Yield and salinity relationships in a country-scale soil and yield field-crop database

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Abstract
Soil and yield field-crop databases are much sought for understanding and predicting factors affecting crop yield. The optimal size of these databases is such that permits their general use but also secures good spatial representativity. In this paper the applicability of the Hungarian AIIR soil and yield field-crop database was tested for describing the effect of soil salinity on crop yields. The expected, already proven decreasing effect of soil salinity on yield was not substantiated by the database. In general the chemical soil properties showed the already proven relationships, but with very large scatter. By the example of a very small database it was shown that the inclusion of widely different soil types complicates the evaluation of the correlations very much. Increasing the number of data records with the inclusion of very different soil types can result in less useful global relationship between soil properties and yield.

Key words
Soil organic matter, chernozem, salt-affected soil, pH.

Introduction
Although there is plenty of knowledge available on the fundamental characteristics of soils, but the perfect knowledge of every soil aggregate is practically impossible. In spite of detailed physical, chemical and biological ground-truthing, the predictions carry statistical uncertainty due to the inherent variability of soil forming processes, management and the resulting soil properties. According to the scale of data collection the uncertainties of data and predicting capacity are expected to increase in the following order: physical and chemical equations < laboratory studies < pot studies < small plot experiments < controlled field experiments < uncontrolled field databases. But since in this order the areas and variation of occurring combinations of soil forming factors is increasing, the overall usefulness of the databases is generally increases. With the increase in uncertainty there can be a scale reached at which there are hardly any relationships that can be used for practical predictions due to the following reasons: inhomogeneity of analytical, data collection, datasourcing techniques, etc (Tóth *et al*. 2007). Therefore every use of databases must be preceded by the process of validation whether the database is suitable for the intended use or not. In this paper the results of the checking of a national soil and yield field-crop database are presented for its usefulness in the prediction of soil and yield relationships, preceded by an internal check of consistencies.

Materials and Methods
For this work the Hungarian "AIIR" soil and yield field-crop database ("Big database") (Tóth *et al*. 2005) was used. Data were collected in the years between 1985 and 1989 from the agronomic field records kept at the farms. These plowlayer data were collected from 60 000 fields covering yearly 4 000 000 ha. From the database the following data were utilized: applied fertilizer level, yield, soil analytical data (pH, Saturation Percent according to Arany method [SP_Arany], Soil Organic Matter content [SOM], soil salinity-Total Dissolved Solutes [TDS]). For ANOVA three fertilizer levels were selected, and named by the applied N level (90, 150 and 210 kg/ha). Average applied K and P were 87, 94, 110 and 65, 67, 68 kg/ha respectively in the mentioned levels).

Data from Ristolainen *et al.* 2009 were also used ("Small database"). The 70 m long transect was crossing non saline Chernozem tall grassland and extremely saline-sodic-alkaline calcareous shortgrassland patches. Samples (0-20 cm) were taken from every fifth meter. Soil clay content, pH, organic matter content (SOM) and electrical conductivity (EC of 1:2.5 soil:water suspensions) were determined according to Buzás 1988.

Results
The first question was whether the database shows the obviously expected decrease of crop yield with increasing salinity or not? Two soil main types, the most productive "Chernozems" (Mollisols) and "Salt-affected soils" and two major crops, the relatively salt tolerant winter wheat and the less salt tolerant

sunflower were selected. As shown below only in the case of Salt-affected soils we found the expected trend, and only in the case of sunflower it was statistically significant.
Correlation coefficients between soil salinity (%) and yield with number of observations in brackets based on the Big database

Soil/Crop	Winter wheat	Sunflower
Chernozems	0.04 (17269)	0.056** (4088)
Salt-affected soils	-.021 (1687)	-41.705

Since fertilizer level can affect the yield (Petróczi 2009) we have checked its effect on crop yield in the Big database as shown below with the number of cases in brackets. Means followed by the same letter are not statistically significant.

	Chernozems			Salt-affected soils		
Crop/Nitrogen Category (kg/ha)	**90**	**150**	**210**	**90**	**150**	**210**
Winter wheat (t/ha)	5.15a(2534)	5.24a(4182)	5.38b(2158)	4.02a(101)	4.12a(405)	4.39a(115)
Sunflower (t/ha)	2.16a(1491)	2.16a(196)	2.26a(50)	2.12a(115)	2.50a(10)	2.9a(1)

Although the tendency of the yields was increasing with increasing N level, there were no statistically significant differences in general between the nitrogen fertilizer categories. Generally sunflower is not considered to be very sensitive for larger fertilizer doses (Petróczi 2009), but this feature was not substantiated by the database. Moreover the salt-affected soils showed somewhat higher sunflower yields than the Chernozems, which is not very likely. Based on these observations the yield data are not considered to be suitable for the analysis of the relationship between soil salinity and crop yield.
Subsequently the second question was whether the proven relationships between soil properties can be detected or not? Table 1 compares the total and salt-affected data sets. A striking feature of the database is that it is not the group of Salt-affected soils which has the largest pH and salinity values.

Table 1. The descriptive statistics of the samples of the Big database for chemical properties

	TOTAL	SOIL	DATABASE	SALT	AFFECTED	SOIL TYPES
	N	Minimum	Maximum	N	Minimum	Maximum
pH (KCl)	286136	3.11	9.33	3627	3.22	8.00
SP_Arany	286136	24	81	3627	24	76
$CaCO_3$ (%)	286136	.00	33.00	3627	.00	33.00
SOM (%)	286136	.00	5.50	3627	.61	5.50
TDS (%)	168218	.01	2.20	3516	.01	2.20

Table 2. shows that there is a contradiction between the correlation coefficients between SOM and pH calculated for the total Big database and those calculated for the subset of salt-affected soils. Due to its acid character the soil organic matter is expected to show negative correlation with pH as it is shown by the salt-affected soils. For the total database the explanation is that the acidic soils typically have smaller SOM than the slightly alkaline Chernozems which are dominating the soil cover and the database.
For understanding the mentioned contradiction the Small database was evaluated, because it contained these variables and was collected in a rather well investigated area. In Table 4 there is no contradictory signs of correlation coefficient between the two halves. The reason is that the composition of the sample was balanced: 7 non salt-affected vs 8 salt-affected samples. Due to the wider range of values (Table 3) of salt-affected soils, there are rather contrasting “hidden” tendencies inside the joined database (Figure 1), but the salt-affected soils will determine the sign of overall correlation. As it is conceivable in this area salinity correlates with alkalinity and sodicity due to the presence of sodium carbonate. In Figure 1.A and B. there is opposite sign of correlation for the separate soil groups, but the sign of global correlation coefficient is determined by the extreme salt-affected soils. In Figure 1.A. the decreasing pH of non saline soils (red) is the consequence of the presence of SOM. The greater the SOM content the less $CaCO_3$ is remaining and therefore the pH decreases in the non saline soils. Since SOM contributes to electrical conductivity EC is increasing. On the other hand increasing salinity caused by alkali (green) will result in extreme high pH values. In Figure 1.B increasing amounts of SOM contribute to the increased measured value of electrical

conductivity (red) and therefore there is positive relationship for non salt-affected soils. But increasing salinity limits biological activity and there is negative relationship for salt-affected soils (green).

Table 2. The upper right part (in red) indicates the correlation matrix for chemical soil properties in the total Big database and the lower left part (in green) indicates the subset of salt-affected soil types according to Table 1. (** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).). Correlation coefficients with opposite signs are shown with the same coloured box pairwise.

	pH (KCl)	SP_Ar	$CaCO_3$	SOM	TDS
pH (KCl)	1	-.042**	.564**	.214**	.032**
SP_Arany	-.049**	1	-.009**	.680**	.245**
$CaCO_3$ content	.467**	-.194**	1	.167	-.006*
Soil Organic Matter	-.111**	.341**	-.012	1	.153**
Total Dissolved Solutes	.146**	.493**	-.043*	.111**	1

Table 3. The descriptive statistics of the samples of the Small database

	TOTAL	SOIL	DATABASE	SALT	AFFECTED	SOIL TYPES
	N	Minimum	Maximum	N	Minimum	Maximum
pH_2.5 (H_2Ol)	15	7.95	10.5	8	9.75	10.5
Clay content (%)	15	20	38	8	20	38
SOM (%)	15	.24	2.65	8	.24	.68
EC_2.5 (dS/m)	15	.17	4.05	8	.86	4.05

There is no contradiction in Figure 1.C, but rather the two tendencies support each other. The reason is the acidifying effect of organic matter. In Figure 1.D increasing clayiness goes together with increasing SOM as is usual for non saline soils (red), but for salt-affected soils increasing clayiness means increasing adsorbed sodium and salinity (green), which would limit biological activity and consequently SOM.

Table 4. The upper right part (in red) indicates the correlation matrix of the total Small database of Transect 2. and the lower left part (in green) indicates the subset of salt-affected soil types according to Table 3. (** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).)

	pH_2.5 (H_2O)	Clay	SOM	EC_2.5
pH_2.5 (H_2O)	1	.695**	-.982**	.823**
Clay content	.245	1	-.641*	.729**
SOM	-.849**	-.293	1	-.771**
EC_2.5	.721*	.467	-.684	1

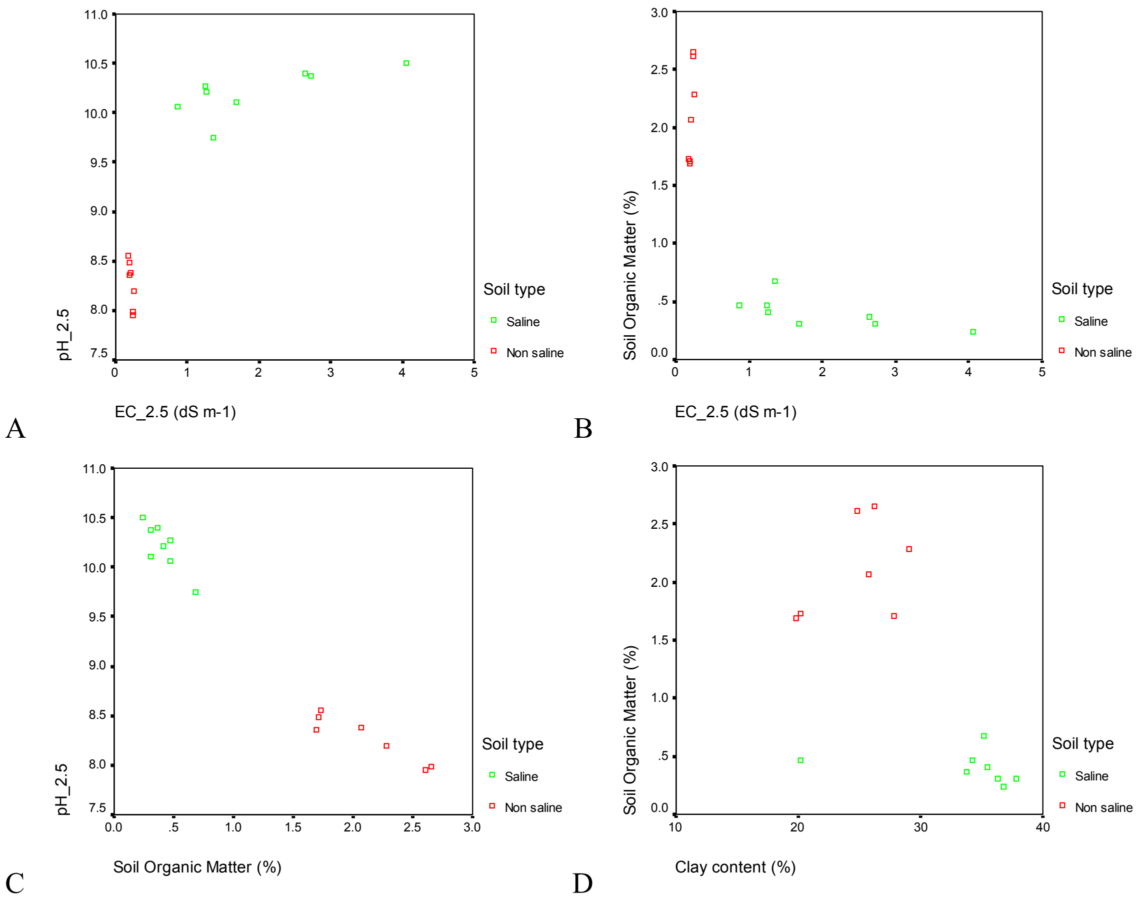

Figure 1. Scatterplots of soil chemical variables. A. soil salinity versus pH., B. soil salinity versus soil organic matter, C. soil organic matter versus pH, D. soil clay content versus soil organic matter. "Saline" indicates salt-affected soils, "Non saline" indicates supposedly Chernozems.

Conclusions

In small databases the contradictory tendencies of soil properties can be explained. But in large mixed soil and yield field-crop databases originating from varied landscapes and widely different soils, it is not easy to understand the relationship between soil properties and the yield.

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