, the use of plant cover as covariable in cokriging of soil properties (Tóth et al. 1991b). The multiple regression analysis (MRA) is a technique in which the plant cover can be used for predicting values of soil properties; we want to show the capacity and limitations of this approach.

The precision of estimating soil properties in the solonetzic grassland given by the predicting variables of plant cover in MRA is limited for several reasons. The correlation between soil properties and vegetation is not the same in every location. In some locations, especially where degradation of vegetation or soil is occurring, the soil properties can be more dynamic or conservative than the vegetation. Also, there are other factors in addition to known important soil properties that influence the occurrence of plants; therefore, the estimation given by MRA is not perfect. Moreover, the nonlinearity of the correlation between the soil properties and the vegetation often corrupts the estimation given by MRA. Consequently, the estimation given by MRA can be improved with appropriate selection of predicted and predicting properties, with the optional transformation of the latter, and with the selection of sample site.

Our objectives were to understand the correlation between the solonetz soil and the seminatural vegetation and to utilize these correlations in the estimation of soil properties. First, correlation analysis was carried out on a 21-m transect. Afterward, on the basis of the experiences on the 21-m transect, two 50-m transects were sampled, and regression equations were calculated between plant cover and other easily available plant parameters, as predicting variables, and ecologically relevant soil properties, as predicted variables. The precision of the estimations was tested by the use of checkpoints.

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MATERIALS AND METHODS

Study Region

The study area was in the Hortobágy National Park, which lies on the Great Hungarian Plain at approximately 47° 30″ N and 21° 30″ E. The region, a good example of a Central European solonetz, includes more than 60,000 ha of solonetzic and related soil types under seminatural vegetation (Fig. 1). It is part of the floodplain of the River Tisza and is flat, lying mostly between 88 and 92 m above sea level. It has a microrelief, with differences in height of no more than 50 cm, that is strongly related to the salinity, alkalinity, sodicity, and moisture regime of the soils. On higher ground there are chernozems, which are mostly cultivated, with small fragments of loess-steppe vegetation. The lowest lying land is occupied by saline swamps. Between these two main formations there are extensive flatlands, with solonetz or solonetzic meadow soils covered with halophyte grasslands.

The solonetzic soil of the study area (Typic Natrustoll) has a characteristic morphology. Its A horizon is fairly uniform, densely rooted, usually salt-free with neutral or slightly acidic pH, with sandy loam to silt loam texture. In the B horizon the soil is alkaline, and the texture is finer, typically clay-loam. The transition from the A to the B horizon is abrupt, with an increase in alkalinity and sodicity, salt content, clay percentage, etc. (Szabolcs 1969). The columnar structure of the upper part of the B horizon is in striking contrast to the weakly developed laminar structure of the A horizon.

The plant associations have a mosaic-like distribution, and *Achilleo-Festucetum pseudovinae* (milfoil grassland) is located on the top of the "szik banks," or microerosional mounds, which are no higher than 50 cm. *Artemisio-Festucetum pseudovinae* (sagebrush grassland) is immediately below the previous association, on lower elevations of the szik bank. *Camphorosmetum annuae* (alkali bare spot vegetation) is on the slopes and at the foot of the mounds, and *Puccinellietum limosae* (scarce grass vegetation of transient waterways) is located in the middle regions of the depressions that drain toward the *Agrosti-Alopecuretum pratensis* (alkali meadow). More details of the environmental conditions and coenological relations of the study area are given in Tóth et al. (1991a).

Sampling

21-m transect

In July 1981, a 21-m-long trench was dug across this land to the groundwater table (between 1.3 and 1.8 m) (Rajkai et al. 1988; Oertli and Rajkai 1988) as shown in Fig. 2. The exposed section was sampled at 1.5-m intervals. Soil was

FIG. 1. View of the solonetzic grassland in the Hortobágy area. The frozen puddles indicate the position of waterways.

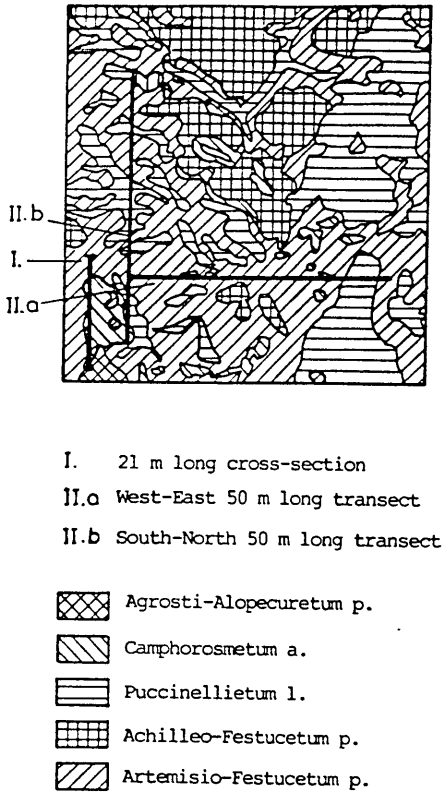


FIG. 2. Layout of the 21-m transect and the 50-m transects on a vegetation map deduced from aerial photography.

taken from each of the genetic horizons of 13 soil profiles and analyzed for pH, $CaCO_3$ content, total salt content, mobile Na (Na extracted with ammonium carbonate solution according to Herke in Darab and Ferencz 1969), cation exchange capacity (CEC), exchangeable sodium percentage (ESP) and alkalinity (by phenolphthalein). Particle size fractions, specific surface, pF-curve, bulk density, and plasticity index were also determined. The groundwater was sampled at each point in the transect and analyzed for pH, electric conductivity (EC), and anion and cation content (Fig. 3).

The height of the soil surface was measured at 10-cm intervals along the transect and at closer intervals on steeper gradients.

The vegetation survey was carried out continuously along the transect by registering the total plant coverage and the occurrence and relative abundance of plant species using the Braun-Blanquet scale in 30 cm × 30 cm contiguous quadrats.

The southern end (about 2 m) of the transect was covered with non-salt-affected meadow vegetation.

50-m transects

On July 10, 1989, two perpendicular, 50-m long transects (West-East and South-North) were marked out adjacent to the 21-m transect (Fig. 4). On each transect, 60 points were located in a nested random scheme. This scheme, with a minimum sampling distance of 10 cm, reduced the total number of points from 1000 possible to 120 realized. Disturbed soil samples and 100 cm^3 soil cores were taken from depths of 0–5 cm and 10–15 cm.

The samples were analyzed for pH, moisture content, total soluble salt content (based on EC of saturated soil paste), and mobile Na. From the soil cores, bulk density and the water contents at saturation (pF0), at approximately field capacity (pF2.3) and at wilting point (pF4.2) were determined.

On May 24, 1990, the relative height of the land surface at the sampling points (relief) was also measured.

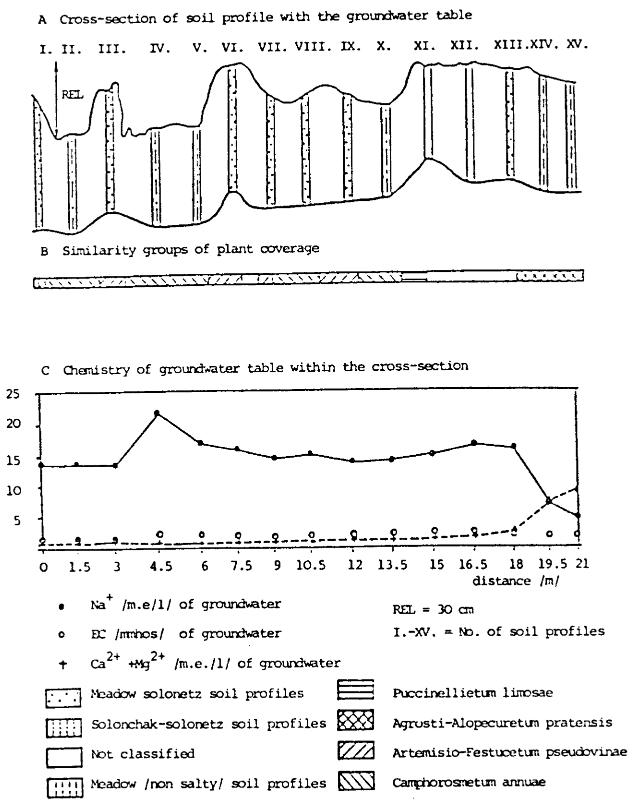
One year after the soil sampling, a detailed vegetation survey was made in 20 cm × 20 cm quadrats at sites adjacent to the soil sampling sites. The preference categories of the dominant plants for important ecological conditions such as those shown in Table 1 were quantified from 1 to 5 for each species found in the quadrats (see rating in table). The average quantified ecological preference of the quadrat for soil temperature, soil moisture, soil nitrogen content, soil alkalinity, and soil salinity was calculated by weighting the quantified preference of each plant with its respective cover percent. Similarly, the Raunkiaer life form of the occurring plants was also averaged.

Statistical Analysis

Multiple regression analysis

The method chosen to select variables in the multiple regression analysis was stepwise selection. In this procedure, each of the potential independent variables of the regression equation is examined for its ability to meet the criteria of entry into or removal from the equation. The "probability of F-to-enter" at each step was 0.05, and the "maximum F-to-remove" was 0.10. The difference in the multiple correlation coefficients of the multiple regression equations was tested according to Simpson and Roe (1939).

FIG. 3. Soil and plant distribution and the chemical composition of the groundwater table along the 21-m transect.



Classification algorithm

Thirteen soil profiles on the 21-m transect were grouped by single linkage agglomeration using the chemical and physical properties of the genetic horizons, the height of the surface and the depth of the groundwater table at the time of sampling (Fig. 3), the chemical composition of the groundwater table under the sampled soil profiles, and plant data of the quadrats just above the soil profiles. Data on the percentage cover of plants from the quadrats were grouped using the same numerical classification algorithm.

Goodness-of-estimation

When regression equations were used to predict soil properties, the quality of the prediction was evaluated by the use of check points. The basis of this was the standard error of the estimate (SEE) (Davis 1986), and for a comparison of the goodness-of-estimation achieved with different variables, estimation efficiency E (%) (1-SEE/standard deviation)×100) was introduced as a new parameter to show the scatter of the estimates related to the standard deviation of the original sample. It indicates how much the original dispersion of the data has been reduced

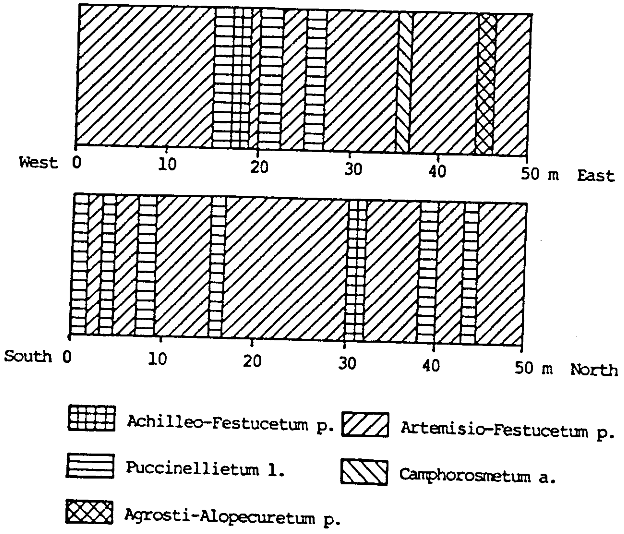


FIG. 4. Botanical categories along the 50-m transects.

by the estimation method. Nearly 100% means almost perfect estimation, whereas no greater than 0% means no improvement in the dispersion.

To evaluate the goodness-of-estimation for the two 50-m long transects, the data for the 120 sample points were divided randomly into two subsets. One set (80 points) was used for generating the predicting regression equations and the other (40 points) for comparing the predicted values with the measured ones. Following Webster (1989), the residual mean square of the regression equation, i.e., the square of the standard error of the estimate of the regression equation, was given as an estimation of the estimation variance.

RESULTS AND DISCUSSION

The 21-m transect

The groups of soil profiles classified with elevation, those classified with depth and chemical composition of the groundwater, those classified by chemical and physical properties of the soil, and the groups of profiles classified by the vegetation gave similar dendrograms. Three groups were differentiated. One of them represented solonetz soils (profiles I, III, VI to IX, and XIII) having a solonetzic A horizon at the higher elevations (szik banks) covered with an *Artemisio-Festucetum pseudovinae* plant association (Fig. 3). In this group the groundwater was deeper than 140 cm below the surface, and its Na content was less than 13 meq/100 g water. The second group comprised solonetz soils without an A horizon. These profiles lie in the microdepressions. The groundwater table of this group, at 130 cm, was somewhat shallower. The vegetation was scarce, and halotolerant species (*Camphorosma annua* and *Puccinellia limosa*) were frequent in this group.

TABLE 1

Ecological preferences of some characteristic species of the solonetzic grassland (mainly after Zólyomi 1964)

Species	Preference for					
	Soil moisture	Rating	Soil pH	Rating	Salt content	Rating
Puccinellia limosa	indifferent	0	neutral	4	halophile	2
Camphorosma annua	dry soil	1.5	alkaline	5	halophile	2
Festuca pseudovina	slightly moist	2	indifferent	0	halotolerant	1
Artemisia maritima	slightly moist	2	indifferent	0	halophile	2

The third group consists of non-saline meadow soils (profiles XIV and XV). The existence of a meadow-like environment in a salt-affected area is not exceptional in the Hortobágy region, but the reason for it is unknown. The chemical composition of the groundwater under the meadow vegetation was different from that under the solonetz soils (Fig. 3). Between profiles XIII and XIV, the Na content of the groundwater decreased abruptly, and the Ca and Mg contents increased. The quality of the groundwater could explain the abrupt transition between solonetz and meadow soil types in cases where the groundwater depth and the texture of the soil horizons do not vary. Treitz (1934) reported similar observations. As yet, there is no acceptable explanation for the abrupt difference in the chemistry of the groundwater.

The interdependence of plant-soil relationships was studied by stepwise regression between plant abundance and the soil properties. In Table 2 and similar subsequent tables of regression analysis, the columns indicate the order in which the first three variables of the regression equation were selected. This order also shows the order of importance of the variables. The sign of the regression coefficient of the three variables entering the equation is also given. For assessing the dependence of plant variables on soil properties, the upper three soil horizons (<40 cm) were sufficient. Rajkai et al. (1988) came to similar conclusion in a study made in the same experimental area.

Total plant cover is determined by the pH of the surface soil horizon. Vegetation is densest where soil is the most acid. However, the square of the correlation coefficient of the regression equation is not large ($R^2 = 0.53$).

The abundance of *Puccinellia limosa* is determined by the salt content of the surface soil horizon. *Puccinellia limosa* and blue alga (*Nostoc commune*) showed similar relationships to the salt content of the soil surface. However, in the case of *Nostoc commune*, the salt content of the surface horizon is the second most important factor, while the $CaCO_3$ content of the surface soil horizon is the most important.

No specific indication was found for *Festuca pseudovina*. *Artemisia maritima* prefers a sandy surface and a large specific surface area within

TABLE 2

Soil variables determining plant cover in regression equations in the 21 m-transect

Dependent (plant) variables[a]	Independent (soil) variables[b]						RMS[c]
	Order of entering equation						
	1		2		3		
	Name	R^2	Name	R^2	Name	R^2	
TOC	PH_1ST	−0.53					524
PUC	SA_1ST	+0.88					25.6
CAM	ALK_2ND	+0.83	MECH5_3RD	−0.92			6.12
FE	SA_2ND	−0.71	NA_3RD	+0.85	SPES_2ND	+0.92	136
AR	MECH2_1ST	+0.76	SPES_2ND	+0.86			7.51
NOS	CAC_1ST	+0.88	SA_1ST	+0.94			1.02

[a] TOC = Total coverage (%); PUC = Coverage of *Puccinellia limosa* (%); CAM = Coverage of *Camphorosma annua* (%); FE = Coverage of *Festuca pseudovina* (%); AR = Coverage of *Artemisia maritima* (%); NOS = Coverage of *Nostoc commune* (%).

[b] PH = pH; SA = Salt content (%); ALK = Phenolphthalein alkalinity (mg Na_2CO_3/100 g soil); CAC = Calcium carbonate (%); SPES = Specific surface (m^2/g); NA = Mobile sodium, the sum of soluble and exchangeable sodium (meq/100 g); MECH2 = 0.25–0.05 mm particle size fraction (%); MECH5 = 0.01–0.005 mm particle size fraction (%); _1ST = First genetic horizon; _2ND = Second genetic horizon; _3RD = Third genetic horizon.

[c] RMS = residual mean square of the regression equation.

the subsoil. Based on the results of the 21-m transect, two 50-m-long transects were selected to cover a wider scale of plant associations and soil properties (Fig. 2) and to test the applicability of the found relationships in predicting soil properties.

The 50-m transects

Basic statistics of the soil variables included for estimation are given in Table 3. These variables, which describe the most important ecological conditions on solonetzic grassland, have very different degrees of constancy. Moisture content and salt content vary the most, while pH is the most stable. On the other hand, for the two layers studied, there is a systematic and stable difference in the values of the chemical properties with increasing depth in the soil profile. There is an increase in pH, salt content, and sodicity with depth, as was described earlier.

The scatterplots of some of the soil variables with plant data showed varying degrees of correlation between the two groups of variables (Fig. 5). The stepwise regression, similar to that of the 21-m transect, showed that the R^2 values of the regression equations for the 50-m transects (Table 4) were smaller than those for the 21-m transect. An explanation of these differences can be found in the differences of transect length and sampling scheme, e.g., in the shorter 21-m transect, there were fewer plant associations, and the genetic horizons have not been mixed.

On the basis of the R^2 values for the 50-m transects, most precise estimations are provided by the regression equations for the cover of *Camphorosma annua*, total plant cover, cover of *Festuca pseudovina*, and that of *Puccinellia limosa* as dependent variables, while the cover of *Artemisia maritima* and that of *Nostoc commune* gave the least precise estimation.

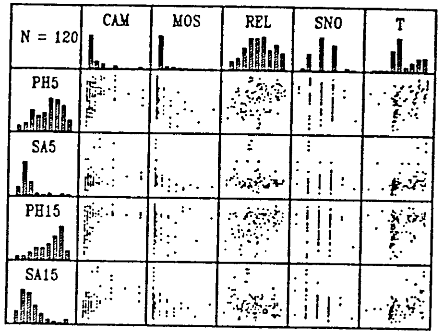


FIG. 5. Scatterplot of some predicted soil properties with predicting plant variables. The soil variables (on the left side of the plot) are the "y" variables and the plant variables (on the top of the plot) are the "x" variables. Abbreviations as in Tables 4 and 5.

As a result of leaching and clay alluviation from the solonetzic A horizon, the topsoil is coarser and has a lower moisture content. Total plant coverage is greater where the topsoil has low bulk density and water retention capacity. These conditions are preferred by *Festuca pseudovina*. The abundance of *Puccinellia limosa* is determined jointly by soil alkalinity and moisture content. In the range of habitats studied, *Artemisia maritima* was not most abundant in the quadrats with higher sodicity. The cover of *Nostoc commune* is found where water retention is greater, but for the mosses, the opposite situation was found: they keep away from the wettest quadrats.

Plant cover data as predictors of soil properties

As the distribution of the plant cover data was often strongly skewed (Fig. 5), these data were transformed by log transformation. Regression equations were computed for all the observations (120). Then 40 points were omitted from the regression calculations for checking purposes. As there were no significant differences between the R values for 120 points or 80 points, it was assumed that the point selection was random. The predictor properties included in the regression equations were grouped in three ways to compare the predictive power of the groups, namely soil variables, plant variables, and soil plus plant variables.

TABLE 3

Statistics of the soil variables of the 50 m-transects (120 quadrats)

Variables	REL[a]	PH5	SA5	NA5	PH15	SA15	NA15	MC5	MC15
Mean	15.03	8.42	0.17	8.71	9.87	0.45	17.68	7.36	15.70
Coef. Var.	45.27	10.32	87.46	47.23	4.94	53.01	31.10	35.86	24.44
Skewness %	−0.13	−0.32	2.02	1.32	−0.89	1.50	0.37	0.49	0.47
Kurtosis	2.31	2.29	6.37	5.05	3.06	5.65	3.62	2.79	2.95

[a] PH5 = pH of the 0-5 cm layer; SA5 = Soluble salt content of the 0-5 cm layer (%); NA5 = Mobile sodium of the 0-5 cm layer (meq/100 g); PH15 = pH of the 10-15 cm layer; SA15 = Soluble salt content of the 10-15 cm layer (%); NA15 = Mobile sodium of the 10-15 cm layer (meq/100 g); MC5 = Moisture content of the 0-5 cm layer (vol. %); MC15 = Moisture content of the 10-15 cm layer (vol. %).

TABLE 4

The variables of the regression equations between soil (independent) and vegetation (dependent) data in the 50-m transects (120 quadrats)

Dependent variable	Independent (soil) variables Order of entering equation 1		2		3		Final n, R^2		
	Name	R^2	Name	R^2	Name	R^2	n[b]	R^2	RMS[c]
TOC[a]	KA5	+0.20	WP5	−0.37	BD5	−0.40	4	0.43	330
PUC	PH5	+0.25	MC5	+0.32	NA15	+0.35	5	0.42	60.0
CAM	SA15	+0.27	KA15	−0.39	NA15	−0.43	7	0.57	6.89
FE	WP5	−0.17	KA5	−0.32	BD15	−0.36	6	0.44	393
AR	NA5	−0.10					1	0.10	15.8
NOS	SC15	+0.09	WP5	+0.12			2	0.12	24.2
MOS	MC5	−0.19	KA5	+0.26	SC15	−0.30	3	0.30	28.0

[a] TOC = Total plant coverage (%); PUC = Coverage of *Puccinellia limosa* (%), CAM = Coverage of *Camphorosma annua* (%); FE = Coverage of *Festuca pseudovina* (%); AR = Coverage of *Artemisia maritima* (%); NOS = Coverage of *Nostoc commune* (%); MOS = Coverage of mosses (%); REL = Relative height (cm); KA5 = Water saturation percentage of 0-5 cm layer; PH5 = pH of 0-5-cm layer; NA5 = Mobile sodium of 0-5-cm layer (meq/100 g); KA15 = Water saturation percentage of the 10-15-cm layer; SA15 = Soluble salt content of the 10-15-cm layer (%); NA15 = Mobile sodium of the 10-15-cm layer (meq/100 g); MC5 = Moisture content of the 0-5-cm layer (vol. %); BD5 = Bulk density of the 0-5 cm layer (g/cm^3); BD15 = Bulk density of the 10-15-cm layer (g/cm^3); SC15 = Water content at saturation of the 10-15-cm layer (vol. %); FC15 = Water content at field capacity of the 10-15-cm layer (vol. %); WP5 = Water content at wilting point of the 0-5-cm layer (vol. %).

[b] n = final number of independent variables in the equation.

[c] RMS = residual mean square of the regression equation.

The variables chosen using the stepwise selection algorithm are given in Table 5. In the table, only equations calculated exclusively with plant variables as predictor properties are presented.

For estimating chemical properties such as alkalinity, salinity, and sodicity, the most useful variables were relief, total plant cover, cover of mosses and *Camphorosma annua*, together with preference for soil temperature. The hottest quadrats were covered almost exclusively by the most halophilic plants, *Camphorosma annua* and *Puccinellia limosa*.

In a typical toposequence, sagebrush grassland (*Artemisio-Festucetum pseudovinae*) lies higher than the scarce vegetation of transient waterways (*Puccinellietum limosae*), but in the study area there were no significant difference between the relative height of the two dominant associations. According to Varga et al. (1982), this can occur when the gaps of the sagebrush grassland are filled up with scarce vegetation of transient waterways.

Soil moisture content is predicted best by the cover of mosses and the quantified average preference for soil moisture. Strangely, a low preference for the soil moisture content indicates a high moisture content in the deeper soil layer. The reason for this misleading behavior can be found in Table 1, which shows that *Puccinellia limosa* is classified as indifferent to moisture content. Indifferent preference was quantified as zero (Table 1), and in this way quadrats with a high coverage of *Puccinellia limosa*, the typical plant for the transient waterways, had low values of T. In this situation the classification of the preference for soil moisture of this plant is questionable.

In the 40 check quadrats, the values of the soil variables were predicted with the regression equations and compared with measured values.

TABLE 5

The variables of the regression equations that predict soil properties from plant data (based on 80 quadrats)

Dependent variable	Independent (plant) variables[a] Order of entering equation 1		2		3		n[b]
	Name	R^2	Name	R^2	Name	R^2	
PH5	R[c]	+0.25	REL	+0.35	MOS	−0.43	4
SA5	T	+0.26	CAM	+0.33	MOS	−0.38	4
NA5	T	+0.30	N	−0.40	MOS	−0.48	4
PH15	CAM	+0.21	REL	+0.40	SNO	−0.45	5
SA15	CAM	+0.33	SNO	−0.42	REL	−0.48	4
NA15	T	+0.15					1
MC5	MOS	−0.24	N	+0.33	TOCO	+0.37	4
MC15	F	−0.12					1

[a] Plant cover data, such as CAM, MOS, and TOCO, were transformed using logit transformation.

[b] n = final number of independent variables in the equation.

[c] R = Preference for soil alkalinity; T = Preference for soil temperature; N = Preference for soil nitrogen content; F = preference for soil moisture; SNO = Number of species found in the quadrat.

The results are given in Table 6. In this table, the comparison of the three groupings of the predicting variables show that soil properties were predicted best by soil data using the regression equations. The inclusion of plant data with soil variables increased the value of R^2. As predicting variables, plant data alone gave about half of the precision that was given by the soil or soil plus plant variables. This performance of plant data is interpreted to be satisfactory. The ratio of the costs of labor using the regression analyses based on soil and plant data are roughly 7:2, with a ratio of 2:1 for precision. Therefore, plant data can be valuable for estimating surface soil properties on solonetzic grasslands at large scale, either used as exclusive predictor variables or in combination with soil variables.

CONCLUSIONS

Quantifying the interrelationships between soil and vegetation in solonetzic grasslands is useful for making an inventory of natural resources, and the occurrence of plants can give quantitative information on the soil properties. The vegetation indicates sharp differences in the status of soil in terms of degradation and in the chemistry of the groundwater. The abrupt boundary found in this report between the *Agrosti-Alopecuretum pratensis* meadow spot and the *Artemisio-Festucetum pseudovinae* salt-affected grassland coincided with a sharp increase in the sodium concentration of the groundwater.

TABLE 6

Precision of estimations given by different sets of predictor variables using 40 check quadrats

Estimated variable	Mean[b]	SD[b]	Predictor variables Soil plus plant E[c]	R^2[d]	RMS[d]	Soil E	R^2	RMS	Plant[a] E	R^2	RMS
PH5	8.57	0.882	46	0.85	1.18E-1	48	0.82	1.40E-1	19	0.45	3.99E-1
SA5	0.18	0.149	49	0.81	1.63E-3	44	0.72	2.32E-3	11	0.41	5.07E-3
NA5	9.41	4.795	41	0.85	2.18	50	0.82	2.62	18	0.52	6.83
PH15	9.89	0.519	52	0.79	5E-2	47	0.79	5.1E-2	34	0.53	1.11E-1
SA15	0.52	0.277	55	0.89	5.07E-3	62	0.85	7.45E-3	31	0.57	2.003E-2
NA15	19.0	6.187	61	0.84	4.27	55	0.78	5.94	14	0.15	21.4
MC5	7.7	2.657	46	0.77	1.69	44	0.77	1.70	28	0.43	4.09
MC15	17.1	4.059	47	0.74	3.44	47	0.72	3.67	2	0.12	10.9

[a] Plant cover data were transformed by logit transformation.

[b] Mean and SD = standard deviation of original check data.

[c] E = estimation efficiency (1-SEE/SD) × 100.

[d] R^2 = square of correlation coefficient and RMS = residual mean square of the prediction regression equation.

Even where there are no sharp changes in the composition of the vegetation, it can still be useful for estimating soil properties. Soil and plant data together give better estimation of soil properties than only soil data. The estimation given by plant data alone is half that of the soil data, but involves significantly lower expenditure.

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