FACTOR ANALYSIS OF HUNGARIAN HYDROPHYSICAL DATA TO PREDICT SOIL WATER RETENTION CHARACTERISTICS

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Abstract: We explore the information associated with soil water retention included in the large scale soil maps of Hungary. We employed factor analysis to investigate the role of different commonly measured soil properties - namely sand and clay content, organic matter content, pH and CaCO3 content - on determining soil water retention at different pF values (pF0, pF2.5, pF4.2 and pF6.2). Analyses were performed on all the samples of the database, that contains 3821 soil horizons of diverse soil types, as well as a selection of the horizons belonging to Chernozem soils of the database. Results show considerable differences of water retention characteristics of Chernozems, mainly at pF0. This suggests that a separate analysis for different soil types might be appropriate in order to characterize the impact of measured soil properties on water retention.

Keywords: soil water retention, factor analysis, soil map information

Introduction

Soil hydraulic properties are key determinants of the soil-plant interrelations. Therefore, the information on these properties are essential for the planning of sustainable utilization of the soil's biomass production function (Tóth et al., 2006). The stability of plant production can be secured by management of the soil physical characteristics (Farkas et al., 2005; Várallyay, 2005). Most commonly used hydraulic properties include the hydraulic conductivity and soil water retention capacity. Measuring these soil properties is costly, labour and time intensive. Thus, these are often estimated on the basis of readily available soil properties. Parameters which are most frequently used for estimating soil water retention include the soil particle size distribution, the organic matter content and the bulk density (Rajkai & Várallyay, 1992; Wösten et al., 2001).
Multivariate statistics offers a convenient framework within which one can analyze the structure of data matrices and the possible cross-correlations between variables (Pachepsky & Rawls, 2005). In the context of principal component analysis, a set of so-called components is formed, allowing to quantify the internal variability of the data set analyzed by means of a reduced set of variables. Lin et al. (1999) used factor analysis to determine the relative importance of quantities defining the structure of their sampled data. Vereecken et al. (1989) used principal component analysis to study the relationship between moisture retention characteristic and measured soil properties.
Hungary offers a unique opportunity for this type of analyses, in that detailed soil properties maps with 1:10 000 scale for 60 % of the Hungarian agricultural areas are available (Tóth & Máté, 2006). The distinctive aim of this paper is to analyze the amount of information included in these maps and relate these to the soil water retention at pF0, pF2.5, pF4.2 and pF6.2. We do so by employing factor analysis to investigate the role of different commonly measured soil properties on determining soil water retention recorded at different pF.

Materials and methods

Dataset

In our study we used 3821 Hungarian soil horizons with varying soil subtype, physical and chemical properties. The database contains information on the soil type and subtype (according Hungarian soil classification), sand (0.02-2 mm), silt (0.002-0.02 mm), clay (< 0.002 mm), organic matter and calcium carbonate content, pH(H2O) and water retention values at pF0, pF2.5, pF4.2 and pF6.2. The soil feature determinations have been measured as reported by Búzás (1993).

Statistical analysis

Multivariate statistical analyses were performed with the statistical package SPSS 14.0 (Norusis, 1994). We performed a Factor Analysis and obtained estimates of the initial factors from principal component analysis. The number of factors to be retained is chosen on the basis of the relative proportions of the variance explained. To simplify the interpretation of the results, VARIMAX rotation with Kaiser normalization was used. On the basis of the rotated component matrix it was then possible to identify the most significant variables within the group of components and the degree of inter-relationship between these. We started by performing Factor Analysis with reference to the whole dataset. The Chernozems main soil type was then analyzed separately, to identify the sensitivity of the analysis to a single main soil type. Silt content of soil was not included as a control variable, since it can be calculated from clay and sand content.

Results and discussion

Factor analysis of the whole database

Three factors were extracted from the nine variables, accounting for about 78.22 % of the variance. Factor I (FI) retains information about 49.66 % of the total variance; Factor II (FII) and Factor III (FIII) respectively explain 18.61 % and 9.95 % of the total variance (Table 1).

Table 1. Key results of the Factor Analysis for the complete dataset. Factor loadings have been omitted when less than 0.4 (in absolute value)

Variable	FI	FII	FIII	Communalities
sand content	-0.85	-	-	0.82
clay content	0.92	-	-	0.88
calcium carbonate	-	0.89	-	0.81
organic matter	-	-	0.81	0.75
pH in water	-	0.85	-	0.73
water content at pF0	-	-	0.71	0.66
water content at pF 2.5	0.87	-	-	0.84
water content at pF 4.2	0.88	-	-	0.81
water content at pF 6.2	0.85	-	-	0.77
% of variance	**49.66**	**18.61**	**9.95**	
cumulative % of variance	**49.66**	**68.27**	**78.22**	

Table 1 reports the rotated factors loadings and communalities, together with the percentage of interpreted variance and the cumulative percentage variance. The interpretation of the factors is provided in terms of the squares of the factor loadings. FI explains (-0.854^2) = 73% of the variance of sand content, (0.923^2) = 85% of the variance of clay content, (0.87^2) = 75.7% of the variance of water retention at pF2.5, (0.882^2) = 77.8% of the variance of water retention at pF4.2, (0.848^2) = 72% of the variance of water retention at pF6.2. FII accounts for (0.892^2) = 79.5% of the variance of calcium carbonate and (0.849^2) = 72% of that of pH. FIII explains (0.814^2) = 66% of the variance of organic matter and (0.707^2) = 50% of that of water retention at pF0. Water retention at pF2.5, 4.2 and 6.2, clay content are positively related to the first Principal Component, while sand content is negative related to it (Table 1.). The calcium carbonate content and pH are related to FII. The organic matter and water retention at pF0 are related to FIII. On the basis of these results, it is clear that pH and calcium carbonate content do not have significant effects on soil water retention. On the other hand, the analysis suggests that the water retention at pF0 is slightly associated with organic matter content.

Factor analysis of Chernozems

Our database contains 733 soil samples which are Chernozems. Within these samples, three factors were extracted from the nine variables examined, accounting for about 74.57 % of the total variance (i.e., the analysis is 74.57% complete). Factors FI, FII and FIII respectively explain 43.43 %, 20.83 %, 10.30 % of the total variance. Factor FI accounts for (-0.77^2) = 59% of the variance of sand content, (0.855^2) = 73% of the variance of clay content, (0.864^2) = 74.6% of the variance of water retention at pF2.5, (0.817^2) = 66.7% of the variance of water retention at pF4.2 and (0.856^2) = 73% of that of water retention at pF6.2. Factor FII explains (0.782^2) = 61% of the variance of calcium carbonate, (-0.8^2) = 64% of that of organic matter and (0.816^2) = 66.7% of that of pH. Finally, factor FIII explains (0.9^2) = 81% of the variance of water retention at pF0. Similarly to what observed for the complete dataset, water retention at pF2.5, 4.2 and 6.2, clay content are positively related to the first Principal Component, while sand content is negative related to it (Table 2).

Table 2. Key results of the Factor Analysis for the Chernozems subset. Factor loadings have been omitted when less than 0.4 (in absolute value)

Variable	FI	FII	FIII	Communalities
sand content	-0.77	-	-	0.70
clay content	0.86	-	-	0.74
calcium carbonate	-	0.78	-	0.75
organic matter	-	-0.80	-	0.71
pH in water	-	0.82	-	0.71
water content at pF0	-	-	0.90	0.86
water content at pF 2.5	0.86	-	-	0.79
water content at pF 4.2	0.82	-	-	0.68
water content at pF 6.2	0.86	-	-	0.78
% of variance	**43.43**	**20.83**	**10.30**	
cumulative % of variance	**43.34**	**64.27**	**74.57**	

The samples contents of pH, organic matter and calcium carbonate are related to the second Principal Component. The water retention at pF0 basically constitutes the third Principal Component. It then follows that pH, organic matter and calcium carbonate content appear not to have notable effect on the water retention. The water retention at pF0 is not related to any of the other variables.

Conclusions

We used factor analysis to explain the relative importance of different measured quantities on soil water retention values at pF0, pF2.5, pF4.2 and pF6.2. Our aim is to explore the type of information which can be extracted by performing factor analysis of variables which are available from the detailed (1 : 10 000) soil maps of Hungary. In the analysis we used sand and clay content, organic matter content, pH and calcium carbonate content next to the water retention values. We started by analyzing the whole database and then treated separately the Chernozems main soil type.

The analysis reveals that there are peculiarities of the Chernozems main soil type which are obscured when all samples are lumped into a single dataset. We believe this is associated with the fact that the water content at pF0 is influenced by the presence of macropores. The presence of the latter is strongly associated with the considerable biological activity and the extent of soil degradation (disaggregation, compaction) which is caused by the intensive cultivation of the Chernozems. This suggests that a separate analysis for different soil types might be appropriate in order to characterize their internal variability.

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