Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

14. Gumpensteiner Lysimetertagung 2011, 195 – 198
ISBN: 978-3-902559-61-6

Spatial distribution of soluble salts in Southeast Bulgaria - Kermen soil monitoring site

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Abstract

Global climate changes are highlighted in recent decades, leading to intensification the processes of drought and desertification. Accumulation of soluble salts as a result from human activity and climate changes has a negative impact on soil fertility. The monitoring site in Kermen is built to observe the processes of soil salinisation in the area. Studied soils occupy non drainage lowering of the relief and they are formed on Pliocene carbonate material under the influence of meadow-grass and meadow vegetation in close, highly mineralized groundwater. There have been recognized Meadow Solonetz – Solonchaks and Meadow Vertisols, saline. Soil pH is basic and may reach pH > 9. Salt content range from 0.05 g/100g to 0.5 g/100g soil (dry residue). Sorption capacity is relatively high and varies from 30 to 60 mequ/100g soil. Quantities of exchangeable sodium are moderate to high and take 5 to 38% of sorption capacity. These data vary both in depth of soil profile, as well as by local seasonal weather conditions. Krigging maps of the spatial variability of studied soil parameters were elaborated for better understanding of parameters and relief relations.

Keywords: soil salinisation, monitoring site, spatial variability, krigging

Introduction

Priority of modern soil science and agriculture is the development of monitoring programs for soils and agricultural lands. The aim of such studies is to follow the parameters indicative for changes in quality and agrochemical status of soils. Based on these studies preventive measures to maintain soil fertility and reduce the environmental risks of processes of acidification, salinisation and etc. are established. In Bulgaria saline and alkaline soils occupy an area of over 36,000 ha, or over 1,2% of arable land and more than 2,5% of areas which could be irrigated. At present time the irrigated area is equal to the area of saline soils.

In 2003 Kermen is included in a national monitoring network to observe the levels of salinisation in Bulgaria, in a representative soil profile (Annual Reports of Executive Environment Agency, 2003-2006). Investigations are conducted twice per year, in spring and autumn, at three depths: 0-20 cm, 20-40 cm and 40-60 cm. Results from the analysis shows that the composition of soluble salts is predominated by sulphates of calcium and magnesium, typical for slightly saline leached Vertisols. For the period 2003 – 2006 the following tendencies are observed: increasing of pH values from 7.3 to 9; stable levels of ESP between 5% and 10% but strong fluctuation of water-soluble and exchangeable sodium and sorption capacity; high parameter values during spring measurements and low in the autumn, which indicates washing out processes.

These studies illustrate the need for updating the soil map for the distribution of saline soils in the area of the town Kermen. It is well seen that a single soil profile could be not representative for the changes of soil salinity in the area. Spatial variability of soil salinity parameters is a better and most reliable method of monitoring in such cases.

Area of investigation

Climate

Kermen is a town in Southern Bulgaria with geographical coordinates – latitude 42.50N and longitude 26.25E. The altitude of the land varies from 100 to 199 m and its lands are about 42 200 ha. According to the weather division of the country (1960) land of Kermen is located in the European continental area of the country, transcontinental sub-area and more accurately in the climatic regions of the Middle Eastern Bulgaria. The average annual temperature is 12°C, a minimum temperature is in January (0.2°C) and the maximum is in July (23.3°C). Annual average rainfall is about 541 mm. Clearly identifiable maximum between May and June is registered, while the minimum is observed in March. The dynamics of rainfall is between 29 and 66 mm per month (1979, 1983 and 1990).

Soils and geomorphology

The first detailed descriptions of the different soil types in the area of Kermen are given in Soil outlines (1960-1975), and subsequently included in the Atlas of Soils in Bulgaria (KOINOV et al. 1998). Described saline soils are classified as Meadow Solonetz – Solonchaks, sulphate-chloride (Mollic Solonchaks – FAO, 2006) and Meadow Vertisols, saline (Mollic Sodic Vertisols – FAO, 2006). According their textural class the soils are classified as – clay loam and clay. The first authors have noted visible salt crystallization on the soil surface. Later the water-soluble salts content is definite as significant and in the surface horizons reaches 4.8 mg/100g soil (dry residue). The predominant cation

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in the solution is sodium, and from the anions – chloride and sulfate. This determines the type of soil salinisation as chloride-sulphate or sulphate-chloride. Sorption capacity is high and relatively uniform in depth profiles – 40-60 mg/100g soil. Quantities of exchangeable sodium (ESP) are high and take 8 to 41% of sorption capacity. It was found that these soils have low to medium permeability, good to high water-holding ability and adverse air regime.

Geomorphological Kermen's soil occupies non-drainage relief lowering. They are formed on Pliocene carbonate material, under the influence of grass-meadow and meadow vegetation. Soil forming process has flowed at a high level of groundwater, which are also highly mineralized.

Monitoring grid set up

Our present work deals with soil samples, taken in a grid of 30 points regularly distributed at a depth of 0-30 cm soil layer. The aim is to establish the current saline/sodic state of the selected area and to study the spatial distribution of components of salinisation. Dynamics and quantity of the water-soluble compounds are determined using parameters pH, EC, SAR, RSC.

Soil sampling

Based on soil and climatic information about Kermen area, we have established a new monitoring grid with 30 sampling points at a depth of 0-30 cm. Soil sampling was taken in June 2009 and was done from every point and from four extra points, each one lying on two meters from the central and located in four main directions. Soil samples were air-dried, ground passed through a 2-mm sieve. The sieved samples were stored in paper bags and used for laboratory analyses.

Laboratory analyses

Soil pH was measured in water and in 1M KCl using 1:2.5 soil : liquid ratio. Electrical conductivity, water-soluble bases (Na, Ca and Mg) and anions (Cl, SO_4, HCO_3) were determined in 1:5 soil : water extraction. Flame photometer determination for sodium and atom adsorption determination for calcium and magnesium were used. The water soluble anions (carbonate, bicarbonate, chloride) were analyzed by titration and the sulfate were determined by classical weighting analysis (PENKOV 1991). Total dissolved solids (salts in %) were obtained multiplying the results for electrical conductivity in mS/cm^{-1} by factor 0.32 (POPANDOVA 1995). Sodium adsorption ratio (SAR) was calculated by dividing the concentration of monovalent Na^+ by the square root of the concentration of divalent calcium and magnesium (in mequ/100g). Residual soil carbonate (RSC) was calculated by subtracting the sum of carbonates and bicarbonates from the sum of calcium and magnesium (in mequ/100g).

Results and Discussion

Results obtained from physical-chemical analyses are treated in statistical software Statgraphics Centurion XVI and presented in *Tables 1* and *Tables 2*. Almost all parameters show wide range of variation (*Table 1*). Only for pH the variation is low but from strongly acid to strongly alkaline, mostly in the alkaline range (pH > 7).

Electrical conductivity and salts show levels from non saline to moderate saline, but in general the content is low. The sodicity (ESP) also varies extensive, matching to different stages of sodium saturation from non sodic to extreme sodic (PENKOV 1991). Sodium adsorption ratio characterizes the sodium status of soil solution and indicates potential risk from sodicity (SAR > 13) not only in the samples with ESP > 5, but also in samples with ESP < 5. These two sodicity parameters are related because of cation exchange and in our case give better understanding of complex salinisation process (saline-sodic). High concentrations of sodium in a soil create a state of easy dispersion, leading to poor soil physical conditions (RENGASAMY and OLSSON 1993), while the soluble salts keep the soil colloids in coagulated state.

Table 1: **Summary statistics of all investigated parameters**

	pH in KCl	pH in H2O	EC in mS/cm	salts in g/100g	Water-soluble cations and anions in mequ/100g soil						ESP	SAR	RSC
					Na	Ca	Mg	SO_4	HCO_3	Cl			
Count	30	30	30	30	30	30	30	26	26	26	30	30	30
Mean	6,46	7,21	0,302	0,10	1,42	0,10	0,03	0,168	0,733	0,087	7,14	8,15	0,51
Standard deviation	0,99	0,97	0,332	0,11	1,81	0,18	0,02	0,167	0,435	0,117	10,61	9,99	0,51
Coeff. of variation, %	15,28	13,44	109,90	109,95	127,41	171,47	47,32	99,14	59,45	134,12	148,72	122,63	99,70
Minimum	3,90	4,80	0,033	0,01	0,06	0,00	0,01	0,000	0,058	0,000	0,46	0,27	-0,32
Maximum	8,20	9,30	1,541	0,49	7,10	0,70	0,07	0,664	1,798	0,592	38,46	37,86	1,71
Stnd. skewness	**-2,30**	-0,98	**5,432**	**5,31**	**4,16**	**5,01**	0,66	**3,277**	1,224	**7,496**	**5,05**	**3,73**	1,38
Stnd. kurtosis	0,80	0,83	**7,056**	**6,67**	**3,16**	**4,91**	-1,27	**2,283**	0,181	**15,132**	**4,62**	**2,51**	-0,15

Table 2: **Correlations between all investigated parameters**

Parameters													
pH in KCl		pH in KCl											
pH in H_2O		**0,96**	pH in H_2O										
salts in g/100g		0,63	**0,74**	salts									
Water-soluble	Na	0,57	**0,72**	**0,96**	Na								
cations	Ca	0,24	0,10	-0,08	-0,27	Ca							
and	Mg	0,30	0,34	0,37	0,32	0,27	Mg						
anions	SO_4	-0,17	-0,14	0,52	0,41	0,08	0,06	SO_4					
in mequ/100g	HCO_3	0,67	**0,72**	0,53	**0,70**	-0,14	0,10	-0,19	HCO_3				
soil	Cl	0,20	0,25	0,66	0,58	-0,14	-0,14	0,63	0,07	Cl			
ESP		0,49	0,64	**0,91**	**0,94**	-0,26	0,40	0,24	0,62	0,21	ESP		
SAR		0,52	0,66	**0,91**	**0,98**	-0,35	0,22	0,29	0,65	0,43	**0,89**	SAR	
RSC		0,43	0,52	0,36	**0,71**	-0,51	-0,09	-0,20	**0,92**	0,12	0,69	**0,73**	RSC

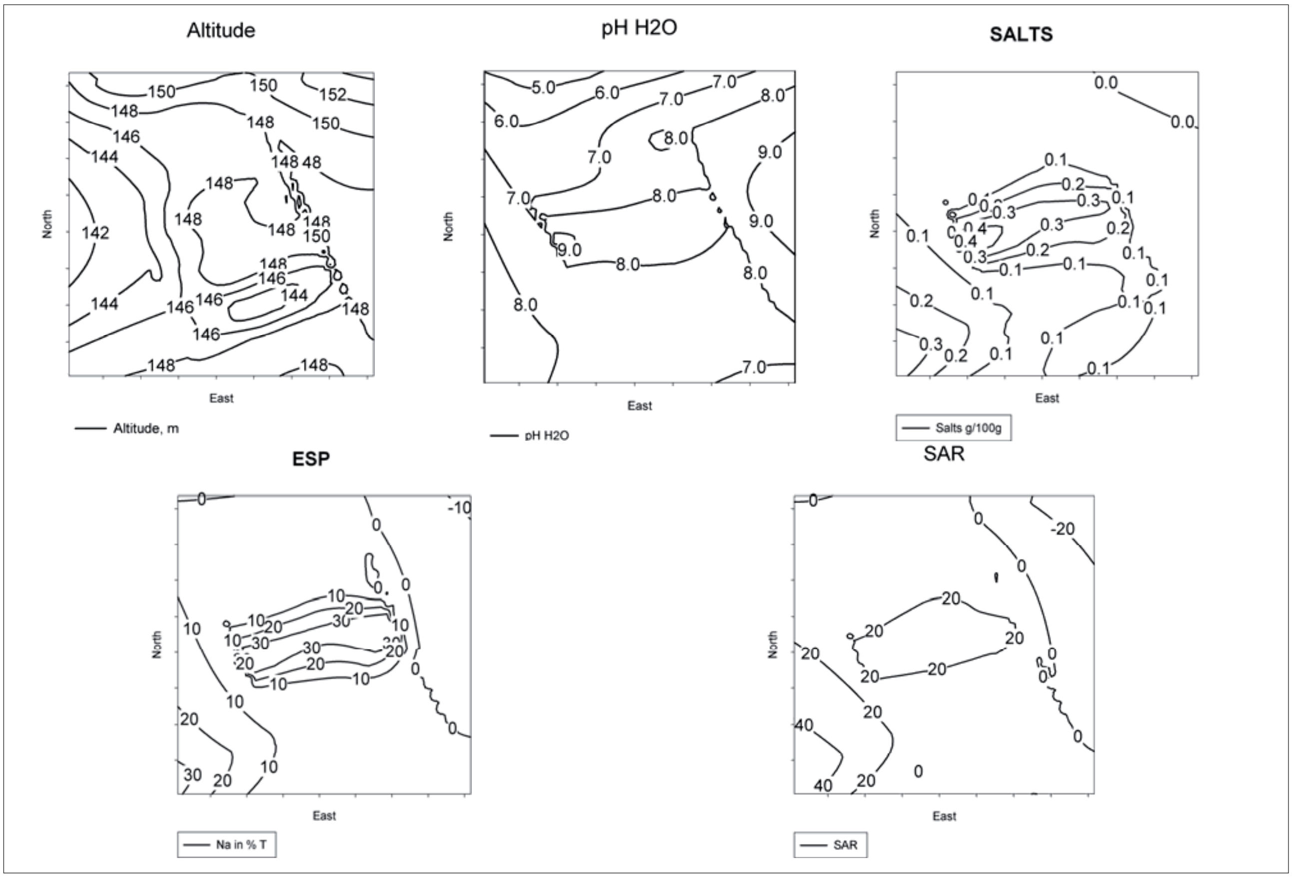

Figure 1: **Cartograms with the spatial variation of the studied parameters**

Residual sodium carbonate (RSC) is used to predict the tendency of calcium carbonate to precipitate from high-bicarbonate waters or soil solutions and thus create a sodium hazard. RSC in studied soils is very low (less then 1.25) even negative, showing no tendency of $CaCO_3$ precipitation, which correspond also to the lack of carbonates at determined pH levels. RSC-values should be consider as incorrect, for the amount of bicarbonate that precipitates depends on the degree to which salts are concentrated by evapotranspiration in the plant root zone (BOHN et al. 2001).

Combining statistical data for the anions the type of salinisation is determined as sulfate-sodic and sodic-sulfate, partly chloride-sulfate. For four of the samples anions were not gained because of the extremely high content of ESP (more then 30%) causing dispersion of clay minerals and organic matter and impossibility to gain proper soil-water extracts for anion's analysis.

There is more than a 3:1 ratio between the smallest standard deviation and the largest. Since the P-value is less than 0,05, there is a statistically significant difference amongst the standard deviations at the 95,0% confidence level. The standardized skewness and/or kurtosis is outside the range of -2 to +2 for 9 columns. This indicates some significant non normality in the data, which violates the assumption that the data come from normal distributions. All data suggest that salinisation is with uneven character and appear in the area as spots and its spatial variation is subject to other external factors different than the factors of soil formation in the region. The underground water depth is one of the factors affecting mainly the salinization processes in soil genesis.

With great significance are the correlations between water-soluble sodium and the parameters salts, ESP, SAR and RSC– basic parameters of soil salinisation (*Table 2*).

Using geo-statistical processing for the gained information, a series of cartograms with the spatial variation of the studied parameters were obtained (*Figure 1*). The comparison with the relief map is showing that salinisation is related with lowest part of the relief and underground water. Close correlation between Na and HCO_3 shows the sodic type of salinisation.

It can be seen graphically the strong correlation between topography and factors associated with salinisation – soil reaction, salts, ESP and SAR.

Conclusions

Studied soil samples from Kermen area are mostly alkaline but only in a few of them are indications for processes of salinity. It is due to the spotty character of salinisation. In the points with moderate salt content values of ESP and SAR are high, showing sodium risks for the plant and soil structure. The character of salinisation process is mixed between sulfate-sodic, sodic-sulfate and chloride-sulfate, saline-sodic. All data vary in wide ranges and suggest that salinisation is with uneven character and its spatial variation is subject to other external factors other than the factors of soil formation in the region. The gained results differ slightly from other former researches. The strong correlation between topography and factors associated with salinisation is confirmed graphically. It is necessary to reactivate existing drainage system and to stop the salinisation in the area. After that melioration of the affected soils will be reasonable.

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