Soil salinity in Veneto plain.

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Introduction

Soil salinization is one of the threats of soil degradation listed in the Soil Thematic Strategyof the European Union (COM231/2006). In the recent proposal of Framework Directive of the European Commission (COM232/2006) salinization is one of threats that must be identified in specific risk areas.

Along Veneto coastal and lagoon inland area soil salinity is an incoming problem: these areas are mainly devoted to highly profitable agriculture and horticulture.

Salinity is due to inherited characteristics of soils, to salinity intrusion increasing induced by intense use of groundwater resources and to brackish water use for irrigation.

Temperature increasing of last decades due to climate change enhanced the risk of crops damage due to soil salinity effects as availability of water is reducing.

Aim of this work is to verify soil salinity level in Veneto plain and describe the relationship between salinity and soil characteristics, to assess the spatial distribution pattern of soil salinity and mapping the probability to exceed reference thresholds using a geostatistical approach.

Study area

The study area is located in Northeast Italy and is a 25 km large strip of plain along northern Adriatic sea, plus a larger area toward the inland, where salinity may be a problem because of the presence of ancient coastal areas probably with residual salinity. This part of Veneto region is characterized by a temperate-suboceanic climate, with a minimum and a maximum average annual temperature from 8.1°C to 18.1°C respectively and a mean annual precipitation ranging from 1060 in the north to 660 mm in the south part.

The area was already investigated with soil survey at different scales 1:50,000 in the Province of Venice and 1:250,000 scale of the Veneto region soil map. In the present study the second map was used; it is based on a hierarchical soil landscape model and identifies 3 soil subregions L2, distinguished by landscape, particle size of the river catchments (for example gravelly and low plains) and the age of the parent material (for example Holocenic and Pleistocenic deposits), 11 great soilscapes L3 distinguished on the basis of soil and terrain morphology relationships (for example fluvial ridges, undifferentiated alluvial plain and alluvial plain depressions) and particle size (sand, silt and clay), and 42 soilscapes L4, based on the main river catchments (Tagliamento, Piave, Brenta, Adige and Po, from north to south).

Material and methods

To verify soil salinity level 480 soil profiles, described within ordinary soil survey, were selected; electrical conductivity (EC1:2) was measured in samples collected at three different depths (topsoil at 0-50cm, subsoil at 50-100cm and substrate at 100-150cm).

For each sample were also measured soil texture (three fractions, USDA), pH, CEC, Organic Carbon and total CaCO3.

Every soil profile was classified with World Reference Base (FAO 2006) and Soil Taxonomy USDA (Soil Survey Staff, 2006) and refered to a soil typological unit (STU) already described in the Veneto region soil map.

Results and discussion
Data analysis showed that electrical conductivity (EC1:2) was higher in subsoil and substrate, compared to topsoil. The mean values grouping data by sampling layers were significantly different at $p<0.05$ (Tukey-Kramer unequal N HSD test).
Quite strong and statistically significant correlations were detected, especially in the substrate (>100 cm) between EC1:2 and organic carbon ($r=0.72$) and pH ($r=-0.67$); in the topsoil the correlations were more weak, respectively $r=0.35$ and $r=-0.3$. The correlations exhibited with other soil properties such as clay content, sand content, and total carbonates were very weak ($r<0.18$), with the exception of CEC which exhibits a moderately strong correlation ($r=0.44$).
The highest EC values were found in soils of reclaimed marshes of Adige and Po plains. They were formed in morphologically depressed areas, behind ancient dunes, from silty or clayey sediments and from peat. These soils have high salinity, being formed in ancient coastal areas covered by brackish water, and high acidity, due to oxidation of sulfidic material in the organic horizons, as reclaiming exposed them to aerobic conditions. Grouping data by kind of horizons, organic and not organic, the first one had higher electrical conductivity values.

Grouping data by soil map units, at the great soilscape level (L3) the highest EC values occurred in units of soils (phaeozems and histosols) of depressed areas formed from silty or clayey sediments and from peat (BR6) and in reclaimed lagoon inland, artificially drained, formed from silty sediments (CL2). At the soilscape level (L4) and at soil typological unit level (STU) data were too scattered for showing significant differences in the mean values. For this reason data were grouped using an aggregation of soil typological units, called functional groups. By first STU were grouped in 5 great groups, in term of great soilscapes, with mean values significantly different at $p<0.05$; then each great group was divided in smaller groups with low or high level of organic carbon: groups with higher carbon content had the highest mean EC value.

In order to assess and map the risk of soil salinization a geostatistical simulation approach was followed.
The risk of salinization is expressed in terms probability to exceed threshold values.
Risk assessment is based on the estimation of the conditional cdf (cumulative density function): in this case at each node of the estimation grid the outcome is not a single value with minimum variance but a statistical distribution of possible outcomes with its own moments.
Assessing uncertainty, i.e. the definition of confidence intervals about the estimated values, requires a data transformation in order to adopt a model for the local or global probability distribution, i.e. we have to identify a *model of uncertainty about the unknown.*
In this case a parametric model (multigaussian) was adopted and required a normal score transformation of the data.
In order to integrate the spatial trend in soil salinity, based on the soil map and on the definition of soil functional groups, the residual values were calculated subtracting from each data point the mean value of the soil mapping unit weighted by the functional group percentage (SMU/SFG) if falls within.

The secondary information available at all unsampled locations derived from the soil map was then used to characterize the spatial trend of soil salinity, replacing the global mean with known varying local means, through the following steps:
1) available data were grouped in terms of MU (functional groups) and for each variable the conditional mean is computed;
2) the MU conditional mean is subtracted from each observation to compute the residuals of each variable;
3) The residuals were normalized with a normal score transform
4) experimental variography of the normalized residuals was carried out; computing the residual semivariograms for the two depths;
5) using the semivariogram models of the normalized residuals, residuals were simulated N times (with N = 100) at the node of a regular grid (1 km mesh size) and back transformed;
6) the corresponding MU mean is added to the residuals values to get EC1:2 at each node of the 1 km regular grid.

The omnidirectional standardized variograms of the normalized residuals (lag 1500 m) were calculated and modelled for the two reference depth.
For both depths a nested double spherical model provided the best fit.
The uncorrelated spatial variance (nugget effect) is quite low at both depths, accounting for 25 and 18% of the semivariance at 0-50 cm and >100 cm depth respectively.
Both models have a short range structure (2530 m and 2730 m at 0-50 cm and >100 cm depth respectively) which accounts for most of the observed semivariance (47 and 63% at 0-50 cm and >100 cm depth respectively) and a long range structure (11730 m and 8190 m at 0-50 cm and >100 cm depth respectively).

The omnidirectional variogram models were then used to infer the ccdfs (N = 100) at the node of a 1000 x 1000 m grid for a total of 4903 estimation nodes with a simple kriging.
In the figure ** the median value of the topsoil is represented with its standard deviation: only a small area, where histosols are dominant, has a mean EC1:2 value of 1.38 dS/m, the rest of the surface has values <0.4 dS/m. In the substrate (fig.***) the same area has a mean value of 5.8 dS/m and there are same areas with phaeozems that show EC values of about 2 dS/m.
The model allows to calculate the probability of exceed a fixed threshould of critical values: 1 and 2 dS/m are chosen because they are used respectively to define soil as moderately saline or saline.
For the topsoil, only 1.26% of the area have a probability >50% to exceed the 1 mS/cm threshold; this figure drops to less than 0.2% for the 2 mS/cm threshold.
In the case of the substrate though, the results show a quite different picture: about the 25% of the area have a probability >50% to exceed the 1 mS/cm threshold, and about 6% of the area have a probability >50% to exceed the 2 mS/cm threshold.

Conclusions
Soil salinity in Veneto region doesn't represent a problem in the surface horizons, except in some particularly and limited areas with organic soils.
Soil salinity in deep horizons is frequently higher, although not interesting a high percentage of total surface. In these areas is very important to intervene in order to avoid a worsening of salinity phenomena.
These maps will be usefull to identify the soil salinity risk where appropriate measures and monitoring will have to be assess in order to prevent soil degradation.

Mapping the probability of exceeding salinity thresholds may help to localize sampling sites in a monitoring program. In these areas also data about land use, agricultural management, river and groundwater salinity must be collected.
Areas with a high uncertainly level could be investigated only if they have an high probability to exceed critical threshold.