EQA *– Environmental quality / Qualité de l'Environnement / Qualità ambientale, 17 (2015) 25-33*

SOIL QUALITY IMPLICATION IN A RECENTLY RECLAIMED SALTY AGRICULTURAL SITE IN ITALY

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Abstract

The paper show a preliminary study on biological parameters of salty recently reclaimed soils in Italy (Valle di Mezzano, Comacchio and Ostellato – Ferrara). The soils were characterized and classified. Biological parameters were measured and calculated: Basal Respiration Carbon (Cbas) (mg C-CO2/kg soil); Cumulative Respiration Carbon (Ccum) (mg C-CO_2/kg soil); Microbial Carbon (Cmic) (mg C/kg soil); Metabolic Quotient (qCO_2) ((10^{-2}) h^{-1}); Mineralization Quotient (qM) (%). The combination of these biological parameters was used to create an index of soil fertility (Benedetti and Mocali 2008) and the same index is on the way of being evaluated for these soils as well. The objectives of the work are: (a) give insights on the dynamics of the salinization processes, (b) better understand biogeochemical cycles of soils affected by high electrical conductivity and fertility loss, and (c) propose land management strategies.

Keywords: *salinity, Mezzano valley, Comacchio, soil quality, reclaimed soil*

Introduction

The need of adaptation to climate changes is a necessity to face for all living being. Many international organizations, such as FAO (2007), underline this necessity since many years, even publishing suggestion on adaption strategies, both for single persons and policy makers. Future food availability is one the main concern connected to the variability of climate, thus, while addressing environmental problems, policy makers must consider effective management options that are cost-effective even form farmers and land managers (Pannell and Ewing, 2005).
Bad practices must be pointed out and land management must be carefully planned in order to avoid population collapses that happened in past (de Menocal, 2001). For instance, the Ancient Mesopotamia was famous for its important agricultural productivity, but the lands were gradually abandoned because of the salt accumulation in soils. The populations were unable to face the situation triggered by themselves and were constrained to move over the centuries from the lower to the central to the upper parts of the Tigris-Euphrates valley (Hillel, 2005).
Soil salinity is still an issue for modern societies and represents one of the main problems in soils under intensive agriculture practices. It inhibits plant growth by an

DOI: 10.6092/issn.2281-4485/6006

osmotic effect, which reduces the ability of plants to take up water; other side-effects are ion excess and nutritional imbalances in plants (Rengasamy, 2010).
According to the European Commission, salinization affects vast areas in European Union and Candidate Countries, most of which are located in the Mediterranean basin (European Commission, 2003). The origin and persistence of soil salinity have always to be related to local climate and soils characteristics (Qadir et al., 2014). Lately, the use of different biological parameters for the interpretation salty soils status spread through the scientific community, although often giving inconsistent and divergent results (Rousk et al., 2011; Setia et al., 2011; Asghar et al., 2012; Mavi et al., 2012; Elmajdoub et al., 2015).
Benedetti and Mocali (2008) proposed an index of soil fertility based on biological parameters, with the aim of improving statistics, better evaluate application strategies and devise future actions (European Commission, 2003). This index has never been tested for soils with salinity problems. Hence, in this work preliminary data of the index are presented; we applied it for a specific area of Italy with salinity problems where, according to production data and private communication of land managers, the yield is decreasing with time. The aim is to uncover the reasons of the yield losses mainly investigating biological parameters and set future strategies for these agricultural lands.

Material and Methods

Study Area

The study site is the lowland Mezzano Valley, located in the southern section of Padana Plain (Fig.1) where migrating branches of Po River and human actions defined the actual settings of the landscape (Bianchini et al 2002; Simeoni and Corbau, 2009; Di Giuseppe et al., 2014). The lowland have been recently reclaimed and is located and very low altitudes near the Adriatic Sea coasts, where the expected sea-level rise is up to 0,36m before 2100 (Antonioli and Leoni, 2001). The valley is part of Nature 2000 (IT4060008 - ZPS - Valle del Mezzano) and it is partially included in the Regional Park of Po Delta. The average rainfall is 700mm per years, concentrated in about 80 days and the average temperature is 13-14°C, with humidity level constantly high (av. 77%).
The reclamation of the wetland started in 1957 and it was completed in 1974 using dewatering pumps, which are nowadays working to keep the fields dry from the groundwater of the freatic aquifer, thus, suitable for agricultural purposes. The groundwater level is by the way still high resulting often in waterlogging (Boschi and Spallacci, 1974; Di Giuseppe, 2014).

Physiographic outlines and sampling strategies

The valley presents high organic matter content (SOM>20% in most of the area) with buried peat levels (mainly Phragmites) confined at the central part of the lowland because of the waves actions that prevented the formation of these plants at the edges of the valley (Boschi and Spallacci, 1974).

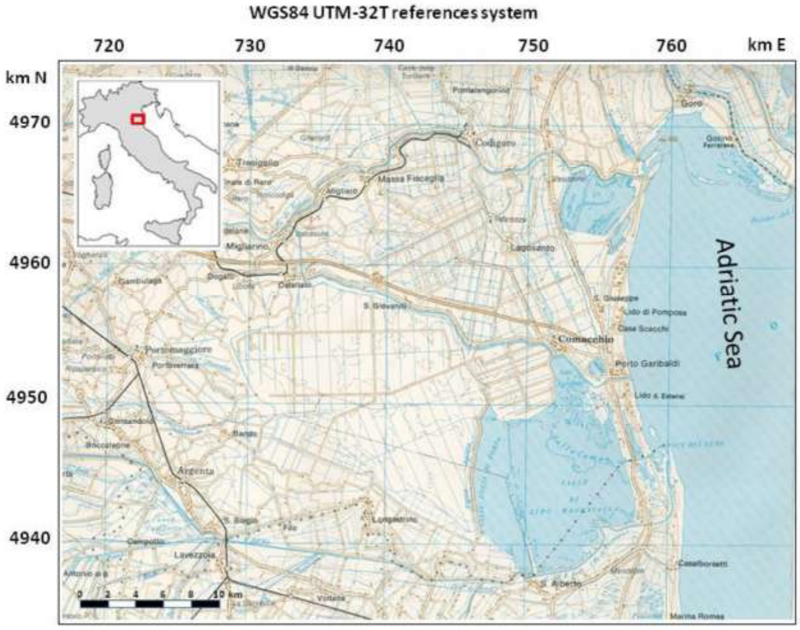

Figure 1
Study-site location

Buried peat sporadically gives birth to self-combustion phenomena (Cremonini, 2008). The high content of organic matter is the cause of low pH which, nevertheless, may be buffered by the widespread presence of bivalve shells (Boschi and Spallacci, 1974). The sediments mixed with the organic material change in relation to the sedimentary facies that were at the bottom of the swamp during soils formation. The Eastern section shows sandy material of paleo-dunes, while the rest consists of alluvial material, sand, clay and silt unevenly distributed.
The salinity inherited by the former wetland brackish water was at the highest in 1967 and it gradually decreased thanks to rainwater (Boschi and Spallacci, 1974). Moreover, the surficial salty aquifer water contributes to salts budget of the area (Di Giuseppe, 2014).
The soil samples were collected during two campaigns in 2014 and 2015. The first (11 profiles), in spring 2014, had the aim of comparing the data with historical ones. The sample-sites were identified through geological and geomorphological maps of the area (geologic maps of Comacchio and Porto Maggiore, 1:50,000, Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna). The second one (10 profiles), during summer 2015, was a site-specific campaign on fields cultivated with tomatoes (cultivar HEINZ 1015). The aim was to provide biological parameters focused on a peculiar crop of the area.
For each sampling point a trench was opened till the buried peat level, in order to read soil profiles. An Edelman auger (Eijkelkamp) was used to collect deeper layers. Each sampling point was geo-referenced with a Global Positioning System (GPS).

DOI: 10.6092/issn.2281-4485/6006

Analytical methods

Samples were air-dried and sieved at 2mm. Soil pH was determined in a 1:2,5 soil:water suspension (pHmeter, Crison) and afterward filtered whit Whatmann 42 for EC measurement (EC; conducimeter Orion). CEC was determined after exchange with hexaamminecobalt(III) chloride according to Orsini and Remy 1976. The sodium adsorption ratio (SAR) was calculated as follow:

$$\text{SAR (meq)}: \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{++}]+[Mg^{++}]}{2}}}$$

Total carbonates ($CaCO_3$) were quantified by volumetric method, according to Loeppert and Suarez (1996). Total organic carbon (OC) was measured by Dumas combustion with EA 1110 Thermo Fisher CHN elemental analyser. Soil basal respiration was measured on 25 g samples adjusted at 60% of WHC, incubated at 25°C for 28 days. The CO_2 emission was measured after 8,9,10,11,14,16,18,21,28 days from the beginning of the incubation using an automated multichannel infrared gas analyser (Brüel and Kjaer Multi-Gas monitor Type 1302, Innova Air Tech Instruments A/S, Ballerup, Denmark). Microbial biomass C and N were determined on the same incubated soils, at the end of the incubation period by the method of Vance et al. (1987) based on the difference between C extracted with 0.5 M K2SO4 (1-to-4 soil-to-extractant ratio for 40min shaking) from chloroform fumigated and unfumigated soil samples, using a Kc value of 0.45.
Biological Fertility Index was calculated using the following parameters (Benedetti and Mocali, 2008):
Total Organic Carbon (TOC) (%)
Organic Matter (OM) (%)
Microbial Carbon (Cmic) (mg C/kg soil)
Basal Respiration Carbon (C_{bas}) (mg C-CO_2/kg soil),
Cumulative Respiration Carbon (C_{cum}) derived from C_t:C_{cum} ($1\text{-}e^{-kt}$) (mg C-CO_2/kg soil) – with *t* as incubation time, *k* is the kinetic respiration constant and C_t is CO_2 released during the incubation time
Metabolic Quotient (qCO_2) ((10^{-2}) h^{-1}) calculated as qCO_2: $\frac{Cbas/Cmic}{24}\ x\ 100$

Mineralization Quotient (qM) (%) calculated as qM: $\frac{Ccum}{TOC\ x\ 100}$

Results

The soil characterization describes two distinct situations in the valley. Along the northern borders (6 soil profiles), at the highest topographic parts: relatively lower ECe, higher pH and $CaCO_3$ (%) and lower Corg content compared to the rest of the study area. The ECe gradually increases with depth and organic carbon content (max content ca. 3%) decreases with depth. According to the Keys to Soil Taxonomy (2014) were classified as *Mesic Loamy Aquic Haplustept*.

Table 1. *Scores assigned to each parameter range*

Parameters		Unit	Score				
			1	2	3	4	5
Organic Matters	OM	%	<1	1-1,5	1,5-2	2-3	>3
Basal Respiration	C_{bas}	mg C-CO_2/kg	<5	5-10	10-15	15-20	>20
Cumulative Respiration	C_{cum}	mg C-CO_2/kg	<100	100-250	250-400	400-600	>600
Microbial Carbon	C_{mic}	mg C/kg	<100	100-200	200-300	300-400	>400
Metabolic Quotient	qCO_2	10^{-2} h^{-1}	>0.4	0.4-0.3	0.3-0.2	0.2-0.1	<0.1
Mineralization Quotient	qM	%	<1	1-2	2-3	3-4	>4

Fertility Class	*I*	*II*	*II*	*IV*	*V*
IBF score	Tiredness Alarm 0 – 6	Stress Pre-alarm 6 – 12	Medium 12 – 18	Good 18 – 24	High 24 - 30

Table 2 *Class scale in relation to the IBF score.*

The rest of the valley (15 profiles) consists typically of relatively higher ECe, lower pH; CaCO3 content is extremely low or null, very high Corg contents and with presence of buried peat levels. Generally, the ECe gradually increases with depth and often the water table is less than 1 meter below the surface. Corg gradually decreases with depth (range: 9 to 30%). According to the Keys to Soil Taxonomy (2014) were classified as Typic Haplohemist.

Two representative soil profiles were chosen to show the results. In Figure 2 the graph showed the average values of the two characteristic soils. The SAR is not shown due to very low value

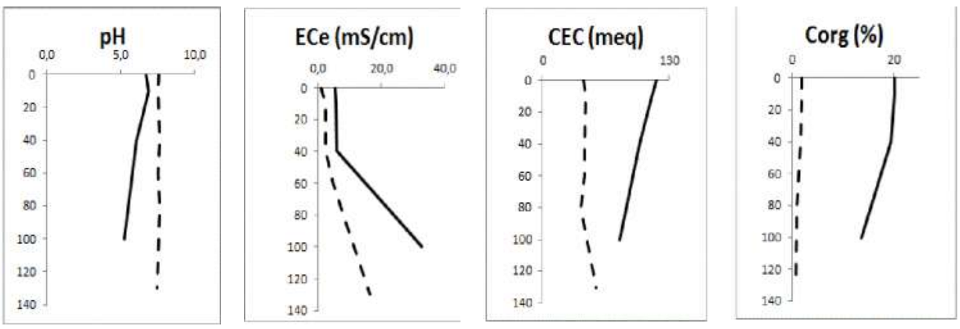

Figure 2. *Graph describing variation with depth of the two soil types average characteristics; solid line refer to Typic Haplohemist, dashed lines refer to Mesic Loamy Aquic Haplustepts.*

Two representative soil profiles were chosen to show the results of basal respiration

DOI: 10.6092/issn.2281-4485/6006

and microbial C. For each profile, the cumulative C_CO_2 of the two most surficial layers (0-10 cm and 10-40 cm; these represent the cultivated layers) and the bottom-most one (about 100 cm) are shown in Figure3.

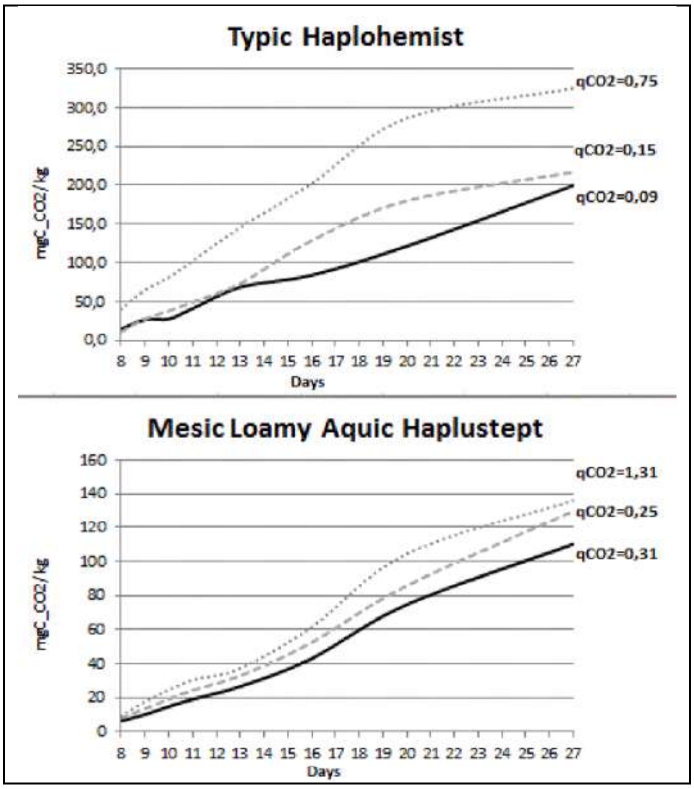

Figure 3
C_CO_2 cumulative data and relative metabolic quotient. Solid lines refer to the most superficial layer; dotted lines refer to the deep layer and dashed lines to the 10-40cm layer.

Peaty soils have clearly higher respiration rates because of the high content of organic matter. The top-most layers of both soils have the lower respiration rate. The respiration rates for the Haplustept are similar for the three layers, while for the Haplohemist the bottom-most layer has respiration rates much higher compared to the cultivated layers.
Metabolic quotient is at its maximum for deep beds. The cultivated layers show low qCO_2, which is always lower in the organic soils.
Considering the environmental condition of the area, it is not possible to exclude that the microbial population comprehends anoxic competitors, which do not contribute to CO_2 build up, but contribute to the microbial total biomass. In fact, the lower metabolic quotients for the Typic Haplohemists can be related to that. Moreover, the reason of the high qCO_2 of the bottom-most layers, it has to be found in the ready oxygen availability, which stimulates organisms that are usually in anoxic condition.
The index score for the Typic Haplohemist horizons ranges between 15 and 22, which corresponds to medium and good health status, while for the Mesic Loamy

Aquic Haplustept ranges from 11 (the deep layer) to 15, thus, the deep layer is in stress pre-alarm staus while the superficial have medium health status.

Conclusion

According to the preliminary data, it seems that the organic soils are healthier, so one may suppose that salinity level do not influence biological parameters in this case, but more data need to be processed to have consistent results. Nevertheless, salinity is not a static parameter and the soluble ions interact in many ways with soil. Investigation on soluble compounds is also important because OM decomposition rate is to be related to the terminal electron acceptors present in the soil solution, which may inhibit or stimulate microbial activity (Brouns et al., 2008).
Reclamation of submerged lands leads to a considerable alteration of vegetation cover, and thus of edaphic characteristics of soils. It exposes organic matter to oxidation and low-rate input of stable organic substrate (Santin et al., 2009). In order to set future strategies for these lands, the next step is to deepen the knowledge on the OM cycle, which in comparison with historical data may give clues on the variation in time of the organic matter compounds health status (De Nobili et al., 2008; Vittori Antisari et al., 2010; Agnelli et al., 2014).

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DOI: 10.6092/issn.2281-4485/6006

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QUALITÀ DEL SUOLO IN UN'AREA AGRICOLA DI RECENTE BONIFICA IN ITALIA

Riassunto

L'articolo mostra uno studio preliminare sui parametri biologici in un'area di recente bonifica con problemi di salinità in Italia (Valle di Mezzano, Comacchio e Ostellato). I suoli sono stati caratterizzati e classificati. I parametri biologici misurati e calcolati sono: Respirazione Basale (Cbas) (mg C-CO2/kg suolo); Respirazione Cumulativa (Ccum) (mg C-CO2/kg suolo); Carbonio Microbico (Cmic) (mg C/kg suolo); Quoziente Metabolico (qCO2) ((10-2) h^{-1}); Quoziente di Mineralizzazione (qM) (%). Benedetti e Mocali (2008) propongono un indice di fertilità del suolo basato sulla combinazione di questi parametri ed in questo lavoro è stato testato per la prima volta su suoli salini. Gli obiettivi del lavoro sono: (a) ampliare le conoscenze sui processi di salinizzazione, (b) comprendere meglio i processi biogeochimici che avvengono i suoli caratterizzati da alta conducibilità e perdita di fertilità, (c) proporre strategie di gestione territoriale.

Parole chiave: *salinità, valle del Mezzano, Comacchio, qualità del suolo, suoli bonificati*

DOI: 10.6092/issn.2281-4485/6006