***Alma Mater Studiorum – Università di Bologna***

**DOTTORATO DI RICERCA IN**

Scienze e tecnologie agrarie, ambientali e alimentari

Ciclo 29°

**Settore Concorsuale di afferenza:** 07/E1 Chimica agraria, genetica agraria e pedologia

**Settore Scientifico disciplinare: Agr/14 Pedologia**

# Soil Bio-indicators in different pedoclimatic regions of the Padana Plain (Northeast Italy)

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*Esame finale anno 2017*

# Introduction

It is true that climate changed, is changing and will continue to change along together with environmental reshaping and it was brightly evident from many kinds of records, like geological, paleontological, archaeological etc. Notwithstanding, it is complicated to depict future scenarios and the only way to improve land management is to watch at past and monitor the present (deMenocal, 2001). The mantra is “climate change adaptation” and it has been meant with a multidisciplinary optic by scientific community, including a variety of ecosystems, as well as agro-ecosystems (FAO, 2007). The ecosystems under agricultural management are clearly developed in different environmental settings and their soils historically managed as bare substrate for growing crops all over the globe. In fact, trying to compile a fertilization management plan, for example in Italy, biochemical indicators are never considered. Hence, if maintaining biodiversity and ecosystem services is crucial to ensuring sustainable livelihoods, questions come spontaneous: what about ecosystem then? Are we really trying to face changes or just carry on as much as exploitation as we can? Soils science community cannot certainly all be blamed, as during recent years involved big efforts in diffusion and exploitation of results on soil biochemistry and biodiversity and their importance for ecosystem resilience: for example, the establishment of the Global Soil Partnership (GSP) that “was established in December 2012 as a mechanism to develop a strong interactive partnership and enhanced collaboration and synergy of efforts between all stakeholders. From land users through to policy makers, one of the key objectives of the GSP is to improve the governance and promote sustainable management of soils” (www.fao.org). GSP then fostered the foundation of the European Soil Partnership with the aim “to bring together the various scattered networks and soil related activities into a common framework, open to all institutions and stakeholders willing to actively contribute to sustainable soil management in Europe” (www.fao.org). From the other side, policy makers must face also sites productivity (and probably are more interested in) and try to be supportive in the development of good practices in order to decrease greenhouse gasses emission, as for example in the project Climate changE-R

(LIFE12 ENV/IT/000404), or in the conversion of degraded lands into semi-natural ecosystems (e.g. +195000 Ha during the period 1976-2003 in Emilia-Romagna region, Italy). Nevertheless, the mantra is still “climate change adaptation” and the sea-level rise is the easiest perspective to include in the adaptive managements, so that coastal areas attracted most of attentions. However, in agricultural land management plans there is no difference whether lands are closed to sea, as reclaimed wetlands and smoothed paleo-dunes, or clayey alluvial deposits more than 100km from the seashores. Moreover, it is quite hard to believe that soil management of Italian agricultural system, which is the biggest producer of quality agro-alimentary products in UE (Istat, 2016), does not include biological and biochemically mediated processes that are so fundamental to terrestrial ecosystem functions. De facto, a database of soil biochemical indicators at regional scale that can allow to include them in land management plans is missing. Thus, the idea of this work was born in the framework of World needing for sustainability indicators, useful for reach ecological, social and economic efficiency and equity (EC, 2001), therefore, while trying to reduce greenhouse gasses emission, like restoring wetlands that are globally recognized as carbon stocks and pool of biodiversity, other strategic plans are in need. The work is divided in three parts: (1) identification of soil delineation and their geochemical characteristics in order to improve territorial maps resolution, (2) study on biochemical features and plan nutrition in three pedoclimatic regions in Emilia-Romagna (Italy) under intensive agricultural management and same crop conduction, (3) historical evolution and soil biochemistry implications in a reclaimed wetland.

# Pedological and geochemical characterization

The study area is located in the southern section of Padana plain, which consists of sedimentary deposits accumulated during the Quaternary evolution and transported by Alpine and Apennines rivers and reshaped by sea, wind and human activity (Stefani & Vincenzi, 2005; Simeoni & Corbau, 2009). The dynamicity of the area is represented by the variety of soils that developed as an interdigitated pattern through the area. It becomes clear watching at the soil map of the area in Fig.1.

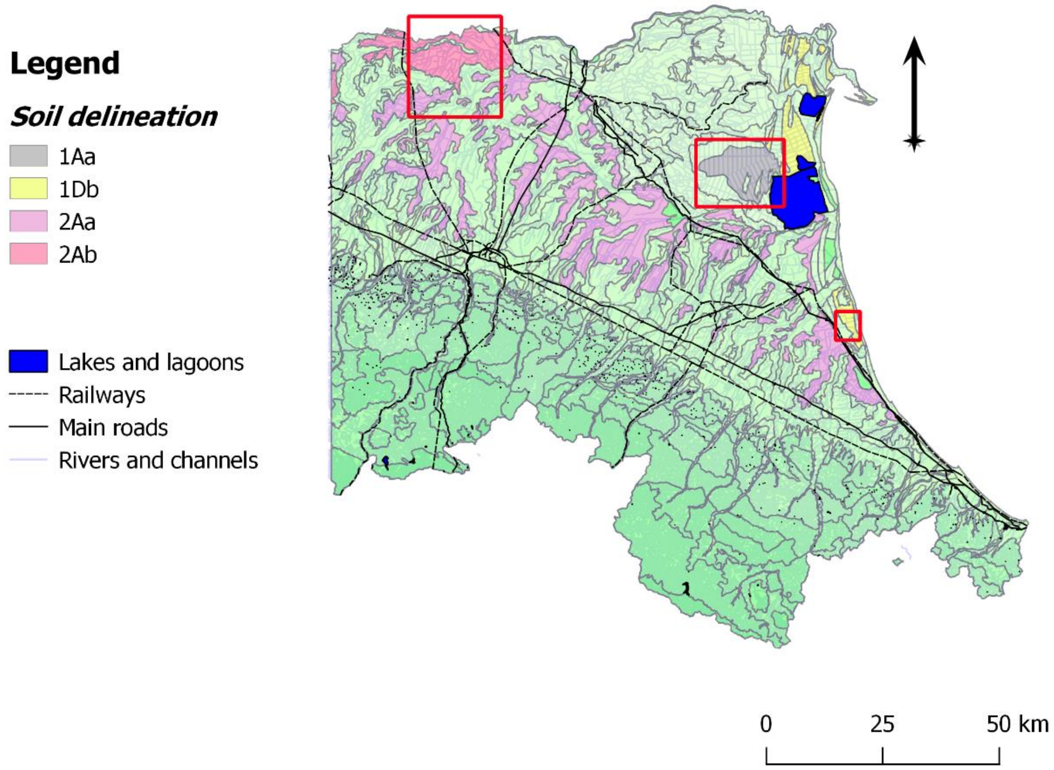



**Figure 1 - Extracted of the soil map of Emilia-Romagna Region 1:250.000. Only the soil occurring in the study areas have been highlighted (further explanation on soil types in the text), while all the other delineations follow a colour ramp from dark-green to light-green. Non-bold lines refer to soil delineations limits. Red squares refer to the study areas.**

The three distinct study areas were selected according to distinct pedoclimatic characteristics, including only those sites that were dedicated to the cultivation of tomatoes HEINZ 1015. The sampling point were superimposed on the soil delineations of Soil Survey of Emilia Romagna Regions (1:250.000) as shown in Fig.2.

The delineations identified by Soil Survey of Emilia-Romagna region represent groups of different soil types, some of which are dominant and others occur as localized spots.

**1Aa**:

The area consisted of a morphologic depression located among paleo-channel of Po river with low slope (0.01 to 0.03%). It was recently reclaimed from brackish water using dewatering pumps that are still in activity to keep lands dry for agricultural activities, mainly arable but soy and rice as well. Soils developed in these areas are deep peaty or thin textured with peaty horizons, with flawed oxygen availability, from slightly to strongly acid and salty.

- Dominant
    - Canale specchio, with humified material - loamy, mixed, euic, mesic Terric Sulfisaprists (Soil Taxonomy, 2014);
    - Jolanda, clayey and clayey silty - fine silty, mixed, acid, mesic level Sulfic Endoaquepts (Soil Taxonomy, 2014);
- Spots
    - Le Contane, clayey silty - Sulfic Endoaquepts fine, mixed, superactive, calcareous, mesic (Soil Taxonomy, 2014);
    - Valle Mezzano, with humified materials - Typic Sulfisaprists, euic, mesic (Soil Taxonomy, 2014);
    - Argine Agosta, with humified material - Terric Sulfisaprists loamy, mixed, euic, mesic (Soil Taxonomy, 2014).

**1Db**:

The delineation developed in paleo-dunes, which nowadays have been levelled and interdunal sects have been reclaimed from stagnant waters (slope 0.05 to 0.1%). They are mainly used as arable lands.

The soils of 1Db are typically deep, calcareous, from neutral to alkaline reaction, with moderate oxygen availability, thin-texture horizons are rarely found.

- Dominant
    - Boschetto, loam - Pachic Haplustolls loamy over sandy, mixed, mesic (Soil Taxonomy, 2014);
    - Cerba, fine sands and loam - Aquic Ustipsamments mixed, mesic (Soil Taxonomy, 2014).
- Spots
    - Marcabò, silty loam - Aquic Haplustepts fine silty, mixed, superactive, mesic (Soil Taxonomy, 2014).
    - Savio, silty loam - Aquic Haplustepts loamy over sandy, mixed, active, mesic (Soil Taxonomy, 2014).

**2Aa**:

The area consisted of depression formerly occupied by swamp that were slowly reclaimed during centuries. Nowadays these lands are mainly arable with low slope (0.05 to 0.01%).

The soils are typically very deep, calcareous and moderately alkaline, with thin texture and swelling attitude. The availability of oxygen is moderate.

- Dominant
    - Risaia del Duca, clayey silty - Ustic Endoaquerts fine, mixed, mesic (Soil Taxonomy, 2014);
- Spots

- Galisano, clayey silty - Vertic Endoaquepts fine, mixed, active, calcareous, mesic (Soil Taxonomy, 2014);
- Boaria, clayey silty - Udertic Haplustepts fine, mixed, active, mesic (Soil Taxonomy, 2014);
- Soragna, clayey silty - Udertic Haplustepts fine, mixed, active, mesic (Soil Taxonomy, 2014);
- Pradoni, fine sands and silty - Aquic Ustochrepts silty, mixed, mesic (Soil Taxonomy, 2014);

**2Ab:**

The area consisted of a transition section between Apennines and Alpine rivers. The geomorphology consisted of alluvial plains and depression formerly occupied by swamp and that were recently reclaimed. Nowadays these lands are mainly arable with low slope (0.05 to 0.01%).

The soils are typically very deep, calcareous, with thin texture and swelling attitude. The availability of oxygen is variable from poor to moderate. Deep horizons present moderate to high salinity that influences the levels of alkalinity from moderate to high.

- Dominant
    - Case Ponte, clayey - Sodic Endoaquerts very fine, mixed, mesic (Soil Taxonomy, 2014);
    - Risaia del duca, clayey silty - Ustic Endoaquerts fine, mixed, mesic (Soil Taxonomy, 2014);
    - Barchessone, clayey silty - Ustic Endoaquerts fine, mixed, active, mesic (Soil Taxonomy, 2014);

- Spots
    - Ramesina, clayey - Halic Endoaquerts very fine, mixed, mesic (Soil Taxonomy, 2014);
    - Tesa, clayey - Aquic Ustochrepts fine silty, mixed, mesic (Soil Taxonomy, 2014);
    - Pradoni, loam clayey silty - Aquic Ustochrepts fine silty, mixed, mesic (Soil Taxonomy, 2014);

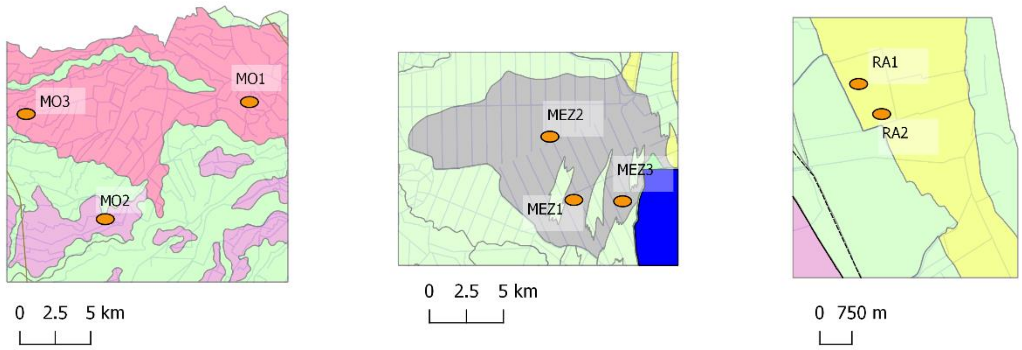



**Figure 2 - Extract from the Fig.1, all the sites are in the Emilia-Romagna region: located in the province of Modena (MO1, MO2, MO3), Ferrara (MEZ1, MEZ2, MEZ3) and Ravenna (RA1, RA2).**

According to our data, classified soils agreed with that of soil delineations found in the Soil Survey of Emilia-Romagna region (Tab.1), except for one profile. The only profile which may be part of different delineation is MEZ1, which showed sandy characteristics that may be attributed to the soil delineation 1Ad (Burano/Mottalunga), developed over paleo-dunes mixed with peaty materials.

| Sampled soil | Soil Taxonomy (2014) | WRB (2014) | Soil Survey of Emilia Romagna Region |
|---|---|---|---|
| **MO1** | Aeric Endoaquerts fine, mixed, active, mesic | Irragric Vertisols (Gleyic) | Barchessone |
| **MO2** | Aeric Endoaquerts fine, mixed, active, mesic | Irragric Vertisols (Gleyic, Calcaric) | Risaia del Duca |
| **MO3** | Aeric Endoaquerts fine, mixed, active, mesic | Irragric Vertisols (Gleyic, Calcaric) | Risaia del Duca |
| **MEZ1** | Typic Sulfisaprists sandy, mixed, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Argine Agosta (Burano/Mottalunga?) |
| **MEZ2** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Valle Mezzano |
| **MEZ3** | Humaqueptic Fluvaquents, mesic | Histic Fluvisol (Siltic) | Canale Specchio |
| **RA1** | Aquic Haplustepts fine silty, mixed, superactive, mesic | Endogleyic Fluvic Cambisols (Calcaric, Siltic) | Marcabò |
| **RA2** | Typic Ustipsamments, mixed, mesic | Fluvic Arenosols | Cerba |

**Table 1 - Sampled soils and respective soil classification.**

The geochemistry of soils developed on sedimentary deposits reflects parent rock composition and related weathering mechanisms, hydrological and geomorphological conditions of the depositional environment, as well as anthropogenic contributions that can overprint the geogenic signatures. Considering the geochemical properties of soils sediments of the study area, it is possible to distinguish between those belonging to Po river discharge basin (Alpine) and those belonging to Reno river and other minor Apennines rivers (Bianchini et al., 2012, 2013, Migani et al., 2015, Borghesi et al., 2016). Mafic–ultramafic detritus contributed to the Po River drainage system by constituting a geochemically and mineralogically unique source for the Po Plain, while Apennines rivers flown predominantly through sedimentary rocks (Amorosi et al., 2002). The main differences are: Po sediments have high-Cr, -Ni and -V contents, while Apennines sediments low-Cr (<150ppm) and Ni (<100ppm) (Bianchini et al., 2002).

To depict geochemical signatures of studied soils, a microwave-assisted digestion with aqua regia was performed an all horizons (detailed methodological procedures were described in the following chapter - p.21). The sampled soils showed geochemical differences, mostly due to sediments types (Fig.3). Except for MEZ2 and MEZ3, all the other soils profiles were well separated in the graph, defining texture composition. It was possible also to distinguish between the clays of MO1 and MO3. The compositional difference of the two sites could be justified by the fact that MO1 developed on Po river sediments while MO3 on Apennines sediments (Fig.4). Fig.3 and Fig.4 refer to analyses performed by the author and more detailed methodological procedures are described in the following chapter (p. 21) - in the figures were presented data of average values found in cultivated layers, that showed no substantial differences with total elemental concentration of deep ones.

**Component Matrix[a]**

| | Component 1 | Component 2 |
|---|---|---|
| Al | ,988 | |
| As | ,722 | -,421 |
| B | ,964 | |
| Ba | ,927 | |
| Be | ,983 | |
| Ca | -,633 | ,698 |
| Cd | ,646 | ,539 |
| Co | ,959 | |
| Cr | ,826 | -,530 |
| Cu | ,815 | |
| Fe | ,989 | |
| K | ,946 | |
| Li | ,954 | |
| Mg | ,620 | ,463 |
| Mn | | ,929 |
| Mo | | -,920 |
| Na | ,842 | -,322 |
| Ni | ,886 | -,414 |
| P | ,385 | ,488 |
| Pb | ,972 | |
| S | | -,855 |
| Sb | ,766 | -,438 |
| Sr | -,629 | ,643 |
| V | ,988 | |
| Zn | ,847 | ,429 |

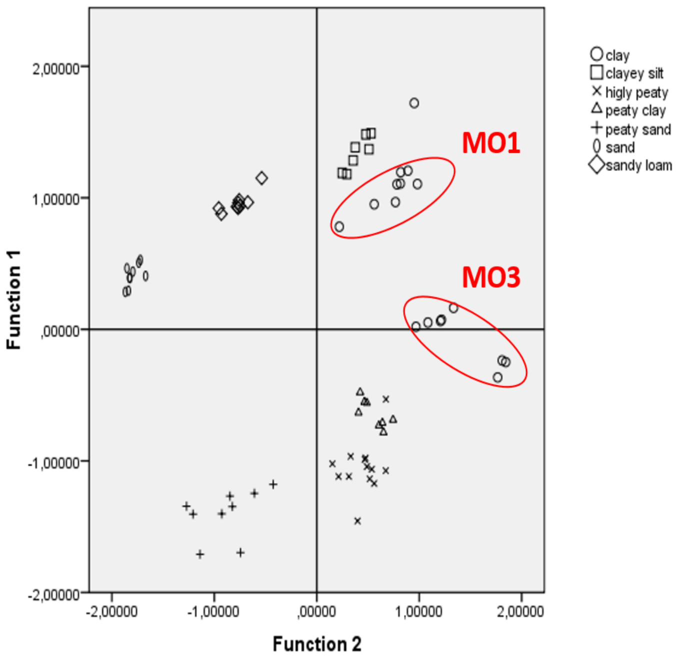



**Figure 3 - Principal Component Analysis (PCA) of total cation composition of the cultivated layers, microwave-assisted extraction with aqua regia. KMO: 0.858. Bartlett test < 0.05. The figure shows the loadings of the two functions extracted and the plot of the scores. Clay: MO1 and MO3, clayey silt: MO2, highly peaty: MEZ2, peaty clay: MEZ3, peaty sand: MEZ1, sand: RA2, sandy loam: RA1.**

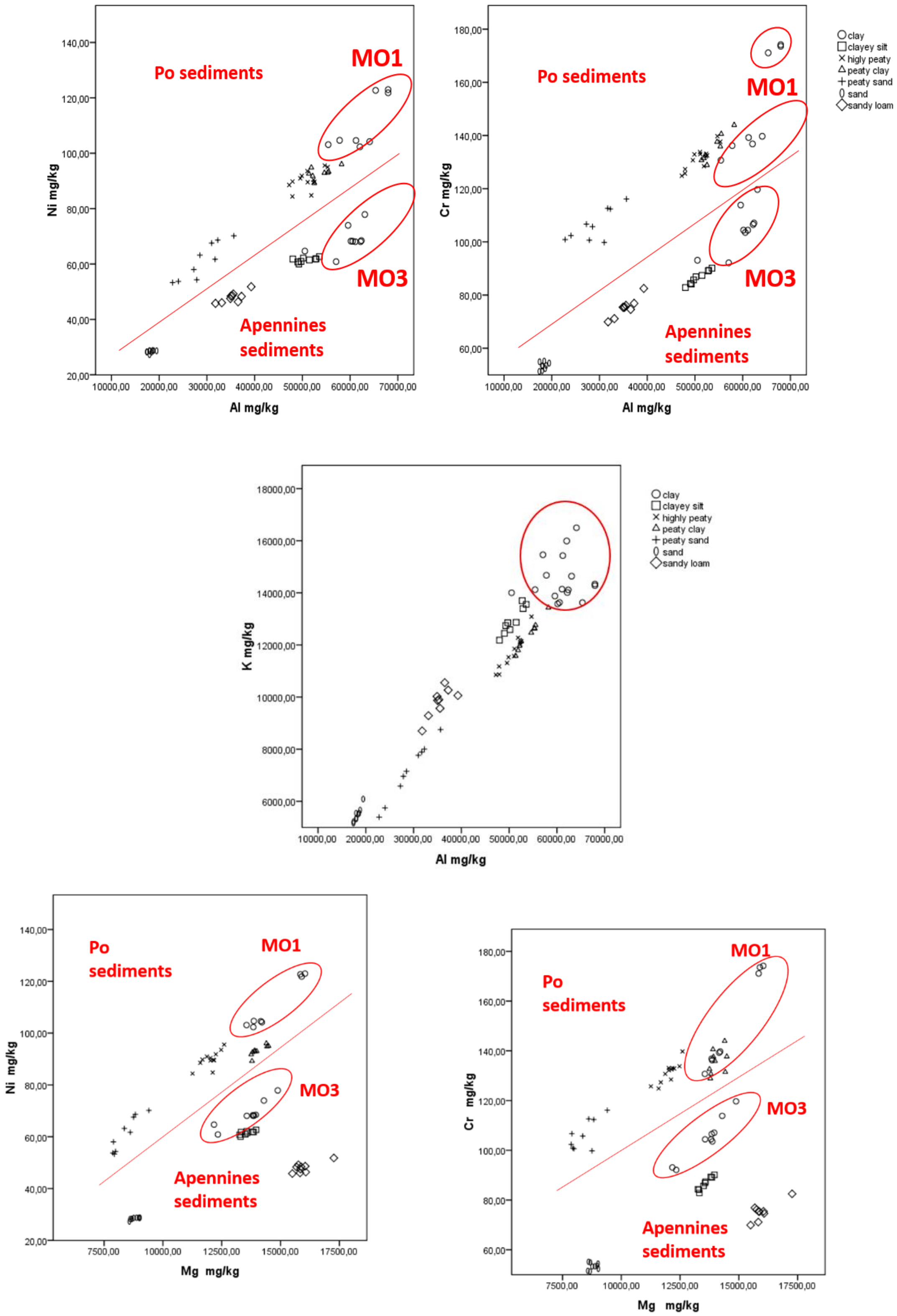



**Figure 4 - Variation diagrams reporting microwave-assisted extraction (with aqua regia as solvent) data of the cultivated layers of the studied soils: Ni, Cr and K vs Al, Ni and Cr vs Mg (data are expressed as ppm). For further information on the use of binary graphs with Al and Mg as dependent variables, and Ni, Cr and K as independent variables see Bianchini et al. (2002).**

## Climate and meteorological frameworks

In Italy, many different climates are found, however showing common general trends as decrease of total annual precipitation and increase of minimum and maximum temperatures (Colantoni et al., 2015). In the particular area of study the climate is usually referred as continental because the Adriatic Sea does not influence the regime, not even at the costal stations. The prevailing winds blow from western and southern quadrants, but in winter there is a strong influence of eastern and northern winds.

The mean precipitation is about 700mm/year, ranging between 600 and 800mm/year, with the lower amounts found in the area of the Po Delta. Specifically, winter average precipitation range from 130 to 190mm, spring from 160 to 230mm, summer from 120 to 180mm, and autumn from 220 to 270mm. Temperatures have wide ranges in all seasons, minimum average annual temperature being 9-11°C and the maximum 17-19°C. In winter temperatures range from averages of 2-4°C as minimum to 9-10°C as maximum (av. 6-8°C). Spring temperatures range from averages of 8°C to 15-19°C (av. 13-14°C). In summer the minimum average temperature rarely goes under 17°C being often over 19°C, while maximum is often over 28°C, but long periods with over 30°C are very common (av. 22-25°C). In autumn, average temperature ranges from 9-11°C to 17-19°C (av. 14-15°C).

The hydroclimatic balances are typically negative from May to August (with peaks of -100mm in July).

The 2015 was an extremely hot year with anomalous trends of precipitation, and summer 2015 being the hottest of the last 80 years (Marchina et al., 2017). Three meteorological station were selected to monitor temperatures and precipitation for the year 2015, which represent the year of field survey of this work: Guagnino (MEZ), San Felice sul Panaro (MO) and San Pietro in Vincoli (RA) – Table 2 and Figure 5.

| | Stations | Guagnino (MEZ) | San Felice sul Panaro (MO) | San Pietro in Vincoli (RA) |
|---|---|---|---|---|
| **Winter** | **Precipitation** | 208.6 | 192.2 | 289.8 |
| | **Temperature** | 7.2 | 5.6 | 6.3 |
| **Spring** | **Precipitation** | 185 | 116.4 | 287.8 |
| | **Temperature** | 18.8 | 18.3 | 17.5 |
| **Summer** | **Precipitation** | 112 | 84.4 | 73.4 |
| | **Temperature** | 24.6 | 25.4 | 23.4 |
| **Autumn** | **Precipitation** | 111.2 | 116.4 | 177.2 |
| | **Temperature** | / | 8.8 | 8.9 |

**Table 2 - Table resuming cumulative precipitation (mm) and average temperatures (°C) for the three selected stations during 2015. It was not possible calculate winter average temperature for Idrovora Guagnino because some technical problems occurred at the station during the month of December.**

According to the data, the average of precipitation and temperatures of the three area were into the historical averages, but anomalies were found. Extremely rainy February and March for the three stations. In May, precipitations were slightly higher than historical average 1961-1991 in RA and MEZ, but mostly due to intense events localized in few days. In MO, cumulative precipitations were lower compared to historical average. Temperatures, either maximum nor minimum showed anomalies in the three areas of study. Hydro-climatic balance was slightly positive in RA and MEZ (0-25mm), and quite negative in MO (-25 to -50mm).

In June, similarly to May, precipitations were slightly higher than historical average 1961-1991 in RA and MEZ, but mostly due to intense events localized in few days. In MO cumulative precipitations were lower compared to historical average. Temperatures, either maximum nor minimum showed anomalies in the three areas of study. Hydro-climatic balance was negative in all sites, RA ranging from -25 to -75mm, MEZ from -50 to -125mm and MO from -100 to -150mm. These values are higher than historical average in RA and MEZ, while are lower in MO (-25 to -50mm).

In July, precipitation was absent in almost all Emilia-Romagna, which means an anomaly of -30 to -40mm of precipitation. Minimum and maximum temperatures were higher than expected of 3-4°C in all sites. Hydro-climatic balance was between -140 and -160mm in RA and MEZ, while

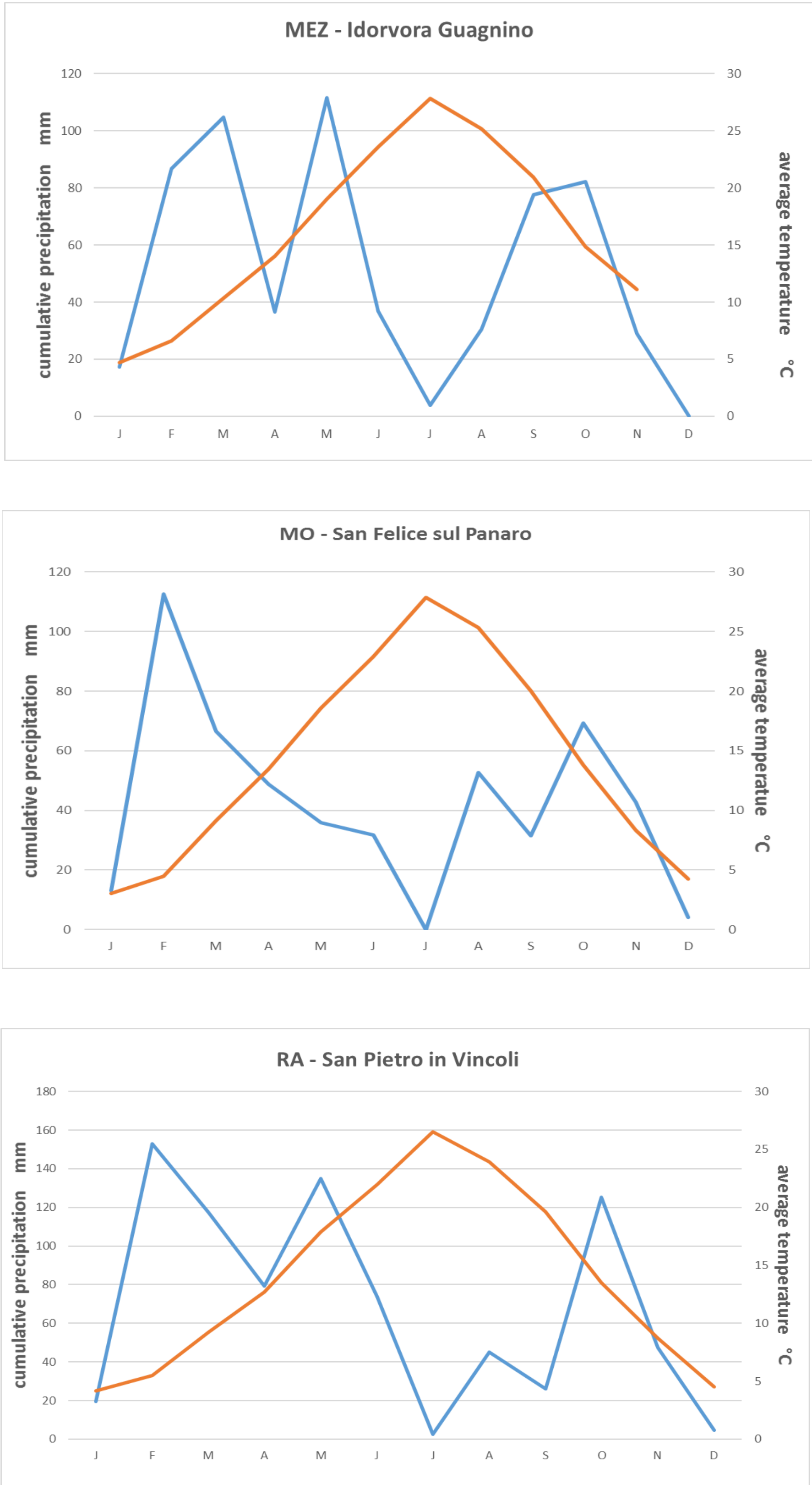



**Figure 5 - Graphs with the monthly meteorological trends of cumulative precipitation and average temperature for year 2015, for the three selected stations.**

between -160 and -200mm in MO. It means an extra-deficit of water of 30-40mm compared to average in all sites.

In August, precipitations were on average with historical data in MO (even if it started to rain consistently after 9th of the month) and slightly lower in MEZ and RA. The first half of the month revealed higher temperatures than historical averages, both minimum and maximum temperatures, while the second half was on average. Hydro-climatic balance was between -80 and -120mm in all sites, which means a slight higher deficit compared to averages.

Interesting is the fact that during Summer 2015 there were more than 45 consecutive days without rain (or day cumulative < 10mm) for all three sites. Watching back to last ten years, apparently, it was a trend for all three sites (even if data had to be collected from different stations for every site). This would mean Xeric hydric regime conditions, not Ustic, and thus a different approach to environmental and agricultural issues.

## Soil quality and its influence on crop stoichiometry in intensive agricultural system

Soil is an ecosystem that provides the habitat for an enormous quantity of living organism on Earth, and it is the result of a complex equilibrium between biophysical and bio-chemical processes, tightly related to climate and "above-ground" ecosystems. In this regard, human impact on soil ecosystem has been so strong through history (Hillel, 2005) that any delimitation between natural and social systems is artificial and arbitrary (Berkes and Folke, 1998). Modern intensive agricultural practices such as tillage, crop rotation and organic amendments have a big impact on soil chemical and physical fertility (Birkhofer et al., 2008), because they induce a profound alteration of the soil structure, change the rate of nutrients release (Abbott and Manning, 2015) and in long terms, they enhance the carbon and nitrogen loss from soils (Bardgett and Van der Putten, 2014). Moreover, the homogenization of landscapes and the loss of natural and semi-natural habitats led to a loss of soil biodiversity (Tsiafouli et al., 2012; Duru et al., 2015). Soil microbial biomass plays a key role in nutrients availability for autotrophs organisms because they require nutrients for their own growth, hence mineralize organic materials to simple inorganic compounds. In this way nutrients become available for plants uptake. Nutrients, such as nitrogen (N) and phosphorous (P) are immobilized in the bodies of the microorganisms and they become available during the turnover of microbial biomass (Van der Heijden, 2008). For this reason, the carbon-to-nutrient ratio in soil determines whether nutrients are fixed in the microbial biomass or mineralized for the plants uptake (Brookes, 2001). Generally, in natural terrestrial environments, plants are the major source of total soil C and N, and the biogeochemical cycle of C and N is tightly coupled. On the contrary, the major source of P is the weathering of primary rocks and soil P dynamic strongly depends on the environmental factors affecting phosphate-solubilizing microorganisms. The study of the P dynamic in soil ecosystem is very important to determine its quality, because P is one of the most limiting nutrient in soil and at the same time it is both an essential element for plants growth and an important driver of microbial community structure (Kuramae et al., 2012).

Soil microbial biomass varies as a function of soil C content (Wardle, 1998). The microbial C concentration is strongly associated with soil microbial N and P content, and the soil microbial quotients (C:N:P – av. 60:7:1) are often used to evaluate the contribution of microbial biomass to soil nutrients (Griffith et al., 2012). Soil microbial community, generally have a relatively consistent C:N ratio (on a mass basis), typically varying between 8:1 and 12:1 (Paul, 2014), with fungal biomass containing relatively more C than bacterial biomass (Scott et al., 2012; Keiblinger et al., 2010). Changes in soil microbial biomass C:P and N:P can be indicative of nutrient limitation within a site, as low soil P availability strongly limits microbial biomass activity and other ecosystem processes (Cleveland and Liptzin, 2007; Griffith et al., 2012). Intensive agriculture techniques use to supply high-rate of NPK fertilization to soil, reasonably inducing a profound alteration in nutrients equilibrium into soil. Consequently, also the balance of nutrients in the crops "forget" the specific signature of the natural soil (or environment), and their nutrient composition will be only influenced by growth rate or by nutrient requirements and availability, when same cultivar is considered (Ågren and Weih, 2012). Notwithstanding, alternative management practices, including organic farming and no-till, are not so directly related with an amelioration of soil "health" and likewise are not able to sustain high-rate production (Nielsen et al., 2015). In order to raise both quality and quantity of agricultural realities, therefore, it is important to find a sustainable way to manage the soils for maintaining both the ecosystem equilibrium and the soil vocation for peculiar production. For this reason, in this study we investigated three different agricultural sites consisting of peculiar soil delineation and dedicated to the same crop production, specifically tomato HEINZ 1015. After the evaluation of the "health" status of the soils, using a specific index of biological fertility, the elemental composition of tomato crops was evaluated. The aim of the work was (1) to evaluate the effect of the same intensive land management on the biochemistry of different pedoclimatic conditions, (2) to determine whether or not a site-specific chemical signature remains in the different part of the plant, even under intensive land-use and (3) find relationships among biochemistry of soils and mineral composition of plant tissues.

## *Materials and methods*

### *Study Area*

The study areas are located at the eastern section of the Padana Plain (Northern Italy; Figure 1). Generally, this part of the Padana Plain consists of deposits accumulated during the Quaternary evolution that resulted in an interdigitated pattern of sediments including alluvial, marine and brackish water deposits (Stefani & Vincenzi, 2005; Simeoni & Corbau, 2009). Furthermore, these lands have been strongly influenced by the human activity since many centuries and now is a highly urbanised and industrialised areas, with a long history of agricultural practices (Federico and Malanima, 2004; Ferronato et al., 2015; Mercuri et al., 2006; Poni and Fronozni, 2005).

Three distinct study areas, showed in Figure 6, were selected according to distinct pedoclimatic characteristics, including only those sites that were dedicated to HEINZ 1015 tomatoes cultivation.

The selected areas were: MO) the northernmost area, located near Modena town where fine sediments (silt and clay) of the Po River occupy the transition section between river course and the Apennines chain; RA) the southernmost area, located near Ravenna city and consists of silt and sand deposited by rivers flowing from the Apennines chain; MEZ) the "Mezzano valley" (near Ferrara city) is a lowland recently reclaimed with high peat content; the sediments mixed with the peat 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 of the valley consists of alluvial materials, sand, clay and silt unevenly distributed (Boschi and Spallacci, 1974; Di Giuseppe et al., 2014). On each studied area, different sampling sites were selected and each sampling point was geo-referenced with a Global Positioning System (Figure 1). The sampling point were superimposed on the soil delineations of Soil Survey of Emilia Romagna Regions (1:50.000).

As support, environmental condition of the nearest meteorological station to the sites (mean daily T°C and cumulative daily precipitation) were analysed: San Felice sul Panaro (MO), Guagnino

(MEZ) and San Pietro in Vincoli (RA). The selected interval was September 2014- September 2015 (data provided by ISPRA, Istituto superiore per la protezione e la ricerca ambientale).

At each station De Martonne aridity index (De Martonne, 1926) was calculated for the whole interval and, for the months of June and July (De Martonne, 1941).

A.I.= $\frac{H}{°C+10}$ (for all 12 months)

H= cumulative annual precipitation in mm

°C= mean annual temperature in °C

A.I. of June and July = $(\frac{Hm*12}{°Cm+10} + \frac{H}{°C+10})$ / 2

Hm= cumulative precipitation of the month

°Cm= average month temperature

*Tomato and soils sampling strategies*

In the distinct investigated areas, two or three tomato fields were selected: MO1, MO2 and MO3 were three different tomato fields representative of northernmost area, RA1 and RA2 were selected for southernmost area, while MEZ1, MEZ2 and MEZ3, respectively were selected for “peat reclaimed soils”.

For every field three profiles replicate were collected and analysed separately. The soils were sampled during spring (end of May and beginning of June) 2015, few weeks after the transplant of the tomatoes on the fields. At every site a profile was opened till groundwater level and described according to et Schoeneberger et al. (2012). The soils samples were subdivided in horizon according to soil description and collected in polyethylene bags and they were preserved in a portable fridge at 4°C during the sampling campaign.

Three tomatoes plants and their rhizospheres were sampled between the end of July and beginning of August in each field and the sampling sites were selected randomly in the distinct fields. Plants were transported to lab for analyses as a whole, while rhizospheres were separated from roots by softly hand-shaking directly into polyethylene bags. All samples were collected in polyethylene bags and they were preserved in a portable fridge at 4°C before transporting in laboratory.

In order to characterize the history of field cultivation, rotation and fertilization plans applied for each site were recorded, shown in the supplementary material together with data of production of 2015. (Table S1).

| ***Modena*** | **World Geodetic System 1984 (WGS-84) UTM fuse 32** | |
|---|---|---|
| | *Coordinates* | *Elevation* |
| **MO1** | 686035.47 m E - 4974881.07 m N | 7 m a.s.l. |
| **MO2** | 675223.52 m E - 4966212.51 m N | 13 m a.s.l. |
| **MO3** | 669445.08 m E - 4973824.04 m N | 10 m a.s.l. |

| ***Mezzano Valley*** | **World Geodetic System 1984 (WGS-84) UTM fuse 33** | |
|---|---|---|
| | *Coordinates* | *Elevation* |
| **MEZ1** | 265632.12 m E - 4946511.81 m N | -5 m a.s.l. |
| **MEZ2** | 264716.08 m E - 4950650.81 m N | -4 m a.s.l. |
| **MEZ3** | 269094.68 m E - 4946090.42 m N | -3 m a.s.l. |

| ***Ravenna*** | **World Geodetic System 1984 (WGS-84) UTM fuse 33** | |
|---|---|---|
| | *Coordinates* | *Elevation* |
| **RA1** | 283281.05 m E - 4916658.39 m N | 0 m a.s.l. |
| **RA2** | 283115.31 m E - 4916668.69 m N | 0 m a.s.l. |

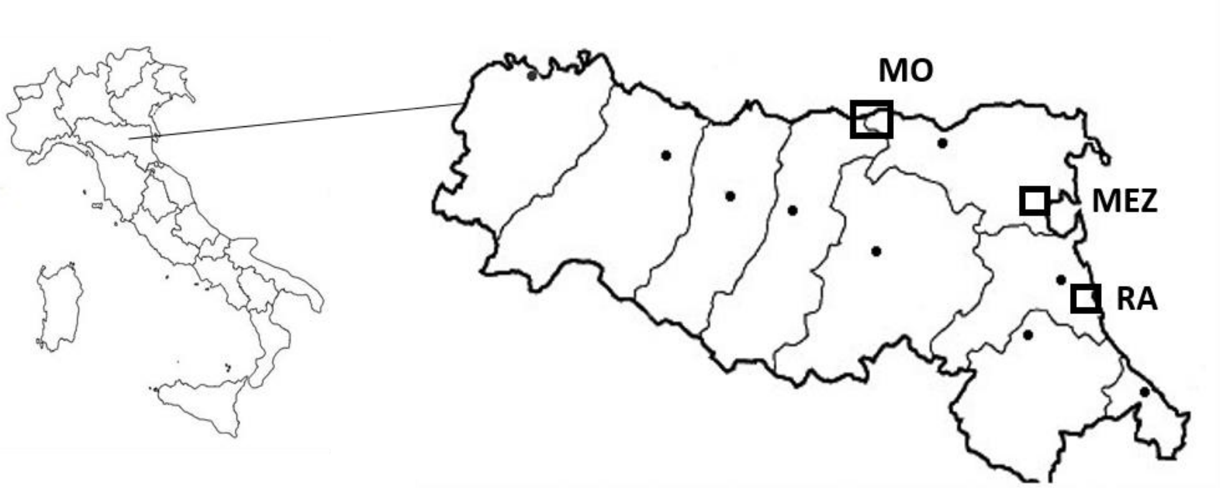



**Figure 6 - Location of study areas on map and coordinates of sampling points.**

### *Analytical methods*

Soil 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 with Whatmann 42 for EC measurement (EC; Orion). The cation exchange capacity (CEC) and the exchangeable cations were determined with Inductive Coupled Plasma – Optic Emission Spectroscopy (ICP-OES, Ametek, Germany) after exchange with hexamminecobalt(III) chloride according to Orsini and Remy (1976). Total carbonates ($CaCO_3$) were quantified by volumetric method, according to Loeppert and Suarez (1996). The soil particle-size distribution was determined by pipette method (Gee and Bauder, 1986). For those horizons with total organic matter content > 10%, soil texture was inferred by specific maps (geologic and geomorphologic maps of Comacchio and Porto Maggiore, 1:50.000, Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna). Total soil organic matter (SOM) was determined by loss of ignition at 550°C for 24h, after 48h of stabilization at 60°C. Total organic carbon (OC) and total nitrogen (TN) were measured by Dumas combustion with CHN elemental analyser (EA 1110 Thermo Fisher). Values of $\delta^{13}C$ were measured contextually to OC. Isotope ratios are expressed in parts per thousands (δ ‰) and were calculated as follows:

$$\delta_x = \left[\left(\frac{Rsample}{Rstandard}\right) - 1\right] * x * 1000$$

x= $^{13}C$ and $R_{sample}$ = $^{13}C/^{12}C$ and $R_{standard}$ is the ratio of the international standard (V-PDB for $^{13}C$).

Soil basal respiration (Cbas; mg_C_$CO_2$ $kg^{-1}$) was measured on 25g samples adjusted at 60% of WHC, incubated at 25°C for 10 days. The $CO_2$ emission was measured after 8, 9 and 10 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, Cmic and Nmic (mg $kg^{-1}$), were determined on the same incubated soils at the end of the incubation period by the method of Vance et al. (1987). The method is based on the difference between C and N extracted with 0.5 M $K_2SO_4$ (1-to-4 soil-to-extractant ratio for 40min shaking) from chloroform fumigated and unfumigated (labile-C and labile-N) soil samples, using the correction factor proposed by Vance et al. (1987) (0.45 for Cmic and 0.54 for Nmic).

Cumulative Respiration Carbon (Ccum; mg_C_$CO_2$ $kg^{-1}$) derived from:

$Ct = Ccum\,(1 - e^{-kt})$ (Benedetti and Mocali, 2008)

t was incubation time, k was the kinetic respiration constant and Ct was the $CO_2$ released during the incubation time.

Metabolic Quotient ($qCO_2$; $(10^{-2})$ $h^{-1}$) calculated as:

$$\frac{\frac{Cbas}{Cmic}}{24} x100$$

Mineralization Quotient (qM; %) calculated as:

$$\frac{Ccum}{OCx100}$$

Microbial biomass P (Pmic; mg $kg^{-1}$) was determined using $NaHCO_3$ 0.5M (pH 8.5) as extractant on soils adjusted at 60% of WHC. After 10days at 25°C, the P was calculated from the difference between the amounts of organic P extracted from soils fumigated with CHCl3 and the amount extracted from the unfuimigated soils (P Olsen) (Parton et al., 1988).

*Soil and plants elements content methods*

For the determination of the soil macronutrients concentration (P, K, S, Na, Ca, Mg, Fe and Mn), the soil samples were grounded in powder with a micro hammer mill. The concentration was detected by Inductive Coupled Plasma – Optic Emission Spectroscopy (ICP-OES, Ametek, Germany) after treating 0.250 g of samples with aqua regia (6ml HCl + 2ml $HNO_3$ suprapure, Fluka) in polyethylene vials and digested in microwave oven (Millestone, 1200) according to Vittori Antisari et al. (2010).

Plants were divided into roots, stems, old leaves, young leaves and fruits; every part was cleaned by ground residues and dried at 60°C for 24h (except fruits) to constant weight, and then grounded in powder with a micro hammer mill. Fruits were lyophilised and then grounded in powder with a micro hammer mill. Plants powder (0.250g) was placed in polyethylene vials and digested in microwave oven with 6ml of $HNO_3$ suprapure + 1.5ml of $H_2O_2$ 30% analytical grade. Afterwards, the extract was transferred quantitatively into a volumetric flask and the total concentration of plants macronutrients (P, K, S, Na, Ca, Mg, Fe and Mn) was detected by Inductive Coupled Plasma – Optic Emission Spectroscopy (ICP-OES, Ametek, Germany).

The soluble concentration of soil macronutrients (P, K, S, Na, Ca, Mg, B and Fe) was detected by Inductive Coupled Plasma – Optic Emission Spectroscopy (ICP-OES, Ametek, Germany) after 2 hours agitation of a 1:5 soil:water suspension, filtered whit Whatmann 42, at which finally were added 2 dots of $HNO_3$ suprapure.

*Statistical Analyses and Biofertility Index*

Important to underline is that the statistical analyses were performed just for the cultivated layers. The maximum depth for cultivated layers was considered 50cm. Not all the profiles have a pedological boundary at 50cm, thus for those profiles, the deepest layer for statistical analyses was considered the one which contains the maximum depth. All statistical analyses were performed using SPSS 17.0.

Data were transformed when necessary to meet assumptions of normality, applying an inverse distribution function (Idf.Normal). Pearson's correlation coefficients (r) were calculated to determine correlations among pairs of soil variables. Univariate data were analysed by one-way ANOVA (Tuckey post-hoc test) using two different factors: main areas (MO, MEZ and RA) and texture ($\alpha < 0.05$). Linear Discriminant Analysis (LDA) inserting all variables together was performed in order to evaluate the appurtenance of soil physicochemical and biochemical properties, total and soluble main cations, to the main areas (used as grouping dependent variables). Principal component analysis

(PCA), using principal components as the factor extraction method, was used to summarize the information in a reduced number of factors.

A Biological Fertility Index (BFI) was calculated for each cultivated layer according to Benedetti and Mocali, (2008). Briefly, six parameters were selected, SOM, Cmic, Cbas, Cum, $qCO_2$ and qM. To each parameter, a score ranging from 1 to 5 was assigned, the higher the score the better for soil health (Table 3). The sum of all the scores is the Biological Fertility Index (IBF), the higher the score the better for soil health (Table 4).

| ***PARAMETERS*** | ***SCORE*** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| ***ORGANIC MATTERS*** | <1 | 1 – 1.5 | 1.5 – 2 | 2 – 3 | >3 |
| ***BASAL RESPIRATION*** | <5 | 5 – 10 | 10 – 15 | 15 – 20 | >20 |
| ***CUMULATIVE RESPIRATION*** | <100 | 100 – 250 | 250 – 400 | 400 – 600 | >600 |
| ***MICROBIAL CARBON*** | <100 | 100 – 200 | 200 – 300 | 300 – 400 | >400 |
| ***METABOLIC QUOTIENT*** | >0.4 | 0.3 – 0.4 | 0.2 – 0.3 | 0.1 – 0.2 | <0.1 |
| ***MINERALIZATION QUOTIENT*** | <1 | 1 – 2 | 2 – 3 | 3 – 4 | >4 |

**Table 3 - Assigned score to each parameter range for the calculation of the Biological Fertility Index (BIF), units of measurement are those referred in the text.**

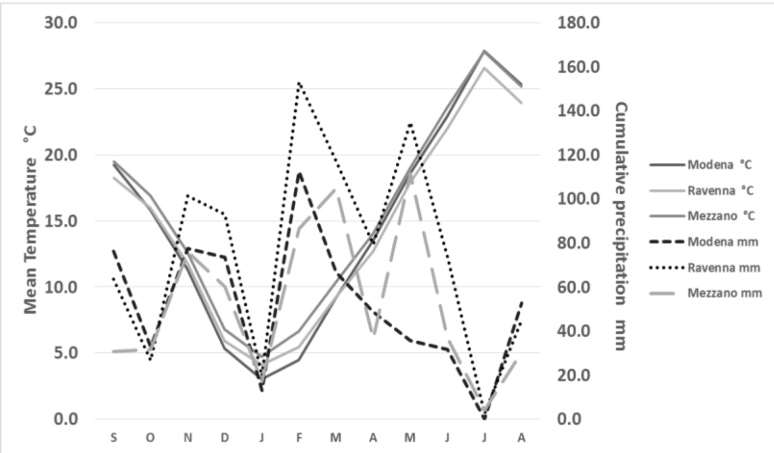
| ***FERTILITY CLASS*** | ***I*** | ***II*** | ***II*** | ***IV*** | ***V*** |
|---|---|---|---|---|---|
| **BIF SCORE** | **Tiredness Alarm** | **Stress Pre-alarm** | **Medium** | **Good** | **High** |
| | 0 – 6 | 6 – 12 | 12 – 18 | 18 – 24 | 24 - 30 |

**Table 4 – Scores' classes ranges that identify BIF score and assigned quality status.**

# Results

## *Climate and soil classification*

Figure 7 presents the Mean monthly temperatures (°C) and cumulative monthly precipitation (mm) from September 2014 to September 2015, for the three chosen stations, and the relative the climatic conditions.




| | *MO* | *RA* | *MEZ* |
|---|---|---|---|
| *CUM. PREC. MM* | 621.4 | 909.2 | 630.4 |
| *AV. T °C* | 14.7 | 14.5 | 15.5 |
| *A.I.* | 23.1 | 34.8 | 23.7 |
| *A.I. JUNE* | 18.4 | 32.4 | 18.9 |
| *A.I. JULY* | 12.6 | 19.0 | 13.0 |

**Figure 7 - Mean monthly temperatures (°C) and cumulative monthly precipitation (mm) from September 2014 to September 2015. Aridity Index of the year, of June and of July for the selected stations.**

According to reference period averages, MEZ was the hottest of the three sites (15.5°C), while in RA was the wettest (909 mm). The A.I. described a humid year in RA, while a semi-humid in MO and MEZ. The A.I. of June and July described different situations. July was the most arid month in all sites. MO and MEZ presented very similar climatic condition with aridity index values of dry climates but closed to the semi-arid climate in July and slightly higher in June but still corresponding to dry climate. RA showed humid condition in June, while dry in July.

Soil profiles description, classification (including WRB) and tables with average values of physicochemical and biochemical characteristics are shown in the supplementary materials (Tables S2, S3, S4, S5). The classification of soils, according to Soil Taxonomy (Soil Survey Staff, 2014) was: MO1, MO2 and MO3 were classified as Aeric Endoaquerts fine, mixed, active, mesic; RA1 was classified as Aquic Haplustepts fine silty, mixed, superactive, mesic; RA2 as Typic Ustipsamments, mixed, mesic; MEZ1 was classified as Typic Sulfisaprists sandy, mixed, euic, mesic; MEZ2 as Typic Sulfisaprists, euic, mesic; MEZ3 Humaqueptic Fluvaquents, mesic.

*Soil physicochemical properties*

Generally, the studied sites differed by soil texture. In particular, RA1 was sandy loam and RA2 sandy, while clay characterized the MO1 and MO2 sites, and clayey–silt MO3. In MEZ study sites, peaty sand of paleo-dunes (MEZ1) and peaty fine sediments of alluvial deposits (MEZ2 and MEZ3) characterized reclaimed soil layers of Mezzano valley. Where the total organic matter content was > 10% soil texture was inferred using geological and geomorphological maps. At the light of the fact that soil delineations were mainly influenced by texture firstly ANOVA of physicochemical parameters with texture as factor are presented (Table 5).

| | **pH** | **EC** | **CaCO3** | **OC** | **TN** | **SOM** | **C/N** | **$\delta^{13}C$** | **CEC** | **Ca exchang.** | **K exchang.** | **Mg exchang.** | **Na exchang.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Clay*** | b | c | c | c | c | c | c | ab | b | bcd | ab | b | bc |
| ***Clayey silt*** | b | c | c | cd | cd | cd | c | a | bc | cd | abc | bc | e |
| ***Sandy peat*** | c | a | d | a | a | a | a | bc | ab | abc | bc | bc | de |
| ***High peat*** | d | a | de | a | a | a | b | c | a | a | a | a | a |
| ***Clayey peat*** | bc | b | e | b | b | b | b | abc | b | ab | abc | b | ab |
| ***Sandy loam*** | a | d | a | de | de | de | c | c | cd | de | cd | c | bc |
| ***Sand*** | a | e | b | e | e | e | c | abc | d | e | d | c | cde |

**Table 5 – One-way ANOVA analysis of soil physicochemical characteristics using soil texture as factors and Tuckey post-hoc test ($p < 0.05$). Different letters refer to statistically different values, decreasing from "a" to "e".**

Clearly, every variable showed some statistically significant difference according to soils' texture, even if these were not always so sharp and mainly driven by pedoclimatic condition. Therefore, ANOVA was replicated using the three tomato cultivated areas as factors (Fig.8).

Statistically different values ($p < 0.001$) of pH were found in the distinct tomato cultivated areas. In particular, the pH ranged from 7.5 to 8.3 in MO, from 8.1 to 8.5 in RA, while lowest values characterized the in the lowland of Mezzano valley (from 5.9 to 7.7). The $CaCO_3$ content in RA soils layers ranged from 18.9 to 27.1% while it decreased significantly in MO (from 7.4 to 8.3%) and in MEZ (meanly 1.4%). The electrical conductivity (EC) values, on the contrary, was significantly lower in RA and MO (from 157 to 495µS $cm^{-1}$) than in MEZ, where high variability was detected (from 508 to 3097µS $cm^{-1}$).

Generally, MEZ soils were enriched by both SOM and nutrients, in comparison to RA and MO sites. The OC and TN of the mineral soils of RA and MO showed typical ranges of cultivated soils, with

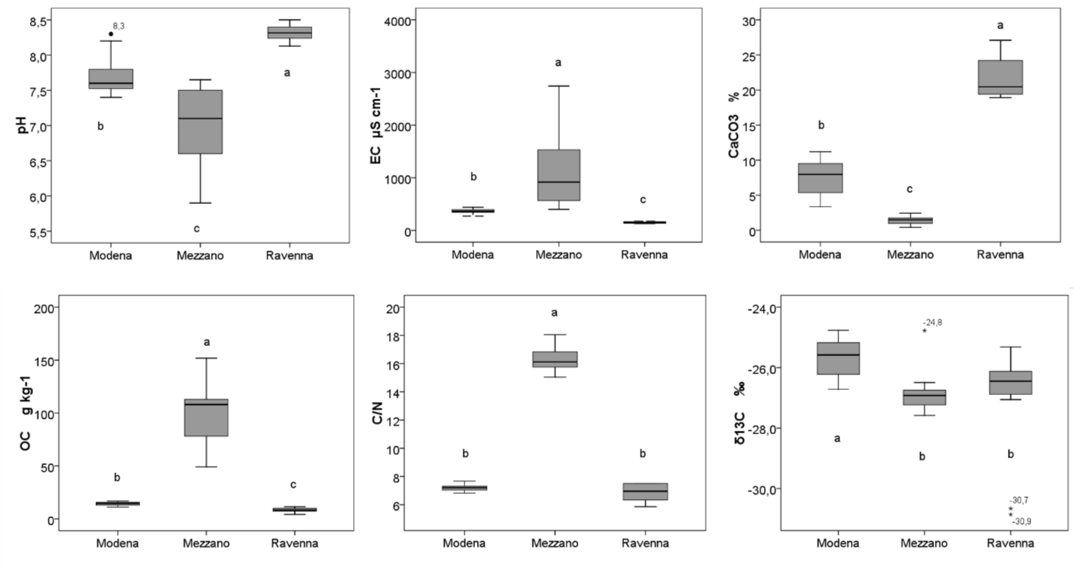
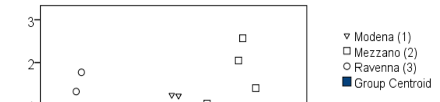


**Figure 8 - Boxplots of soil physicochemical characteristics. Different letters refer to statistically different values, decreasing from "a" to "c" obtained by One-Way ANOVA, using main sites as factors, and Tuckey post-hoc test ($p < 0.05$).**

1.4-0.8 mean % of OC and 0.8-0.28% of TN, respectively. In Mezzano Valley the OC and TN were significantly higher and ranged from 5.0 to 15.2% (OC) and 0.3 to 0.9% (TN). The CEC, being related to the soils' texture and SOM content, increased from RA (2.39 to 18.51$cmol_{(+)}$ $kg^{-1}$) to MO (29.9 to 60.0$cmol_{(+)}$ $kg^{-1}$) and MEZ (28.4 to 78.0$cmol_{(+)}$ $kg^{-1}$), and among the cations contributing to the exchangeable complex, $Ca^{2+}$ was the most represented in all sites, even if with different proportions. $\delta^{13}C$ was constrained with no statistical differences between MEZ (-26.5 to -27.5‰) and RA (-25.4 to -26.7‰). It was more spread in MO (-24.8 to 26.7‰) and was statistically different from MEZ and RA.

The discriminant analysis (LDA) was performed on pH, EC, OC and $CaCO_3$ in order to verify their capability to effectively distinguish the three sites (groups in the LDA) (Fig.9). The two functions (F1 and F2) represents the projection (normalized values) on a bi-dimensional space of the variables. Wilks' Lambda was significant (< 0.001) just for F1 (low Wilks' lambda indicate greater discriminatory ability of the function). Coefficients with large absolute values correspond to variables with greater discriminating ability, in this case: $CaCO_3$ > EC > OC > pH, respectively. Predicted group membership was < 100% just for group 2 (92%). Hence, according to discriminant analysis, soil physicochemical properties were good predictors of main areas membership (Fig.9; CEC. TN and SOM were not included in the analysis because strongly correlated with included variables).




**Standardized Canonical Discriminant Function Coefficients**

| | Function 1 | Function 2 |
|---|---|---|
| **pH** | -,129 | ,696 |
| **EC** | ,560 | -,151 |
| **CaCO3** | -,791 | -,005 |
| **OC** | ,389 | ,830 |

**Figure 9 - Discriminant analyses. The two functions (F1 and F2) represents the projection of pH, EC, OC and CaCO3 (normalized values) on a bi-dimensional space. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant**

## *Soil biochemical characteristics*

Biochemical parameters consisted of two different types: measured (Cbas, Labile-C, Labile-N, Cmic and Nmic) and calculated (Cmic/Nmic, $qCO_2$, qM and Cmic/OC). Biochemical characteristics showed little variation according to soil texture (Tab. 6). Measured parameters were generally higher in peaty soils, except for Cmic and Nmic. Cmic/OC and qM were higher in mineral soils (sandy generally higher than clay and clayey silt), Cmic/Nmic was higher in clay, clayey silt and high peat. $qCO_2$ showed the lowest values in clay and sandy loam.

Anyway, either according to texture or to pedoclimatic environments differences were few, in fact, discriminant analysis using main sites (MO, MEZ, RA) as groups did not lead to any significant groups' prevision: the only discriminant characteristic (considering measured parameters) was Cbas, that leaded to significant variation of $qCO_2$ and qM.

| | **Cbas** | **Labile-C** | **Labile-N** | **Cmic** | **Nmic** | **Cmic/Nmic** | **qCO2** | **qM** | **Cmic/OC** |
|---|---|---|---|---|---|---|---|---|---|
| Clay | b | c | bc | a | ab | a | c | c | ab |
| Clayey silt | b | c | c | ab | b | ab | bc | bc | c |
| Sandy peat | a | a | a | ab | a | c | a | de | c |
| High peat | a | b | a | a | ab | ab | ab | e | c |
| Clayey peat | a | b | ab | ab | ab | bc | a | d | c |
| Sandy loam | b | c | c | ab | ab | bc | c | b | a |
| Sand | b | d | c | b | b | bc | ab | a | ab |

**Table 6 - One-Way ANOVA analysis of soil biochemical characteristics using soil texture as factors and Tuckey post-hoc test ($p < 0.05$). Different letters refer to statistically different values, decreasing from "a" to "e".**

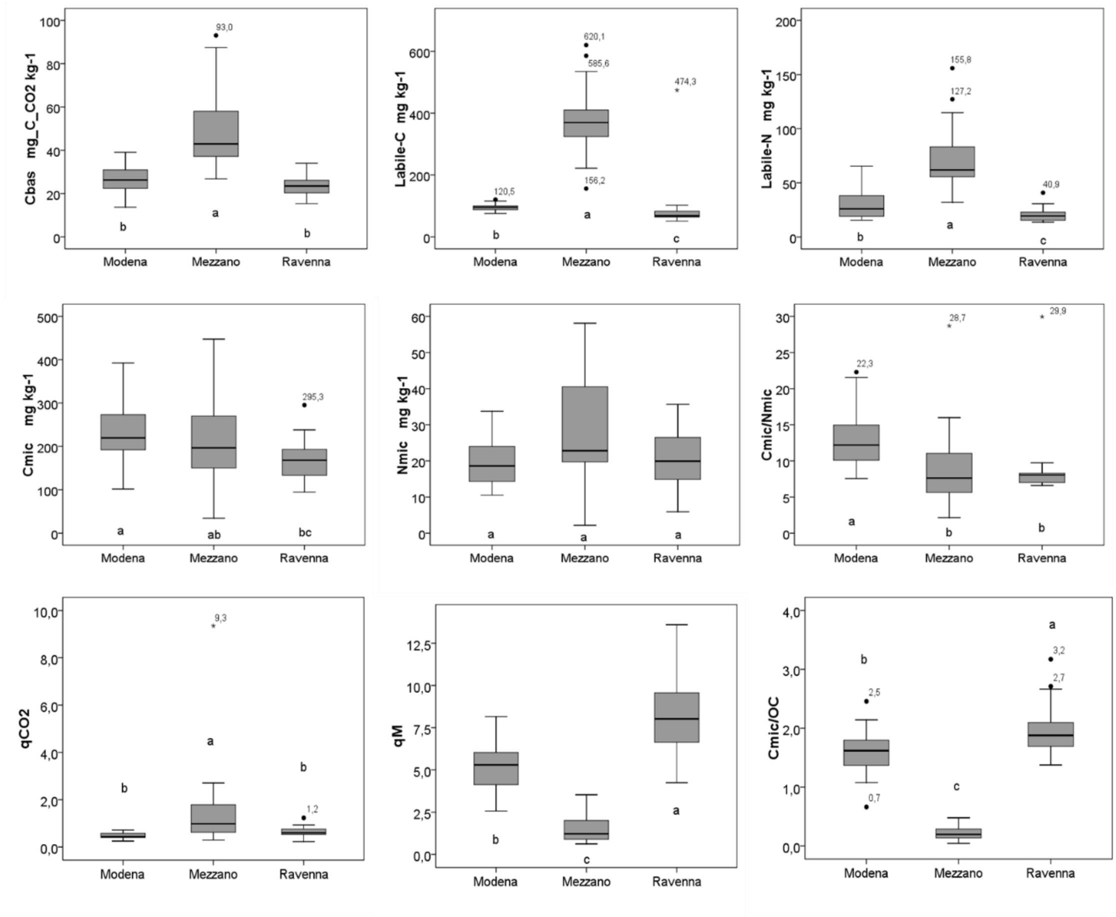


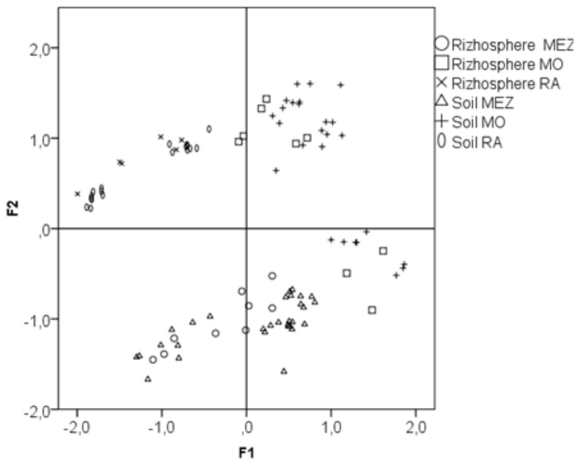

**Figure 10 - Boxplots of soil biochemical characteristics. Different letters refer to statistically different values, decreasing from "a" to "c", obtained by One-Way ANOVA, using main sites as factors, and Tuckey post-hoc test (p < 0.05).**

As expected, the content of labile SOM (C and N) MEZ soils was significantly higher than those of the other investigated sites, as well as Cbas and $qCO_2$. Not true for Cmic and Nmic content. Cmic amount in MO sites was significantly higher than that in MEZ and RA, while no significant differences were noted for Nmic. Both qM and Cmic/OC showed statistical differences between all sites: RA > MO > MEZ.  High variability for P Olsen and Pmic content was detected probably due to high variability within the sites. Carbon/Nutrients ratio in microbial biomass presented wide ranges: Cmic/Nmic from 7.6 to 22.2 in MO, from 2.2 to 28.7 in MEZ and from 6.6 to 29.5 in RA. It was negatively related to C/N of SOM (-0.272, sig at $p < 0.01$). Cmic/Pmic and Nmic/Pmic showed a huge variability do to the high heterogeneity of Pmic.

According to Benedetti and Mocali (2008) index of biological fertility (BFI): all the analysed soils showed scores ranging between 18 and 24, which means good health status. MEZ and MO presented similar singular scores: high scores for SOM, Cbas and Ccum (4-5), very variable for Cmic (1-4), very low for $qCO_2$ (1) and high for qM (4). RA presented very low scores for SOM (1-2), high for Cbas and Ccum (4-5), variable for Cmic (1-4), very low for $qCO_2$ (1) and high for qM (4-5).

*Nutrients content in soil-tomato system*

In the first section of the work (chapter "Pedological and geochemical characterization") the differences of total elements content in studied soils were presented. Some of the elements that determine most of differences were heavy metals as Ni, Cr, As, Cd and Zn. As explained, these differences were already documented in the area and cases of bioaccumulation in plants were also identified, such as in lettuce, alfalfa and corn (Bianchini et al., 2012; Di Giuseppe at al., 2014). However, in this work no case of bioaccumulation of metals in tomato plants have been detected and




| | Component 1 | Component 2 |
|---|---|---|
| Al | ,979 | |
| As | ,673 | -,469 |
| B | ,935 | |
| Ba | ,926 | |
| Be | ,976 | |
| Ca | -,583 | ,726 |
| Cd | ,668 | ,436 |
| Co | ,922 | |
| Cr | ,787 | -,582 |
| Cu | ,746 | |
| Fe | ,989 | |
| K | ,931 | |
| Li | ,949 | |
| Mg | ,596 | ,420 |
| Mn | | ,920 |
| Na | ,805 | -,363 |
| Ni | ,836 | -,477 |
| P | ,377 | ,540 |
| Pb | ,898 | |
| S | | -,792 |
| Sr | -,569 | ,664 |
| V | ,982 | |
| Zn | ,859 | ,418 |

**Figure 11 - Principal Component Analysis (PCA) of total cation composition of the cultivated layers and rhizospheres (microwave-assisted extraction with aqua regia). KMO: 0.820. Bartlett test < 0.05. The figure shows the loadings of the two functions extracted and the plot of the scores.**

therefore, after verify whether rhizospheres composition was comparable to that of cultivated soil layers, only macronutrients were considered at first (rhizosphere total and soluble, and plant tissues). Finally, the total range of detectable elements were investigated in plant tissues to understand if plant retained the chemical fingerprint of specific soils.

Considering all elements, rhizospheres were comparable to cultivated layers in all sites, as shown in Figure 11.

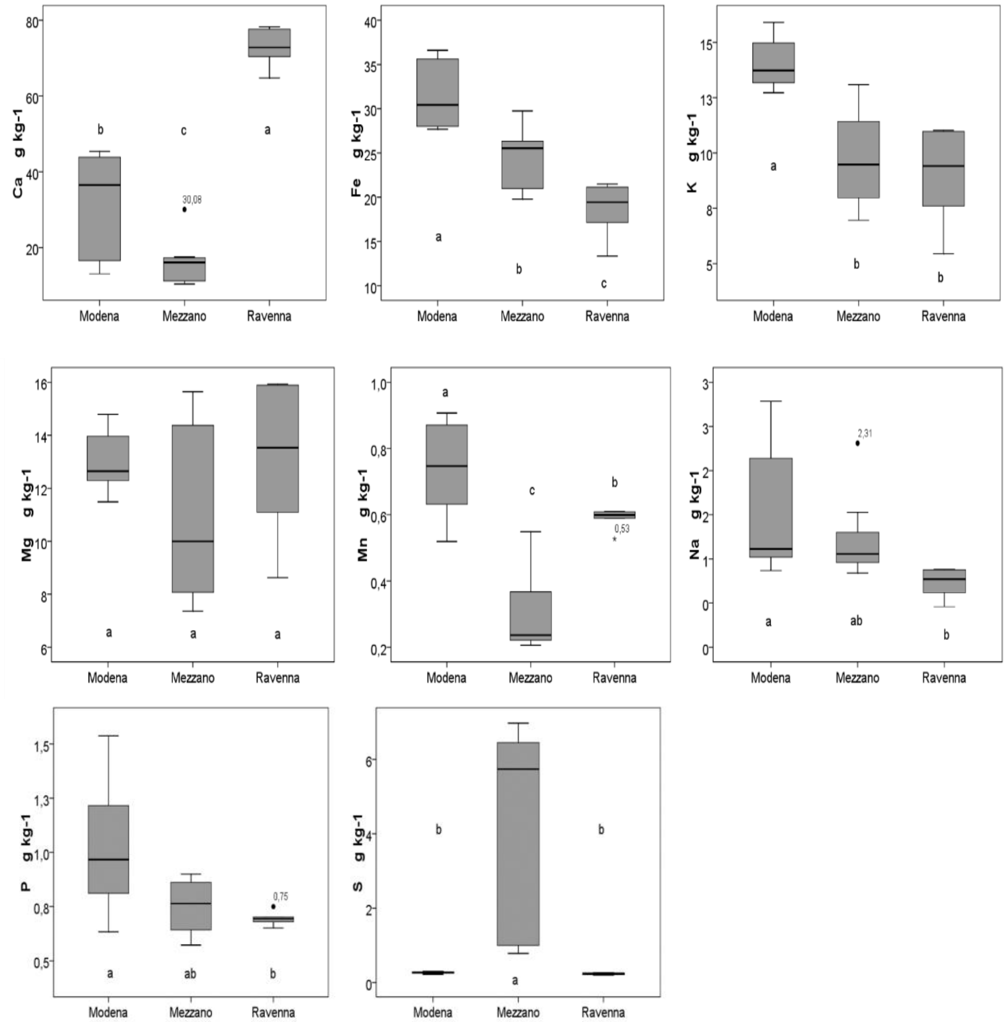
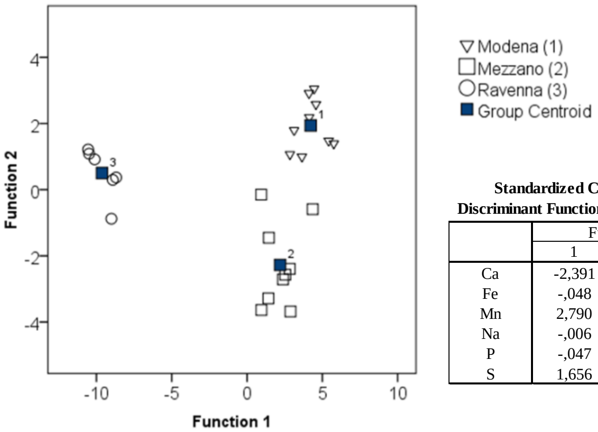


**Figure 12 - Boxplots of rhizosphere macronutrients content. Different letters refer to statistically different values, decreasing from "a" to "c", obtained by One-way ANOVA, using main sites as factors, and Tuckey post-hoc test (p < 0.05).**

Total S content was very high in MEZ rhizosphere (0.78 to 6.98g $kg^{-1}$) compared to other sites, which never exceeded 0.3g $kg^{-1}$. K was statistically higher in MO (12.72 to 15.90g $kg^{-1}$). Fe, Mn and Ca were statistically different in all sites, with Ca being very high in RA (64.78 to 78.28g $kg^{-1}$). Na and P of MO were statistically higher compared to RA but not to MEZ, and RA and MEZ did not show differences for both elements. Mg was comparable in all sampling points (Fig. 12). Hence, in order to verify the capability of rhizosphere macronutrients to effectively distinguish the three sites, LDA was performed on Ca, Fe, Mn, Na, P and S. Wilks' Lambda was significant (< 0.001) for both F1 and

F2. Coefficients with large absolute values correspond to variables with greater discriminating ability. F1: Mn > Ca > S >> Na, P, Fe; F2: Fe > Mn, Ca, P, S > Na. Predicted group membership was equal to 100% for RA and MO, 77.6% for MEZ. Hence, according to discriminant analysis, soil main cation were good predictors of main areas membership (Fig.13).

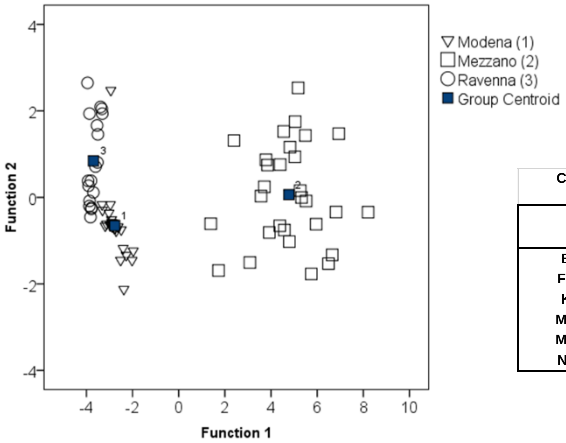



**Standardized Canonical Discriminant Function Coefficients**

| | Function | |
|---|---|---|
| | 1 | 2 |
| Ca | -2,391 | ,365 |
| Fe | -,048 | ,473 |
| Mn | 2,790 | ,374 |
| Na | -,006 | ,199 |
| P | -,047 | ,360 |
| S | 1,656 | -,316 |

**Figure 13 -Discriminant analyses. The two functions (F1 and F2) represents the projection of total Ca, Fe, Mn, Na, P and S of soils on a bi-dimensional space. The excluded elements from the analysis were strongly correlated to at least one of the elements used. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1 and F2. Predicted group membership was equal to 100% for Mo and Ra, while 77.6% for MEZ.**

Soluble macronutrients also showed differences among sites. B, Ca, K, Mg and Na were statistically higher in MEZ compare to both RA and MO. Soluble B was substatially statistically lower in RA compared to MO, while not true for soluble Ca, K, Mg and Na. Soluble Fe was statistically higher in RA compared to MO but not to MEZ (no differences between MEZ and MO either). Soluble P was statistically higher in MO compared to MEZ, while in RA it was barely detected (Fig.15). A discriminant analysis was performed also on the soluble elements extracted from the rhizosphere. The two functions (F1 and F2) represents the projection (normalized values) on a bi-dimensional space of the variables. Wilks' Lambda was significant (<0.001) for both F1 and F2 (low Wilks' lambda indicate greater discriminatory ability of the function). Coefficients with large absolute values correspond to variables with greater discriminating ability. F1: B > Mn >> Na, Mg, K, Fe; F2: Mn > Fe > B > K, Mg, Na. Predicted group membership was equal to 96.3% for group 1, 96.6% for group 2 and 66.7% for group 3. As a result of this analysis, Figure 14 shows how using soluble elements, it was possible only partially to predict areas membership.




**Canonical Discriminant Function Coefficients**

| | Function | |
|---|---|---|
| | 1 | 2 |
| B | 3,360 | -,142 |
| Fe | ,013 | ,434 |
| K | -,027 | ,026 |
| Mg | ,009 | ,003 |
| Mn | -1,063 | ,720 |
| Na | -,004 | -,010 |

**Figure 14 - Discriminant analyses. Total function extracted were four, here were presented just two. The two functions (F1 and F2) represents the projection of soluble B, Fe, K, Mg, Mn, Na in soils on a bi-dimensional space. The excluded cations from the analysis were strongly correlated to at least one of the elements used. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1. F2 was slightly lower sig. < 0.01. Predicted group membership was equal to 96.6% for Mezzano, 96.3% for Modena, 66.7% for Ravenna.**

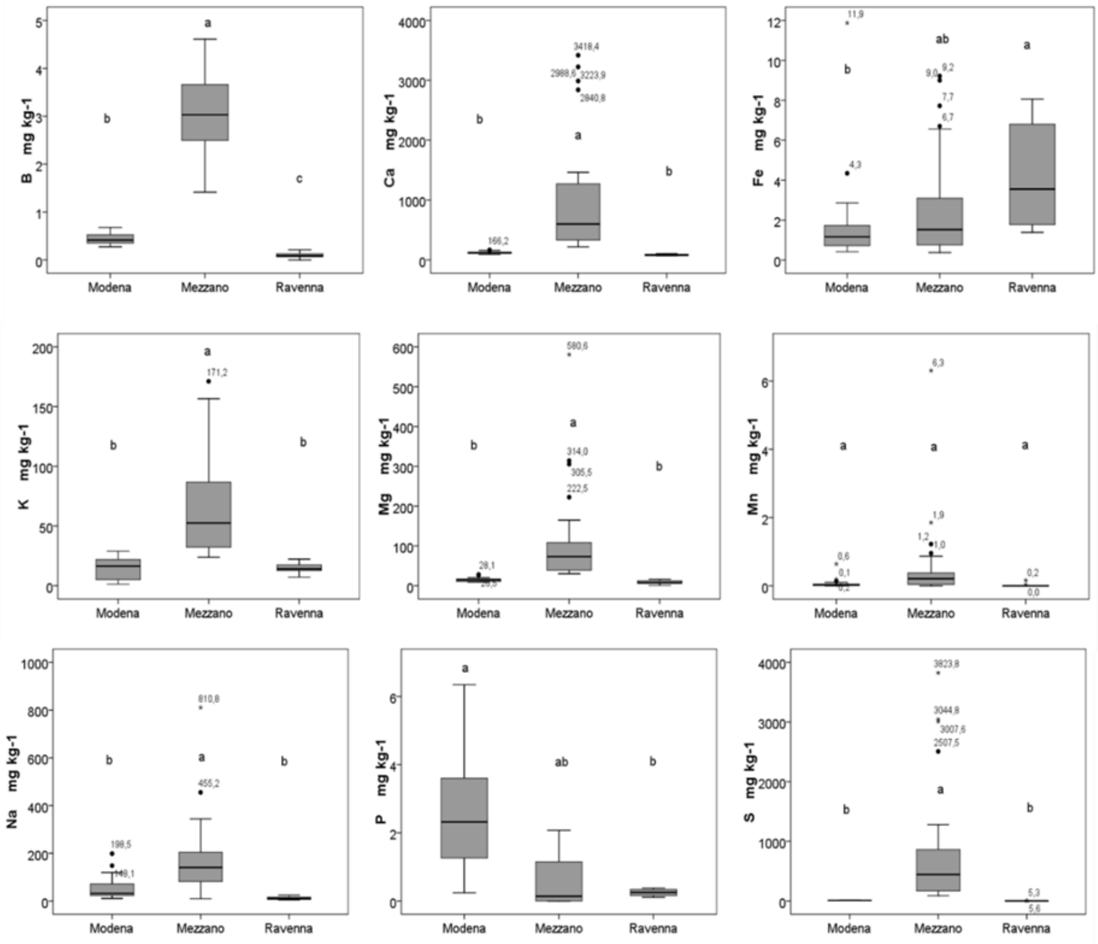
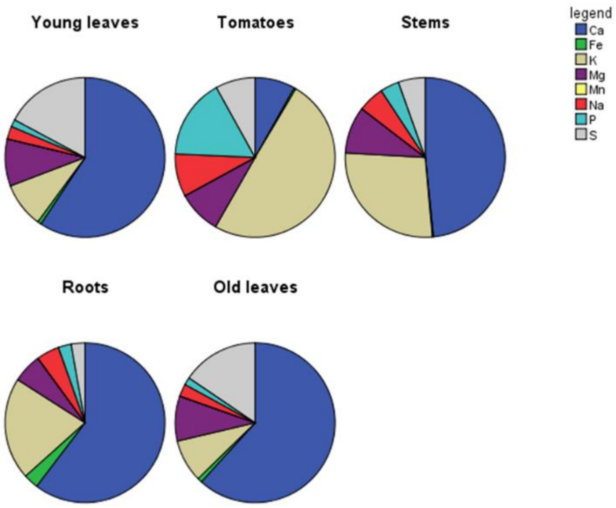



**Figure 15 - Boxplots of rhizosphere soluble macronutrients content. Different letters refer to statistically different values, decreasing from "a" to "c", obtained by One-way ANOVA, using main sites as factors, and Tuckey post-hoc test ($p < 0.05$).**




| *Old Levaes* | **Ca** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** |
|---|---|---|---|---|---|---|---|---|
| MO | a | a | a | a | a | a | b | a |
| MEZ | b | a | a | a | a | a | b | a |
| RA | ab | a | a | a | a | a | a | a |

| *Young Leaves* | **Ca** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** |
|---|---|---|---|---|---|---|---|---|
| MO | a | a | a | b | a | a | a | a |
| MEZ | a | a | a | b | a | a | a | a |
| RA | a | a | a | a | a | a | a | a |

| *Stems* | **Ca** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** |
|---|---|---|---|---|---|---|---|---|
| MO | a | a | ab | b | a | a | b | b |
| MEZ | a | a | b | b | a | a | b | a |
| RA | a | a | a | a | a | a | a | ab |

| *Fruits* | **Ca** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** |
|---|---|---|---|---|---|---|---|---|
| MO | b | a | a | a | a | a | a | a |
| MEZ | b | a | a | a | b | a | a | a |
| RA | a | a | a | a | a | a | a | b |

| *Roots* | **Ca** | **Fe** | **K** | **Mg** | **Mn** | **Na** | **P** | **S** |
|---|---|---|---|---|---|---|---|---|
| MO | a | a | b | a | a | a | b | b |
| MEZ | a | a | ab | a | b | a | ab | a |
| RA | a | a | a | a | a | a | a | b |

**Figure 16 - Pie charts representing %wt average values of macronutrients in different plant tissues, reported to 100%. Table shows results of One-way ANOVA, post-hoc Tuckey $p < 0.05$, for plant tissues, using main site as factors. Different letters refer to statistically different values, decreasing from "a" to "c".**

Considering macronutrients in plants' tissues (average values for every site with SD in supplementary materials, Table S6), Ca was the most concentrated in all tissues (about 50g $kg^{-1}$ in leaves, 15g $kg^{-1}$ in stems and 20g $kg^{-1}$ in roots) except for fruit (1g $kg^{-1}$). In fruits, in fact, the most concentrates cation was K (about 7g $kg^{-1}$). On the contrary, Fe was totally absent in fruits, while it was equally concentrated in all the other tissues (about 1g $kg^{-1}$). Mg, Na and S were higher in leaves (Mg from 5.6 to 13.2g $kg^{-1}$, Na from 1.1 to 2.7g $kg^{-1}$ and S from 5.9 to 19.2g $kg^{-1}$) than in the other tissues (about 1g $kg^{-1}$). K reached 7g $kg^{-1}$ in all al plant tissues (Fig.16).

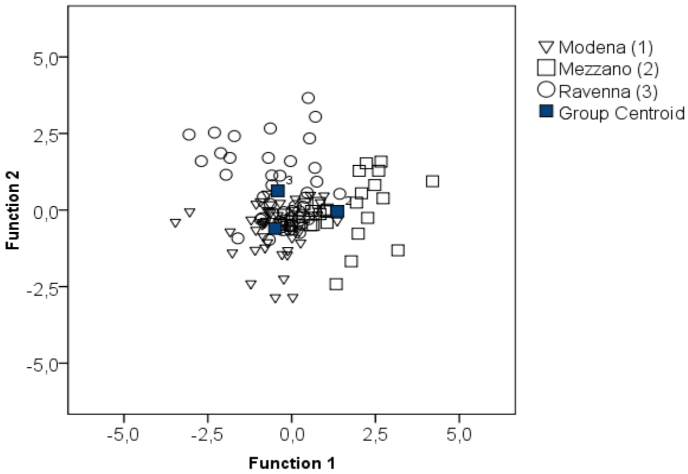
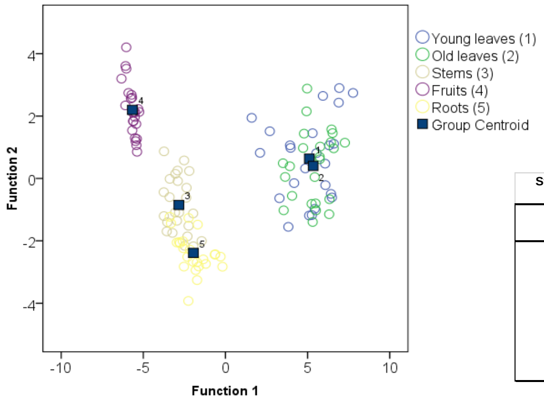



**Figure 17 - Discriminant analyses. Total function extracted were four, here were presented just two. The two functions (F1 and F2) represents the projection of total contents of Ca, Fe, K, Mg, Mn, Na, P and S in plant tissues on a bi-dimensional space. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1 and F2. Predicted group membership was equal to 63.3% for Mezzano, 62.2% for Modena, 51.1% for Ravenna.**

Some (few) statistical differences among sites were found in all plant tissues: Ca and P in old leaves; Mg in young leaves; S, P, Mg and K in stems; Ca, Mn and S in fruits; K, Mn, P and S in roots. Despite these differences, variables were not able to distinguish the three sites performing LDA (Fig.17).

On the contrary, using plant tissues as grouping variables two statistically significant functions were obtained. F1: Mg, S > P > Ca, Mn > K > Fe > Na; F2: Ca, S > Fe, P, Na > K > Mn, Mg. Old and young leaves showed membership to the same group. Predicted group membership was 100% for groups 3 and 4, 87.5% for group 5. Hence, using total concentration of macronutrients was possible to distinguish plant tissues but not three studied sites (Fig.18).




Standardized Canonical Discriminant Function Coefficients

| | Function 1 | Function 2 |
|---|---|---|
| Ca | ,664 | 1,836 |
| Fe | ,393 | -,434 |
| K | ,449 | -,263 |
| Mg | 1,551 | ,085 |
| Mn | -,629 | ,150 |
| Na | -,197 | ,455 |
| P | ,980 | ,444 |
| S | -1,523 | -1,835 |

**Figure 18 - Discriminant analyses. Total function extracted were four, here were presented just two. The two functions (F1 and F2) represents the projection of total contents of Ca, Fe, K, Mg, Mn, Na, P and S in plant tissues on a bi-dimensional space. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1 and F2. Predicted group membership was equal to 100% for stems and tomatoes, 87.5% for roots, 50% for old leaves and 45.8% for young leaves.**

Afterwards, also other analysed elements were included in all statistical analyses: Al, Mo did not show any difference in any tissue, B was higher in MEZ just for leaves, Ba was lower in MEZ for all tissues, Cr was lower in RA just for leaves, Cu showed lower values in RA for all tissues except stems, Li was higher in RA in al tissues besides roots, Ni was not detected in RA and MO stems while in MEZ leaves showed higher concentration, Pb showed higher concentration in MO and RA fruits, Sb was higher in MEZ stems, Sr was higher in in all RA tissues, Ti was higher in MEZ stems and old leaves, V was not detected in fruits and stems, while no differences were detected for other tissues, Zn was higher in MEZ stems, fruits and roots (Table 7). No elements reached concentration dangerous for human health in fruits.

Repetition of LDA of Figure 17 including all elements leaded to an increases of groups membership: MO 78.8% (+16.6%), MEZ 70.8% (+7.3%) and RA 78.9% (+27.8%). Coefficients with large absolute values correspond to variables with greater discriminating ability (Fig.19). F1: Al > Fe, Ca > Sr > Ti > B, Ba, Na, S > Li, Mg > Cr, Cu, K, Mn, Sb > Zn > P, Pb; F2: Fe > B, Al, Pb > Ba, Li, P, Sr > Ca, Cr, Zn > Ti > Cu, Mn, Na > K, Sb > Mg, S.

Repetition of LDA of Figure 18 leaded to changes of groups membership: young leaves 60.0% (+14.2%), old leaves 54.5% (+4.5%), stems 91.7% (-8.3%), fruit 100% (=), roots 91.7% (+4.2%).

Coefficients with large absolute values correspond to variables with greater discriminating ability (Fig.20). F1: Ca, Sr > Fe, Mg > K > Cu > B, Li > Mn, Pb > P > Ba, Ti > Na, S, Sb, Zn; F2: Sr > Mg > P > Zn > Ti, Al > Cu, Li > Cr > Ba > B, Fe, Na, Pb, S, Sb > Ca, Mn, K.

| *Old levaes* | **Al** | **B** | **Ba** | **Cr** | **Cu** | **Li** | **Mo** | **Ni** | **Pb** | **Sb** | **Sr** | **Ti** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MO | a | b | a | a | a | b | a | a | a | a | a | b | a | a |
| MEZ | a | a | b | a | a | ab | a | a | a | a | b | a | a | a |
| RA | a | ab | a | a | b | a | a | ab | a | a | a | ab | a | a |

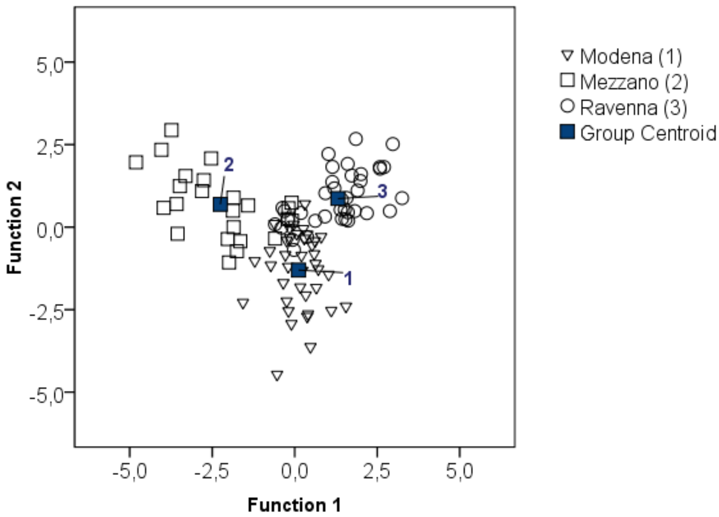
| *Young leaves* | **Al** | **B** | **Ba** | **Cr** | **Cu** | **Li** | **Mo** | **Ni** | **Pb** | **Sb** | **Sr** | **Ti** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MO | a | b | a | ab | a | b | a | b | a | a | b | a | a | a |
| MEZ | a | a | b | a | a | b | a | a | a | a | b | a | a | a |
| RA | a | ab | a | b | b | a | a | b | a | a | a | a | a | a |

| *Stems* | **Al** | **B** | **Ba** | **Cr** | **Cu** | **Li** | **Mo** | **Ni** | **Pb** | **Sb** | **Sr** | **Ti** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MO | a | a | a | a | a | b | a | n.d | a | ab | b | b | n.d | b |
| MEZ | a | a | b | a | a | b | a | a | a | a | b | a | n.d | ab |
| RA | a | a | a | a | a | a | a | n.d | a | b | a | ab | n.d | a |

| *Fruits* | **Al** | **B** | **Ba** | **Cr** | **Cu** | **Li** | **Mo** | **Ni** | **Pb** | **Sb** | **Sr** | **Ti** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MO | a | a | a | a | ab | b | a | a | a | a | a | a | n.d | ab |
| MEZ | a | a | b | a | a | b | a | a | b | a | b | a | n.d | a |
| RA | a | a | a | a | b | a | a | a | ab | a | ab | a | n.d | b |

| *Roots* | **Al** | **B** | **Ba** | **Cr** | **Cu** | **Li** | **Mo** | **Ni** | **Pb** | **Sb** | **Sr** | **Ti** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MO | a | a | a | a | a | a | a | a | a | a | a | a | a | b |
| MEZ | a | a | b | a | ab | a | a | a | a | a | a | a | a | a |
| RA | a | a | ab | a | b | a | a | a | a | a | a | a | a | ab |

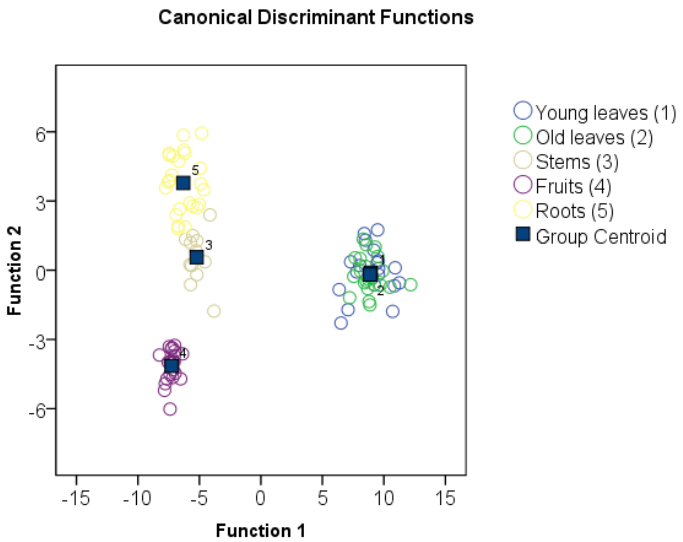
**Table 7 - Table shows results of One-way ANOVA, post-hoc Tuckey $p < 0.05$, for plant tissues, using main site as factors. Different letters refer to statistically different values, decreasing from “a” to “c”.**




**Standardized Canonical Discriminant Function Coefficients**

| | Function 1 | Function 2 |
|---|---|---|
| Al | 3,952 | 1,289 |
| B | -,765 | -1,541 |
| Ba | -,601 | ,574 |
| Ca | 2,740 | ,422 |
| Cr | -,311 | -,466 |
| Cu | -,232 | ,279 |
| Fe | -2,649 | -2,228 |
| K | -,331 | ,182 |
| Li | -,567 | ,582 |
| Mg | ,402 | -,045 |
| Mn | ,255 | ,247 |
| Na | ,666 | ,214 |
| P | -,079 | ,585 |
| Pb | -,091 | 1,222 |
| S | ,693 | -,092 |
| Sb | ,250 | ,184 |
| Sr | -2,080 | ,525 |
| Ti | -,890 | -,330 |
| Zn | -,193 | -,424 |

**Figure 20 - Discriminant analyses. Total function extracted were four, here were presented just two. The two functions (F1 and F2) represents the projection of total contents of all analysed elements in plant tissues on a bi-dimensional space. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1 and F2. Predicted group membership was equal to 78.8% for Mezzano, 70.8% for Modena, 78.9% for Ravenna.**




**Standardized Canonical Discriminant Function Coefficients**

| | Function 1 | Function 2 |
|---|---|---|
| Al | -,140 | ,541 |
| B | ,636 | ,165 |
| Ba | ,185 | ,225 |
| Ca | 1,834 | -,003 |
| Cr | ,062 | -,321 |
| Cu | ,750 | -,476 |
| Fe | -1,221 | -,172 |
| K | ,906 | ,033 |
| Li | ,675 | -,428 |
| Mg | 1,229 | -,819 |
| Mn | -,307 | ,001 |
| Na | ,033 | ,165 |
| P | ,265 | -,726 |
| Pb | ,396 | ,134 |
| S | -,050 | -,146 |
| Sb | ,019 | ,118 |
| Sr | -1,845 | 1,032 |
| Ti | ,182 | ,538 |
| Zn | -,036 | ,613 |

**Figure 19 - Discriminant analyses. Total function extracted were four, here were presented just two. The two functions (F1 and F2) represents the projection represents the projection of total contents of all analysed elements in plant tissues on a bi-dimensional space. Group centroids are the mean discriminant score for each group: the closer the group centroids, the more errors of classification likely will be. Wilks' Lambda was significant (<0.001) for both F1 and F2. Predicted group membership was equal to 100% for tomatoes, 91.7% for roots and stems, 54.5% for old leaves and 60% for young leaves.**

To conclude, correlation matrixes were performed between Cmic, Nmic and, total and soluble cations of rhizospheres. Cmic and Nmic were the biochemical parameters that shown the less variation in soils, thus the matrixes were intended to find possible other relations (Table 8).

Considering that composition of fruits did not show any significant variation through the study area, we decided to not perform further biochemical investigation on soils, for example at the end of cultivation period, because the composition seemed to be not influenced anyhow by pedoclimatic factors.

| | *Cmic* | *Nmic* | *Cmic* | *Nmic* |
|---|---|---|---|---|
| **Al** | .356$^{**}$ | -.110 | -.100 | .001 |
| **As** | .142 | .012 | | |
| **B** | .410$^{**}$ | -.054 | .073 | .199 |
| **Ba** | .187 | -.143 | -.006 | -.009 |
| **Be** | .357$^{**}$ | -.108 | | |
| **Ca** | -.193 | -.111 | -.035 | .331$^{**}$ |
| **Cd** | .301$^{**}$ | -.155 | | |
| **Co** | .190 | -.115 | | |
| **Cr** | .237$^{*}$ | .057 | | |
| **Cu** | .242$^{*}$ | -.074 | .238$^{*}$ | .039 |
| **Fe** | .330$^{**}$ | -.132 | -.232$^{*}$ | -.052 |
| **K** | .337$^{**}$ | -.147 | .083 | .282$^{*}$ |
| **Li** | .346$^{**}$ | -.110 | .327$^{**}$ | .038 |
| **Mg** | .172 | -.161 | .032 | .238$^{*}$ |
| **Mn** | .017 | -.279$^{*}$ | .060 | .027 |
| **Mo** | .103 | .391$^{**}$ | | |
| **Na** | .246$^{*}$ | -.045 | .120 | .024 |
| **Ni** | .175 | .017 | | |
| **P** | .373$^{**}$ | -.017 | .376$^{*}$ | .024 |
| **Pb** | .234$^{*}$ | -.043 | | |
| **S** | .065 | .367$^{**}$ | -.056 | .295$^{*}$ |
| **Sb** | .194 | -.053 | | |
| **Sn** | .236$^{*}$ | -.117 | | |
| **Sr** | -.137 | -.030 | -.063 | .349$^{**}$ |
| **Ti** | .086 | .190 | | |
| **V** | .361$^{**}$ | -.087 | | |
| **Zn** | .347$^{**}$ | -.132 | -.146 | -.258$^{*}$ |

**Table 8 - Correlation matrixes of soil total (white background) and soluble (grey background) cations, with Cmic and Nmic**

## ***Discussion***

The results showed that the study areas have well distinguished soil characteristics, which includes both physicochemical properties and total cations content. In fact, many rivers contributed to the formation of the plain, either draining water from the Alps (e.g. the Po River, which is the most important river flowing in the Italian territory) or from the Apennines chain (e.g. Reno River). The rivers distributed sediments with the peculiar mineralogical characteristics of their drainage basins (Amorosi et al., 2002; Bianchini et al., 2013, 2012) and not surprisingly, the soil physicochemical properties and total content of macronutrients were good predictors of main areas membership, according to discriminant analysis. High $CaCO_3$ contents of RA derived by Apennine rivers discharge basin, which mostly account of carbonates and marls, and high pH was a consequence of $CaCO_3$. In the cultivated layers of MEZ, the pH is buffered by the diffuse presence of shells even if the total $CaCO_3$ content was very low or absent, while below a certain depth the pH became strongly acid. High EC of MEZ was considered a heritage of former swamp brackish water (Di Giuseppe et al., 2014). Total content of main nutrients also clearly underlined the mineralogical differences of soils: SOM was the reason for high S contents in MEZ, clay for K and P in MO, carbonates and feldspar for Ca in RA. As expected, phosphorous, both total and soluble, was low in organic soils (MEZ is historically P-deficient, Boschi and Spallacci, 1974). Realise of soluble cations by agricultural soils did not clearly distinguished between MO and RA soils and strangely Na contents did not account for variation for MEZ either.

### *Physicochemical and biochemical properties of soils*

Ravenna soils presented low CEC, low OC, NT and Cmic content (not the best from an agronomical point of view). On the contrary, Modena and Mezzano soils, even if experienced a tough summer, showed characteristics (e.g. clay and OC, P total and soluble contents) that created a slightly more suitable environment for microbial population.

The positive correlations of total Na, K and Fe with microbial biomass were attributed to their higher contents in MEZ and MO. While the positive correlation of some heavy metals (Cr, V, Zn, Pb, Cd) had to be attributed to their presence in the Alpine sediments that in this case were represented by MO and MEZ. The correlation of soluble cations with microbial biomass was poor because Cmic and Nmic of MEZ were not as high as expected, and probably it could be considered as a negative impact of salinity on these soils.

Strangely, according to the IBF, the combination of biological parameters resulted in "good health status" scores, which can be interpreted as influence of NPK fertilization that enhances microbial activity. In fact, considering Cmic/Corg, that can be used to understand if land degradation processes are hitting the studied lands (Lagomarsino et al., 2009), three completely different equilibrium status were described. As a matter of fact, the three sites did also produce different quantities of tomatoes, with Mezzano being the less productive and Modena the most. It seemed that thinner soils texture had a positive impact on production of tomato HEINZ 1015, in fact among MEZ sites, MEZ3 was the most productive, and among RA sites, RA1 was. Hence, it was clear that comparable results of the IBF must not be taken as a positive result but as indication of an artificial effect of fertilization (or probably not applicable to sites, as MEZ, with high SOM that may follow different equilibrium and trends of potentiality). Specifically, SOM was very high in MEZ and very low in RA. In MO, SOM contents were much lower than MEZ but still sufficiently high to be considered as good contents. SOM did exert a certain influence on microbial biomass, as underlined by Pearson correlation coefficients of OC and NT, but high SOM content of MEZ did not lead to a statistical difference of Cmic and Nmic compared to other soils. This is possibly due to high amount of recalcitrant SOM in peaty soils, as ligninic material or plant residues, which are less suited for microbial activity, highlighted also by the $\delta^{13}C$ (De Nobili et al., 2008). While, statistical differences found between RA and MO microbial biomass is probable due to clay and SOM contents (Insam et al., 1989). These results were partially unexpected, considered also the significant differences in crop rotation, pH and EC (Insam et al., 1989; McDaniel et al., 2014; Wardle, 1998). The reasons of the slightly higher Cmic of MO3 could be found in the fact that this field was the only one to which was added pig manure among the studied plots (Insam et al., 1989). Nevertheless, such a constrained microbial population had to carry on all biological fertility, underlined by high $qCO_2$, which means excessive and uncontrolled $CO_2$ emissions. High metabolic activities could be attributed to recently added easily degradable substrate (Insam, 1990) or to conditions of stress, such as low pH (Anderson and Domsch, 1993). All sites showed high quotients reflecting instable systems or stress conditions, with MEZ showing the significantly highest values. Finally, the qM was high in all sites, that means that soils contained easy degradable organic matter, that according to the C/N of SOM, in RA and MO soils it was mainly derived from NPK fertilization. However, C/N of Mezzano's soils was high, corresponding to slow mineralization processes, which was in contrast with the high qM. Thus, it could support the idea of microbial activity sustained just thanks to chemical fertilization. Moreover, according to the negative correlation between microbial C:N ratio and SOM C:N ratio, the increasing recalcitrance of SOM in MEZ was coupled with a microbial population more represented by bacteria communities, while fungi are considered as those skilled for degradation of recalcitrant SOM (Nielsen et al., 2015). Considering the $\delta^{13}C$, that may give insights on recalcitrance and history of SOM, as expected all three areas have ratios derived from $C_3$ plants decomposition (Zaccone et al., 2011) even if the higher ratios in Modena seem to be in contrast with the idea of higher protection that clay plus silt offer to SOM against microbial decomposition – mostly if compared to Ravenna's values (Six et al. 2002). Nevertheless, the fields of Modena lay far away from the seashore, thus have been used for cultivation for a longer period compared to the other sites and thus undergone a longer period of exposition to high grades of decomposition. Cmic/Pmic and Nmic/Pmic did not lead to interpretable results due to their widespread ranges.

*Tomato plants*

According to our results, macronutrients showed no peculiar mineral composition in any part of the plants in relation to site of production, with no possibilities of distinguish whether it was due to intensive crop management or specific plant requirements or bizarre combination of coincidences. Tomatoes (fruits) macronutrients concentration agreed with other studies (Hernandez Suarez et al., 2007, Erba et al., 2013): K was the main cation, followed by P and Mg. No anomalies were found for S and Na concentration, it meant that salinity level and SOM of MEZ did not influence uptake of the elements. The higher content of Ca in RA tomatoes was probably due to high Ca and $CaCO_3$ in rhizospheres. However, contrary to what found in Hernandez Suarez et al. (2007), the region of production, whether near to the sea or faraway, did not affect macronutrient (or just extremely slightly) concentration. Interesting was the fact that sodium concentration of MEZ soils did not influence plants tissues stoichiometry, hence Na concentration was not necessarily related to bio-availability of the element. What it seemed from the results was that tomatoes HEINZ 1015 had a specific element composition and stoichiometry reflected nutrients requirements. Other way around, in other tissues macronutrients showed some statistical differences and clearly distinguished sites of production. When all detected elements were considered for statistical analyses, site-specific fingerprints came at light. Contrary to expectations, Ni, Cr and V were not determinant in differentiate sites, so probably bioavailability of these elements is low for tomatoes HEINZ 1015 in these soils. Ba, Cu, Li, Sr and Zn showed the biggest differences through sites and tissues.

*Final Remarks*

Actual differences in suitability of these sites to this specific cultivar of tomato were mostly evident in production per hectares then all other indicators: Modena produced more than other sites and Mezzano less. It meant that even if the biofertility indexes described good quality status and all soils reacted similarly to conduction from a biochemical point of view, it was evident that production was not optimal in Mezzano Valley and a different conduction may be considered. Mezzano Valley has been reclaimed about 40 years ago and it may be considered as the youngest site and thus, the highest metabolic quotient consistent with the hypothesis of the energetic optimization during ecosystems development (Anderson and Domsch, 1990). Therefore, Mezzano Valley is probably following a stabilization path after reclamation and microbial community is slowly acclimating with the new environment, even if intensive agricultural management weary it. Moreover, the recalcitrance of SOM and the low content of fungi reasonably contributed to low microbial total content, even if the presence of soluble Na may increase DOM solubility (Mavi et al., 2012) and decrease its sorption to soil (Setia et al., 2013). Nevertheless, respiration rates were anyway higher compared to other agricultural lands and this situation is clearly in contrast with the necessity of decreasing greenhouse gasses emission. The area also requires constant monitoring for being kept dry, from both rainwater accumulation and groundwater rise, and for maintaining level of salinity suitable for lands cultivation. Recently, regeneration of wetland has been a very fashion approach, anyway the processes are expensive and may not assure good levels of restored ecosystem functions (Moreno-Mateos et al., 2015, 2012). Thus, any plan of land-use change in Mezzano Valley must carefully assess all negative and positive aspects, considering also greenhouse gasses emissions.

Ravenna and Modena soils require an increase of stable SOM contents in order to improve soils structure and thus help microbial populations to ameliorate their capacity to provide nutrients to plants and increase their resilience to adverse environmental condition, so that inputs of fertilizers and ammendants may gradually decrease (Bronick and Lal, 2005). A strategy is to better plan crop rotation with implementation of cover crops either in the fallow or in contemporary to cultivation.

## *Conclusion*

Concluding, the idea is that pedo-environmental superimposition on soil health was effective just in the range that land management allowed it and more, opinion of the author is that Mezzano Valley must be considered separately from the other sites due to its peculiar pedological characteristics. Tomatoes' fruits HEINZ 1015 were not affected by different pedological substrate and environmental condition of growing season, even if production per hectares differed widely from site to site. From one sight, it can be pleasing to researcher that lately were committed to find solution for improving nutritional values of crops and reducing bioaccumulation toxic element. From another sight, these should not directly legitimize inappropriate lands conduction. In fact, all three studied sites need improvement in management and it could be also claimed that Mezzano Valley represent an important source of greenhouse gasses if not managed according to pedoclimatic conditions and land vocation, and actual strategies for greenhouse gasses reduction are weak and unsatisfying, thus big steps towards sustainability must be done.

# Supplementary Materials I

**S 1 - Plant rotation, fertilization strategies, production Qi/Ha for year 2015 and average brix degrees of 2015 for each studied field**

| | ***MO1*** | | ***Qi/Ha*** | ***Brix °*** | ***MO2*** | | ***Qi/Ha*** | ***Brix °*** | ***MO3*** | | ***Qi/Ha*** | ***Brix °*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *2015* | Tomato | 1015 | 5.11 | *2015* | Tomato | 980 | 5.27 | *2015* | Tomato | 905 | 5.52 |
| | *2014* | Wheat | | | *2014* | Wheat | | | *2014* | Sorghum | | |
| *Fertilization* | NPK | | | | NPK | | | | NPK+ pig manure | | | |
| | ***MEZ1*** | | | | ***MEZ 2*** | | | | ***MEZ 3*** | | | |
| | *2015* | Tomato | 654 | | *2015* | Tomato | 627 | | *2015* | Tomato | 743 | |
| | *2014* | Corn | | | *2014* | Tomato | | | *2014* | Lolium multifiorum | | |
| | *2013* | Pea/soy | | | *2013* | Soy | | | *2013* | Lolium multifiorum | | |
| | *2012* | Corn | | | *2012* | Wheat | | | *2012* | Corn | | |
| | *2011* | Pea/soy | | | *2011* | Wheat | | | *2011* | Corn | | |
| *Fertilization* | NPK | | | | NPK | | | | NPK | | | |
| | ***RA1*** | | | | ***RA1*** | | | | | | | |
| | *2015* | Tomato | 835 | | *2015* | Tomato | 627 | | | | | |
| | *2014* | Common wheat | | | *2014* | Common wheat | | | | | | |
| | *2013* | Alfalfa | | | *2013* | Alfalfa | | | | | | |
| | *2012* | Alfalfa | | | *2012* | Alfalfa | | | | | | |
| | *2011* | Alfalfa | | | *2011* | Alfalfa | | | | | | |
| *Fertilization* | NPK | | | | NPK | | | | | | | |

**S 2 – Soils' profiles descriptions.**

| MO1 | MO2 |
|---|---|
| **Crust:** 0-2cm - Horizon boundary**:** clear, wavy Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5YR 4/2) moist. Texture: Clay. Strong medium angular blocky. Reaction Neutral (pH=7.6). Slightly effervescent with 1N HCl. | **Crust:** 0-2 cm Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clayey silt. Strong, fine and medium, sub-angular blocky. Scarce vegetal rests. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. |
| **Ap1**: 2-10 cm – Horizon boundary: clear, wavy. Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5YR 4/2) moist. Texture: Clay. Strong massive. Reaction neutral (pH=7.7). Slightly effervescent with 1N HCl. | **Ap1**: 2-15 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and olive brown (2,5Y 4/3) moist. Texture: clayey silt. Strong, massive. Reaction slightly alkaline (pH=7.5). Slightly Effervescent with 1N HCl. |
| **Ap2**: 10-60 cm – Horizon boundary: clear, wavy. Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction neutral (pH=7.7). Slightly effervescent with 1N HCl. | **Ap2**: 15-60 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clayey silt. Strong, fine and medium, sub-angular blocky. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. |
| **Bssg1:** 60-100 cm – Horizon boundary: gradual, wavy. Colour dark greyish brown (2,5Y 4/2) dry and very dark greyish brown (2,5Y 3/2) moist. Strong, medium, angular blocky. Reaction neutral (pH = 7.7). Slightly effervescent with 1N HCl.. | **Bssg1:** 60-110 cm – Horizon boundary: gradual, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction slightly alkaline (pH = 7.6). Slightly effervescent with 1N HCl. |
| **Bssg2** : 100-120 cm – Horizon boundary: clear, wavy. Colour light yellowish brown (2.5Y 6/3) dry and olive brown (2.5Y 4/3) moist. Texture: loam silt clay. Strong, sub-angular blocky. Reaction alkaline (pH = 8.0). Slightly with 1N HCl. | **Bssg2:** 110-125 cm – Horizon boundary: gradual, wavy. Colour: light brownish grey (2.5Y 6/2), greyish brown (2,5Y 5/2), light olive brown (2,5Y 5/4) dry and dark grey (2,5Y 4/1) moist. Texture: clay. Strong, medium, polyhedral blocky. Reaction slightly alkaline (pH = 7.6). Slightly effervescent with 1N HCl. |
| **Soil Taxonomy**<br>(2014) Aeric Endoaquerts fine, mixed, active, mesic<br>**WRB**<br>(2014) Irragric Vertisols (Gleyic) | **Soil Taxonomy**<br>(2014) Ustic Endoaquerts fine, mixed, active, mesic<br>**WRB**<br>(2014) Irragric Vertisols (Gleyic, Calcaric) |

| MO1 | MO2 |
|---|---|
| **Crust:** 0-2cm - Horizon boundary**:** clear, wavy Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5YR 4/2) moist. Texture: Clay. Strong medium angular blocky. Reaction Neutral (pH=7.6). Slightly effervescent with 1N HCl. | **Crust:** 0-2 cm Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clayey silt. Strong, fine and medium, sub-angular blocky. Scarce vegetal rests. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. |
| **Ap1**: 2-10 cm – Horizon boundary: clear, wavy. Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5YR 4/2) moist. Texture: Clay. Strong massive. Reaction neutral (pH=7.7). Slightly effervescent with 1N HCl. | **Ap1**: 2-15 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and olive brown (2,5Y 4/3) moist. Texture: clayey silt. Strong, massive. Reaction slightly alkaline (pH=7.5). Slightly Effervescent with 1N HCl. |
| **Ap2**: 10-60 cm – Horizon boundary: clear, wavy. Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction neutral (pH=7.7). Slightly effervescent with 1N HCl. | **Ap2**: 15-60 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clayey silt. Strong, fine and medium, sub-angular blocky. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. |
| **Bssg1:** 60-100 cm – Horizon boundary: gradual, wavy. Colour dark greyish brown (2,5Y 4/2) dry and very dark greyish brown (2,5Y 3/2) moist. Strong, medium, angular blocky. Reaction neutral (pH = 7.7). Slightly effervescent with 1N HCl.. | **Bssg1:** 60-110 cm – Horizon boundary: gradual, wavy. Colour: light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction slightly alkaline (pH = 7.6). Slightly effervescent with 1N HCl. |
| **Bssg2** : 100-120 cm – Horizon boundary: clear, wavy. Colour light yellowish brown (2.5Y 6/3) dry and olive brown (2.5Y 4/3) moist. Texture: loam silt clay. Strong, sub-angular blocky. Reaction alkaline (pH = 8.0). Slightly with 1N HCl. | **Bssg2:** 110-125 cm – Horizon boundary: gradual, wavy. Colour: light brownish grey (2.5Y 6/2), greyish brown (2,5Y 5/2), light olive brown (2,5Y 5/4) dry and dark grey (2,5Y 4/1) moist. Texture: clay. Strong, medium, polyhedral blocky. Reaction slightly alkaline (pH = 7.6). Slightly effervescent with 1N HCl. |
| **Soil Taxonomy**<br>(2014) Aeric Endoaquerts fine, mixed, active, mesic<br>**WRB**<br>(2014) Irragric Vertisols (Gleyic) | **Soil Taxonomy**<br>(2014) Ustic Endoaquerts fine, mixed, active, mesic<br>**WRB**<br>(2014) Irragric Vertisols (Gleyic, Calcaric) |

| MO3 | MEZ1 |
|---|---|
| **Crust:** 0-2 cm Horizon boundary: clear, wavy. Colour: grey (2,5Y 6/1) dry and dark grey (2,5Y 4/1). Texture: clay. Strong medium angular blocky. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. | **Oap1**: 0-10 cm – Horizon boundary: clear, wavy. Colour very dark grey (10YR 3/1) dry and black (10YR 2/1) moist. Weak, fine, clumpy. Roots and pores scarce, fine. Reaction neutral (pH=7.1). Not effervescent with 1N HCl. |
| **Ap1**: 2-10 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (2,5Y 6/2) dry and very dark greyish brown (2,5Y 3/2) moist. Texture: clay. Strong massive. Reaction slightly alkaline (pH=7.6). Slightly effervescent with 1N HCl. | **Oap2**: 10-30 cm – Horizon boundary: clear, wavy. Colour very dark grey (10YR 3/1) dry and black (10YR 2/1) moist. Weak, fine, angular blocky. Roots and pores scarce, fine. Shells fine and scarce. Reaction neutral (pH=7.1). Not effervescent with 1N HCl. |
| **Ap2**: 10-60 cm –Horizon boundary: clear, wavy. Colour greyish brown (2,5Y 5/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction neutral (pH=7.4). Slightly effervescent with 1N HCl. | **Oa3:** 30-60 cm – Horizon boundary: clear, wavy. Colour dark grey (10YR 4/1) and light grey (10YR 7/2) dry and black (10YR 2/1) moist. Weak, fine, clumpy. Common faints brownish yellow (10YR 6/8). Reaction neutral (pH=6.9). Not effervescent with 1N HCl. |
| **Bssg1:** 60-90 cm – Horizon boundary: gradual, wavy. Colour: grey (2,5Y 6/1) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Very strong, fine, polyhedral blocky. Reaction slightly alkaline (pH = 7.7). Slightly effervescent with 1N HCl. | **Cg1**: 60-80 cm – Horizon boundary: clear, wavy. Principal colour: grey (10YR 4/1) dry and black (10YR 2/1) moist. Secondary colour: light grey (10YR 7/2) dry and greyish brown (10YR 5/2) Weak, clumpy. Common faints brownish yellow (10YR 6/8). Reaction neutral (pH=7.0). Not effervescent with 1N HCl. |
| **Bssg2:** 90-110 cm – Horizon boundary: gradual, wavy. Colour light brownish grey (2,5Y 6/2) dry and dark greyish brown (2,5Y 4/2) moist. Texture: clay. Strong, fine and medium, sub-angular blocky. Reaction slightly alkaline (pH = 7.7). Moderately effervescent with 1N HCl. | **Cg2:** 80-130 cm — Horizon boundary: clear, wavy. Colour light brownish grey (2,5YR 5/2) dry and black (10YR 2/1) moist. Texture: Sand. Loose. Roots and pores scarce, fine. Shells fine and scarce. Reaction slightly alkaline (pH=7.5). Not effervescent with 1N HCl. |
| **Cg: >110** cm – Horizon boundary: clear, wavy. Colour: greyish brown (2,5Y 5/2) dry and dark grey (2,5Y 4/1) moist. Texture: silt. Strong, polyhedral, blocky. Reaction slightly alkaline (pH=7,7). Moderately effervescent with 1N HCl. | **Soil Taxonomy**<br>(2014) Typic Sulfisaprists sandy, mixed, euic, mesic<br>**WRB**<br>(2014) Thionic Sapric Histosols (Sulfidic) |
| **Soil Taxonomy**<br>(2014) Aeric Endoaquerts fine, mixed, active, mesic<br>**WRB**<br>(2014) Irragric Vertisols (Gleyic, Calcaric) | |

| MEZ2 | MEZ3 |
|---|---|
| **Crust:** 0-1cm Horizon boundary: clear, wavy. Colour very dark grey (10YR 3/1) and grey (10YR 5/1) dry and black (10YR 2/1) moist. Weak, fine, clumpy. Shells scarce, fine. Reaction slightly acid (pH=6.7). Not effervescent with 1N HCl. | **Crust:** 0-0.5cm - Horizon boundary: clear, wavy. Colour: grey (2,5Y 5/1) dry and black (2,5Y 2/1) moist. Strong, medium, angular blocky. Common shells. Reaction slightly alkaline (pH=7.5). Not effervescent with 1N HCl. |
| **Oap1**: 1-5 cm – Horizon boundary: clear, wavy. Colour dark grey (10YR 4/1) dry and black (10YR 2/1) moist. Weak, fine, clumpy. Roots and pores scarce, fine. Shells fine and scarce. Reaction slightly acid (pH=6.7). Not effervescent with 1N HCl. | **Oap1**: 0.5-10 cm – Horizon boundary: clear, wavy. Colour: light brownish grey (10YR 5/1) dry and very dark grey/black (2,5Y 2,5/1) moist. Massive, moderately strong. Common fine organic rests. Shells common and fine. Reaction slightly alkaline (pH=7.5). Not effervescent with 1N HCl. |
| **Oap2**: 5-20 cm – Horizon boundary: clear, wavy. Colour dark grey (10YR 4/1) dry and black (10YR 2/1) moist. Moderately strong, massive. Roots and pores scarce, fine. Shells fine and scarce. Reaction slightly acid (pH=6.6). Not effervescent with 1N HCl. | **Oap2 (Ap1)**: 10-45 cm – Horizon boundary: clear, wavy. Colour: greyish brown (2,5Y 5/1) dry and very dark greyish brown (2,5Y 3/1) moist. Moderately strong, fine and medium, polyhedral blocky. Common shells. Scarce organic rests fine. Reaction neutral/slightly alkaline (pH=7.6). Not effervescent with 1N HCl. |
| **Oap3:** 20-50 cm – Horizon boundary: clear, wavy. Colour dark grey (10YR 4/1) dry and black (10YR 2/1) moist. Moderately strong, medium, angular blocky. Roots and pores scarce, fine. Shells fine and scarce. Reaction acid (pH=5.9). Not effervescent with 1N HCl. | **Cg1:** 45-70 cm – Horizon boundary: gradual, wavy. Grey (2,5Y 6/1) dry and very dark grey (2,5Y 3/2) moist. Strong, fine, polyhedral blocky. Common faints yellowish red 5YR 5/8. Reaction slightly alkaline (pH = 7.3). Not effervescent with 1N HCl. |
| **Oa:** 50-60 cm –Peat level very dark grey (10YR 2/1) and strong brown (7,5YR 5/8). Reaction acid (pH=4.7) | **Cg2:** 70-85 cm – Horizon boundary: gradual, wavy. Colour light brownish grey (2,5Y 6/2) dry and very dark grey (2,5Y 3/2) moist. Strong, medium, polyhedral blocky. Reaction slightly alkaline (pH = 7.7). Not effervescent with 1N HCl. |
| **Oa:** 60-80 cm – Horizon boundary: clear, wavy. Colour very dark grey (5YR 3/1) dry and black (10YR 2/1) moist. Soft, medium, polyhedral blocky. Reaction acid (pH=4.6). Not effervescent with 1N HCl. | **Soil Taxonomy**<br>(2014) Humaqueptic Fluvaquents, mesic<br>**WRB**<br>(2014) Histic Fluvisol (Siltic) |
| **Cg:** >80 cm – Horizon boundary: clear, wavy. Colour grey (10YR 5/1) and very dark grey (10YR 3/1) dry and black (10YR 2/1) moist. Moderately hard, medium, polyhedral blocky. Reaction acid (pH=4.4). Not effervescent with 1N HCl. | |
| **Soil Taxonomy**<br>(2014) Typic Sulfisaprists, euic, mesic<br>**WRB**<br>(2014) Thionic Sapric Histosols (Sulfidic) | |
| | |

| RA1 | RA2 |
|---|---|
| **Crust:** 0-0.5 cm Horizon boundary: clear, wavy. Colour light grey (2,5Y 7/2) dry and dark greyish brown (2,5YR 4/2) moist. Texture: sandy loam. Weak, medium, angular blocky. Common shells. Reaction alkaline (pH=8.1). Strongly effervescent with 1N HCl. | **Crust:** 0-0.5cm -- Horizon boundary: clear, wavy. Colour light olive brown (2,5Y 5/3) dry and olive brown (2,5Y 4/3) moist. Texture: sandy loam. Weak, fine, angular blocky. Reaction alkaline (pH=8.3). Effervescent with 1N HCl**.** |
| **Ap1**: 0.5-10 cm – Horizon boundary: clear, wavy. Colour light grey (10YR 7/2) dry and dark greyish brown (10YR 4/2) moist**.** Texture: sandy loam. Weak, fine, clumpy. Common shells. Reaction alkaline (pH=8.2). Strongly effervescent with 1N HCl. | **Ap1**: 0.5-10 cm – Horizon boundary: clear, wavy. Colour olive brown (2,5Y 4/3) dry and dark olive brown (2.5Y 3/3) moist. Texture: sandy loam. Weak, fine, clumpy. Reaction alkaline (pH=8.4). Effervescent with 1N HCl. |
| **Ap2**: 10-50 cm – Horizon boundary: clear, wavy. Colour light grey (10YR 7/2) dry and dark greyish brown (10YR 4/2) moist. Texture: loam. Strong, fine and medium, sub-angular blocky. Common shells. Reaction alkaline (pH=8.2). Strongly effervescent with 1N HCl. | **Ap2**: 10-70 cm – Horizon boundary: clear, wavy. Colour olive brown (2,5Y 4/3) dry and dark olive brown (2,5Y 3/3) moist. Texture: sandy loam. Weak, fine, clumpy . Reaction alkaline (pH=8.4). Effervescent with 1N HCl. |
| **B:** 50-100 cm – Horizon boundary: clear, wavy. Colour light grey (2,5Y 7/2) dry and dark greyish brown (2.5YR 4/2) moist**.** Texture**:** silty loam. Weak, fine, angular blocky. Common, faint, yellowish red (2,5Y 6/8). Common shells. Reaction alkaline (pH = 8.6). Strongly effervescent with 1N HCl. | **C1:** 70-90 cm – Horizon boundary: clear, wavy. Colour pale brown (2,5Y 7/3) dry and light olive brown (2,5Y 5/3) moist. Texture: sandy loam. Weak, fine, clumpy. Common yellowish brown (10YR 5/8) faints. Reaction alkaline (pH=8.6). Effervescent with 1N HCl. |
| **Cg1:**: 100-136 cm – Horizon boundary: clear, wavy. Colour light greenish grey (GLEY1 7/10Y) dry grey (GLEY1 5/N) moist. Texture: clay. Very strong, fine, angular blocky. Many, distinct, yellowish brown (10YR 5/8) dry ferriargillans. Reaction basic (pH = 8.9). Strongly effervescent with 1N HCl. | **C2:** 90-120 cm Horizon boundary: clear, wavy. Colour pale brown (2,5Y 7/3) dry and light olive brown (2,5Y 5/3) moist. Texture: sandy loam. Weak, fine, clumpy. Common yellowish brown (10YR 5/8) faints. Reaction alkaline (pH=8.7). Effervescent with 1N HCl. |
| **Cg2:** >136 cm – Horizon boundary: wavy. Colour light greenish grey (GLEY1 7/10Y) dry grey (GLEY1 5/N) moist. Clay with thin sand interlayers. Moderate, fine, sub-angular blocky. Reaction basic (pH=8.8). Strongly effervescent with 1N HCl. | **Soil Taxonomy**<br>(2014) Typic Ustipsamments, mixed, mesic<br>**WRB**<br>(2014) Fluvic Arenosols |
| **Soil Taxonomy**<br>(2014) Aquic Haplustepts fine silty, mixed, superactive, mesic<br>**WRB**<br>(2014) Endogleyic Fluvic Cambisols (Calcaric, Siltic) | |

**S 3 - Soil profiles average characteristics.**

| | *Modena* | Depth | pH | EC 1:2.5 | $CaCO_3$ | Sand | Silt | Clay | CEC | Ca | K | Mg | Na | O.M. | OC | NT | C/N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Horizon*** | **cm** | | **µS cm$^{-1}$** | **%** | **%** | **%** | **%** | | **Cmol$_{(+)}$ kg$^{-1}$** | | | | **%** | **g kg$^{-1}$** | **g kg$^{-1}$** | |
| MO1 | **Crust** | ***0 - 2*** | 7.8 | 330 | 4.5 | 6 | 36 | 58 | 60.0 | 21.2 | 0.4 | 1.9 | 0.3 | 2.7 | 15.7 | 2.1 | 7.3 |
| | **Ap1** | ***2 - 10*** | 7.7 | 345 | 4.0 | 5 | 30 | 65 | 51.8 | 21.1 | 0.2 | 2.0 | 0.4 | 2.7 | 15.5 | 2.2 | 7.1 |
| | **Ap2** | ***10 - 60*** | 7.8 | 353 | 4.5 | 5 | 47 | 48 | 52.8 | 20.9 | 0.3 | 2.2 | 0.6 | 2.7 | 15.6 | 2.2 | 7.3 |
| | **Bssg1** | ***60 - 100*** | 7.7 | 1028 | 2.7 | 5 | 32 | 63 | 60.5 | 21.0 | 0.2 | 4.1 | 2.6 | 2.5 | 14.7 | 1.8 | 8.0 |
| | **Bssg2** | ***100 - 120*** | 8.0 | 825 | 8.4 | 15 | 52 | 32 | 35.9 | 10.8 | 0.1 | 2.3 | 2.0 | 0.9 | 5.0 | 0.7 | 6.8 |
| MO2 | **Crust** | ***0 - 2*** | 7.8 | 356 | 9.8 | 5 | 51 | 44 | 31.7 | 12.6 | 0.4 | 1.4 | 0.0 | 2.2 | 12.7 | 1.7 | 7.4 |
| | **Ap1** | ***2 - 15*** | 7.8 | 288 | 8.7 | 5 | 64 | 31 | 34.4 | 11.7 | 0.4 | 1.6 | 0.0 | 2.1 | 12.3 | 1.8 | 7.0 |
| | **Ap2** | ***15 - 60*** | 7.8 | 311 | 10.5 | 4 | 51 | 45 | 29.9 | 12.0 | 0.3 | 1.7 | 0.1 | 2.2 | 12.6 | 1.7 | 7.3 |
| | **Bssg1** | ***60 - 110*** | 7.6 | 398 | 12.5 | 9 | 38 | 54 | 34.6 | 11.3 | 0.2 | 2.6 | 0.2 | 2.0 | 11.7 | 1.6 | 7.1 |
| | **Bssg2** | ***110 - 125*** | 7.6 | 487 | 7.3 | 2 | 30 | 68 | 31.1 | 11.1 | 0.1 | 2.3 | 2.0 | 1.2 | 7.1 | 1.1 | 6.4 |
| MO3 | **Crust** | ***0 - 2*** | 7.5 | 472 | 8.7 | 4 | 51 | 45 | 47.9 | 19.1 | 0.6 | 3.2 | 0.1 | 1.9 | 16.2 | 1.5 | 7.0 |
| | **Ap1** | ***2 - 10*** | 7.5 | 396 | 8.4 | 5 | 34 | 61 | 46.9 | 18.5 | 0.6 | 3.2 | 0.2 | 2.7 | 15.4 | 2.2 | 7.1 |
| | **Ap2** | ***10 - 60*** | 7.7 | 316 | 8.0 | 4 | 34 | 62 | 47.6 | 19.1 | 0.6 | 3.2 | 0.2 | 2.6 | 14.9 | 2.1 | 7.1 |
| | **Bssg1** | ***60 - 90*** | 7.7 | 586 | 9.8 | 5 | 34 | 61 | 44.9 | 18.0 | 0.3 | 3.5 | 1.0 | 2.2 | 12.6 | 1.8 | 6.9 |
| | **Bssg2** | ***90 - 110*** | 7.7 | 1304 | 13.9 | 1 | 41 | 58 | 38.2 | 13.3 | 0.3 | 4.6 | 2.8 | 1.2 | 7.2 | 1.2 | 6.0 |
| | **Cg** | ***>110*** | 7.7 | 1792 | 15.29 | 0 | 100 | 0 | 37.2 | 11.9 | 0.3 | 5.2 | 3.6 | 1.1 | 6.6 | 1.0 | 6.4 |
| | ***Mezzano Valley*** | **Depth** | **pH** | **EC 1:2.5** | **$CaCO_3$** | **Sand** | **Silt** | **Clay** | **CEC** | **Ca** | **K** | **Mg** | **Na** | **O.M.** | **OC** | **NT** | **C/N** |
| | ***Horizon*** | **cm** | | **µS cm$^{-1}$** | **%** | **%** | **%** | **%** | | **Cmol$_{(+)}$ kg$^{-1}$** | | | | **%** | **g kg$^{-1}$** | **g kg$^{-1}$** | |
| MEZ1 | **Oap1** | ***0 - 10*** | 7,3 | 667 | 1.5 | *Peat* | *Peat* | *Peat* | 65.6 | 31.1 | 0.2 | 1.6 | 0.0 | 24.2 | 125.3 | 7.3 | 17.1 |
| | **Oap2** | ***10 - 30*** | 7,2 | 1421 | 1.7 | *Peat* | *Peat* | *Peat* | 69.8 | 24.7 | 0.1 | 1.5 | 0.1 | 24.1 | 123.1 | 7.2 | 17.1 |
| | **Oa3** | ***30 - 60*** | 7,0 | 1942 | 2.1 | *Peat* | *Peat* | *Peat* | 55.2 | 29.6 | 0.2 | 2.0 | 0.2 | 24.5 | 114.2 | 6.9 | 16.7 |
| | **Cg1** | ***60 - 80*** | 7,0 | 1890 | 1.5 | *Peat* | *Peat* | *Peat* | 38.2 | 26.3 | 0.1 | 1.4 | 0.2 | 11.1 | 61.1 | 3.5 | 17.6 |
| | **Cg2** | ***80 - 130*** | 7,5 | 1951 | 1.0 | 92 | 8 | 0 | 13.0 | 24.1 | 0.0 | 0.2 | 0.1 | 8.0 | 10.1 | | |
| MEZ2 | **Crust** | ***0 -1*** | 6,5 | 1973 | 1.6 | *Peat* | *Peat* | *Peat* | 74.7 | 33.3 | 0.7 | 4.7 | 1.2 | 24.0 | 121.3 | 7.9 | 15.3 |
| | **Oap1** | ***1 - 5*** | 6,4 | 1166 | 1.2 | *Peat* | *Peat* | *Peat* | 75.1 | 33.2 | 0.6 | 4.0 | 0.6 | 24.1 | 109.6 | 6.9 | 15.8 |
| | **Oap2** | ***5 - 20*** | 6,5 | 1217 | 1.3 | *Peat* | *Peat* | *Peat* | 70.8 | 31.7 | 0.5 | 3.7 | 0.4 | 24.1 | 110.0 | 6.9 | 15.9 |
| | **Oap3** | ***20 - 50*** | 6,3 | 1653 | 1.1 | *Peat* | *Peat* | *Peat* | 72.1 | 37.3 | 0.5 | 5.0 | 1.2 | 23.5 | 109.0 | 6.8 | 16.1 |
| | **Oa** | ***50 - 60*** | 4,7 | 4850 | 1.5 | *Peat* | *Peat* | *Peat* | 58.1 | 39.7 | 0.8 | 9.6 | 7.6 | 39.2 | 179.5 | 10.7 | 16.8 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Oa** | ***60 - 80*** | 4,6 | 5817 | 1.4 | *Peat* | *Peat* | *Peat* | 77.5 | 51.7 | 0.9 | 11.1 | 6.8 | 35.1 | 156.1 | 8.9 | 17.6 |
| | **Cg** | ***> 80*** | 4,4 | 8870 | 1.2 | *Peat* | *Peat* | *Peat* | 29.0 | 12.0 | 1.2 | 8.8 | 10.3 | 15.4 | 59.1 | 3.2 | 18.2 |
| MEZ3 | **Crust** | ***0 - 0.5*** | 7.5 | 569 | 1.0 | *Peat* | *Peat* | *Peat* | 55.1 | 22.8 | 0.4 | 3.3 | 0.8 | 14.7 | 71.8 | 4.3 | 16.7 |
| | **Oap1** | ***0.5 - 10*** | 7.5 | 521 | 1.3 | *Peat* | *Peat* | *Peat* | 52.9 | 23.1 | 0.3 | 3.0 | 0.4 | 14.3 | 67.9 | 4.3 | 15.7 |
| | **Oap2** | ***10 - 45*** | 7.6 | 502 | 1.2 | *Peat* | *Peat* | *Peat* | 28.4 | 48.2 | 0.4 | 3.8 | 0.5 | 11.7 | 68.9 | 4.3 | 16.0 |
| | **Cg1** | ***45 - 70*** | 7.3 | 2495 | 1.0 | 15 | 53 | 32 | 53.0 | 24.3 | 0.5 | 2.7 | 0.2 | 7.5 | 14.7 | | |
| | **Cg2** | ***70 - 85*** | 7.7 | 2695 | 1.9 | 23 | 54 | 23 | 24.8 | 44.7 | 0.6 | 5.6 | 0.7 | 6.2 | 21.9 | | |
| | ***Ravenna*** | **Depth** | **pH** | **EC 1:2.5** | **$CaCO_3$** | **Sand** | **Silt** | **Clay** | **CEC** | **Ca** | **K** | **Mg** | **Na** | **O.M.** | **OC** | **NT** | **C/N** |
| | ***Horizon*** | **cm** | | **µS $cm^{-1}$** | **%** | **%** | **%** | **%** | | **$Cmol_{(+)}$ $kg^{-1}$** | | | | **%** | **g $kg^{-1}$** | **g $kg^{-1}$** | |
| RA1 | **Crust** | ***0 - 0.5*** | 8.3 | 159 | 25.8 | 45 | 28 | 27 | 12.9 | 3.9 | 0.1 | 0.7 | 0.2 | 1.7 | 9.8 | 1.4 | 7.0 |
| | **Ap1** | ***0.5 - 10*** | 8.3 | 167 | 22.0 | 43 | 31 | 26 | 17.7 | 5.5 | 0.1 | 0.8 | 0.2 | 1.3 | 7.8 | 1.2 | 6.7 |
| | **Ap2** | ***10 -50*** | 8.3 | 197 | 23.9 | 31 | 63 | 6 | 17.6 | 5.3 | 0.1 | 0.9 | 0.2 | 1.7 | 10.1 | 1.4 | 7.2 |
| | **B** | ***50 - 100*** | 8.6 | 408 | 28.2 | 33 | 62 | 5 | 18.0 | 3.8 | 0.1 | 2.0 | 0.5 | 2.8 | 16.3 | 2.0 | 8.1 |
| | **Cg1** | ***100 - 136*** | 8.9 | 793 | 24.4 | 12 | 32 | 56 | 19.1 | 2.6 | 0.3 | 2.8 | 0.9 | 0.9 | 5.0 | 1.0 | 5.2 |
| | **Cg2** | ***>136*** | 8.8 | 413 | 20.7 | 85 | 7 | 7 | 17.8 | 5.6 | 0.1 | 0.8 | 0.2 | 0.4 | 2.3 | 0.6 | 4.1 |
| RA2 | **Crust** | ***0 - 0.5*** | 8.3 | 136 | 19.5 | 81 | 9 | 10 | 7.5 | 3.1 | 0.1 | 0.2 | 0.1 | 1.2 | 7.2 | 1.2 | 6.1 |
| | **Ap1** | ***0.5 - 10*** | 8.3 | 131 | 19.7 | 77 | 9 | 14 | 8.1 | 3.2 | 0.1 | 0.2 | 0.1 | 1.5 | 8.6 | 1.0 | 8.8 |
| | **Ap2** | ***10 - 70*** | 8.3 | 145 | 20.0 | 76 | 11 | 13 | 5.7 | 2.6 | 0.1 | 0.2 | 0.2 | 1.2 | 7.0 | 0.9 | 8.0 |
| | **C1** | ***70 - 90*** | 8.6 | 127 | 20.3 | 84 | 8 | 8 | 1.5 | 1.5 | 0.0 | 0.1 | 0.2 | 0.3 | 2.0 | 0.6 | 3.2 |
| | **C2** | ***90 - 120*** | 8.7 | 132 | 21.7 | 88 | 10 | 3 | 0.0 | 1.1 | 0.0 | 0.0 | 0.2 | 0.3 | 1.6 | 0.5 | 3.2 |

**S 4 - Soil physicochemical characteristics of cultivated layers and relative standard deviations (SD).**

| | | pH | E.C. (μS cm$^{-1}$) | $CaCO_3$ (%) | OC (g kg$^{-1}$) | TN (g kg$^{-1}$) | SOM (g kg$^{-1}$) | $\delta^{13}C$ (‰) | P tot (g kg$^{-1}$) | CEC (cmol$_+$ kg$^{-1}$) | Ca (cmol$_+$ kg$^{-1}$) | K (cmol$_+$ kg$^{-1}$) | Mg (cmol$_+$ kg$^{-1}$) | Na (cmol$_+$ kg$^{-1}$) | Clay (%) | Silt (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***MO1*** | ***Mean*** | 7.8 | 343 | 4.4 | 15.6 | 2.2 | 26.9 | -26.3 | 0.7 | 54.9 | 21.1 | 0.3 | 2.0 | 0.4 | 55 | 29 | 5 |
| | ***SD*** | 0.2 | 52 | 1.0 | 0.9 | 0.1 | 1.5 | 0.2 | 0.0 | 4.5 | 0.1 | 0.1 | 0.2 | 0.2 | 21 | 11 | 2 |
| ***MO2*** | ***Mean*** | 7.8 | 319 | 9.7 | 12.5 | 1.7 | 21.6 | -25.6 | 1.4 | 32.0 | 12.1 | 0.4 | 1.6 | 0.1 | 35 | 40 | 4 |
| | ***SD*** | 0.3 | 93 | 1.1 | 0.8 | 0.1 | 1.3 | 0.1 | 0.2 | 2.3 | 0.5 | 0.1 | 0.1 | 0.0 | 20 | 22 | 3 |
| ***MO3*** | ***Mean*** | 7.6 | 395 | 8.4 | 15.5 | 1.9 | 23.8 | -25.0 | 1.3 | 47.5 | 18.9 | 0.6 | 3.2 | 0.2 | 56 | 40 | 4 |
| | ***SD*** | 0.2 | 82 | 0.7 | 1.0 | 0.7 | 8.4 | 0.2 | 0.1 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 18 | 17 | 2 |
| ***MEZ1*** | ***Mean*** | 7.1 | 1343 | 1.8 | 120.8 | 7.1 | 242.5 | -26.8 | 0.8 | 63.5 | 28.5 | 0.2 | 1.7 | 0.1 | | | |
| | ***SD*** | 0.2 | 637 | 0.5 | 23.4 | 1.4 | 46.6 | 0.1 | 0.1 | 7.5 | 3.3 | 0.0 | 0.2 | 0.1 | | | |
| ***MEZ2*** | ***Mean*** | 6.4 | 1502 | 1.3 | 112.5 | 7.1 | 239.4 | -27.3 | 0.8 | 73.2 | 33.9 | 0.6 | 4.3 | 0.8 | | | |
| | ***SD*** | 0.3 | 746 | 0.4 | 11.7 | 0.8 | 13.0 | 0.1 | 0.1 | 2.9 | 5.4 | 0.1 | 0.8 | 0.5 | | | |
| ***MEZ3*** | ***Mean*** | 7.5 | 531 | 1.2 | 69.5 | 4.3 | 147.8 | -26.7 | 0.8 | 45.5 | 31.4 | 0.4 | 3.4 | 0.6 | | | |
| | ***SD*** | 0.1 | 142 | 0.6 | 12.8 | 0.7 | 23.7 | 0.2 | 0.1 | 14.8 | 14.6 | 0.0 | 0.4 | 0.2 | | | |
| ***RA1*** | ***Mean*** | 8.3 | 175 | 23.9 | 9.2 | 1.3 | 15.9 | -27.2 | 0.7 | 16.1 | 4.9 | 0.1 | 0.8 | 0.2 | 20 | 41 | 40 |
| | ***SD*** | 0.1 | 24 | 2.8 | 1.8 | 0.2 | 3.1 | 1.4 | 0.1 | 4.4 | 1.4 | 0.0 | 0.1 | 0.1 | 10 | 17 | 7 |
| ***RA2*** | ***Mean*** | 8.3 | 137 | 19.7 | 7.6 | 1.0 | 13.1 | -26.6 | 0.7 | 7.1 | 3.0 | 0.1 | 0.2 | 0.1 | 13 | 9 | 78 |
| | ***SD*** | 0.1 | 9 | 0.7 | 1.7 | 0.3 | 3.0 | 1.6 | 0.1 | 1.9 | 0.4 | 0.0 | 0.1 | 0.0 | 2 | 1 | 3 |

**S 5 - Soil biochemical features in the cultivated layers and relative standard deviation (SD).**

| | | Cbas ($mg\_C\_CO_2\ kg^{-1}$) | Labile-C ($mg\ kg^{-1}$) | Labile-N ($mg\ kg^{-1}$) | Labile-P ($mg\ kg^{-1}$) | Cmic ($mg\ kg^{-1}$) | Nmic ($mg\ kg^{-1}$) | P mic ($mg\ kg^{-1}$) | C:N | C:P | N:P | $qCO_2$ | qM (%) | Cmic/OC (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***MO1*** | ***Mean*** | 19.9 | 97.2 | 22.6 | 1.8 | 209.2 | 17.6 | 1.9 | 13.0 | 164.3 | 15.4 | 0.4 | 3.6 | 1.3 |
| | ***SD*** | 4.1 | 7.0 | 7.5 | 0.7 | 55.8 | 4.8 | 1.3 | 2.1 | 122.6 | 13.8 | 0.1 | 0.7 | 0.4 |
| ***MO2*** | ***Mean*** | 25.6 | 86.9 | 27.1 | 6.6 | 192.4 | 18.4 | 6.7 | 10.8 | 33.1 | 3.0 | 0.6 | 5.7 | 1.5 |
| | ***SD*** | 3.2 | 10.1 | 11.8 | 1.9 | 30.7 | 4.3 | 3.3 | 2.4 | 13.9 | 0.8 | 0.1 | 0.7 | 0.2 |
| ***MO3*** | ***Mean*** | 32.9 | 98.5 | 44.6 | 6.6 | 295.7 | 21.9 | 18.6 | 14.7 | 20.9 | 1.7 | 0.5 | 6.0 | 4.1 |
| | ***SD*** | 3.3 | 13.2 | 15.7 | 0.3 | 53.7 | 7.0 | 14.3 | 4.9 | 14.5 | 1.5 | 0.1 | 1.0 | 6.5 |
| ***MEZ1*** | ***Mean*** | 55.2 | 493.1 | 66.7 | 2.0 | 204.1 | 35.9 | 14.5 | 5.8 | 12.6 | 2.7 | 1.5 | 1.3 | 0.2 |
| | ***SD*** | 17.2 | 93.4 | 13.4 | 1.0 | 123.2 | 14.3 | 7.0 | 2.1 | 0.1 | 1.1 | 0.8 | 0.4 | 0.1 |
| ***MEZ2*** | ***Mean*** | 37.5 | 338.7 | 85.0 | 2.1 | 241.5 | 24.9 | 3.8 | 12.2 | 69.7 | 5.5 | 0.8 | 0.9 | 0.2 |
| | ***SD*** | 9.3 | 64.2 | 37.5 | 0.2 | 81.9 | 11.7 | 0.0 | 6.7 | 0.0 | 0.0 | 0.5 | 0.3 | 0.1 |
| ***MEZ3*** | ***Mean*** | 60.7 | 338.3 | 57.8 | 3.7 | 182.0 | 25.7 | 3.6 | 8.6 | 55.4 | 8.0 | 2.2 | 2.4 | 0.3 |
| | ***SD*** | 21.0 | 64.8 | 14.3 | 0.5 | 85.1 | 16.2 | 2.1 | 3.6 | 0.4 | 2.6 | 2.7 | 0.7 | 0.1 |
| ***RA1*** | ***Mean*** | 21.8 | 124.3 | 22.1 | 7.0 | 196.5 | 22.7 | 1.0 | 10.5 | 259.0 | 26.4 | 0.5 | 6.7 | 2.2 |
| | ***SD*** | 5.4 | 131.7 | 8.7 | 0.0 | 46.8 | 8.2 | 0.1 | 7.3 | 120.1 | 21.2 | 0.1 | 1.6 | 0.5 |
| ***RA2*** | ***Mean*** | 25.6 | 61.5 | 19.9 | 4.0 | 135.7 | 18.0 | / | 7.7 | 5.0 | 0.7 | 0.8 | 9.7 | 1.8 |
| | ***SD*** | 5.8 | 7.0 | 4.3 | 0.4 | 34.5 | 6.1 | / | 1.0 | 0.0 | 0.0 | 0.2 | 2.1 | 0.4 |

**S 6 - Average cconcentration of main nutrients and relative standard deviations (SD) in plant tissues expressed as g kg$^{-1}$.**

| *Old leaves* | | Ca | Fe | K | Mg | Mn | Na | P | S |
|---|---|---|---|---|---|---|---|---|---|
| MO1 | *Av* | 62.00 | 0.47 | 4.55 | 5.88 | 0.03 | 4.58 | 1.14 | 13.69 |
| | *SD* | 5.71 | 0.18 | 1.49 | 0.25 | 0.01 | 0.96 | 0.16 | 2.10 |
| MO2 | *Av* | 52.00 | 0.19 | 7.78 | 6.30 | 0.04 | 0.80 | 1.35 | 13.67 |
| | *SD* | 2.60 | 0.08 | 0.03 | 0.15 | 0.00 | 0.07 | 0.18 | 1.35 |
| MO3 | *Av* | 52.95 | 0.47 | 6.78 | 8.08 | 0.07 | 1.06 | 0.78 | 5.92 |
| | *SD* | 7.69 | 0.30 | 1.19 | 2.08 | 0.04 | 0.44 | 0.23 | 1.54 |
| MEZ1 | *Av* | 49.57 | 0.68 | 7.64 | 4.53 | 0.05 | 2.57 | 1.21 | 14.15 |
| | *SD* | 2.42 | 0.22 | 0.32 | 0.27 | 0.05 | 0.40 | 0.40 | 1.94 |
| MEZ2 | *Av* | 40.76 | 0.58 | 7.41 | 6.78 | 0.03 | 2.55 | 1.27 | 14.43 |
| | *SD* | 3.24 | 0.35 | 0.27 | 0.54 | 0.00 | 0.33 | 0.17 | 2.74 |
| MEZ3 | *Av* | 45.92 | 2.36 | 6.70 | 9.13 | 0.05 | 2.41 | 0.79 | 15.51 |
| | *SD* | 3.41 | 1.41 | 1.16 | 0.57 | 0.03 | 0.66 | 0.09 | 3.28 |
| RA1 | *Av* | 48.71 | 0.80 | 7.69 | 10.00 | 0.04 | 1.96 | 1.56 | 14.11 |
| | *SD* | 6.78 | 0.32 | 0.19 | 0.64 | 0.01 | 1.21 | 0.07 | 1.74 |
| RA2 | *Av* | 48.33 | 0.45 | 7.50 | 8.17 | 0.03 | 0.85 | 1.86 | 9.08 |
| | *SD* | 3.52 | 0.12 | 0.16 | 3.13 | 0.01 | 0.14 | 0.39 | 2.23 |

| *Youth leaves* | | Ca | Fe | K | Mg | Mn | Na | P | S |
|---|---|---|---|---|---|---|---|---|---|
| MO1 | *Av* | 52.46 | 0.67 | 5.45 | 5.59 | 0.03 | 5.04 | 1.35 | 12.72 |
| | *SD* | 14.67 | 0.41 | 2.04 | 0.56 | 0.00 | 0.52 | 0.53 | 3.62 |
| MO2 | *Av* | 48.69 | 0.23 | 7.73 | 6.03 | 0.04 | 0.71 | 1.25 | 14.69 |
| | *SD* | 5.74 | 0.11 | 0.31 | 0.29 | 0.01 | 0.04 | 0.03 | 2.29 |
| MO3 | *Av* | 49.48 | 0.56 | 7.11 | 7.16 | 0.06 | 1.16 | 0.85 | 7.23 |
| | *SD* | 8.09 | 0.37 | 1.03 | 2.06 | 0.03 | 0.48 | 0.14 | 2.17 |
| MEZ1 | *Av* | 50.47 | 0.83 | 7.71 | 4.83 | 0.06 | 2.55 | 1.14 | 15.78 |
| | *SD* | 6.44 | 0.08 | 0.12 | 0.68 | 0.07 | 0.47 | 0.36 | 4.24 |
| MEZ2 | *Av* | 37.83 | 0.27 | 7.87 | 6.70 | 0.02 | 2.46 | 1.28 | 13.93 |
| | *SD* | 6.10 | 0.03 | 0.10 | 1.09 | 0.00 | 0.29 | 0.10 | 3.15 |
| MEZ3 | *Av* | 45.70 | 1.53 | 6.76 | 8.42 | 0.04 | 2.54 | 0.79 | 17.23 |
| | *SD* | 1.99 | 0.60 | 0.92 | 0.94 | 0.01 | 0.68 | 0.08 | 3.35 |
| RA1 | *Av* | 45.13 | 0.32 | 7.72 | 13.22 | 0.02 | 2.58 | 1.23 | 19.22 |
| | *SD* | 6.37 | 0.09 | 0.12 | 1.98 | 0.00 | 1.81 | 0.18 | 2.07 |
| RA2 | *Av* | 45.79 | 0.39 | 7.43 | 8.15 | 0.03 | 0.95 | 1.41 | 8.02 |
| | *SD* | 10.72 | 0.21 | 0.79 | 0.86 | 0.00 | 0.26 | 0.38 | 2.12 |

| *Roots* | | Ca | Fe | K | Mg | Mn | Na | P | S |
|---|---|---|---|---|---|---|---|---|---|
| MO1 | *Av.* | 22.32 | 0.54 | 7.35 | 1.61 | 0.01 | 1.39 | 0.92 | 1.18 |
| | *SD* | 1.84 | 0.20 | 0.21 | 0.07 | 0.01 | 0.23 | 0.30 | 0.13 |
| MO2 | *Av.* | 23.59 | 0.95 | 7.34 | 2.69 | 0.01 | 1.64 | 0.95 | 1.53 |
| | *SD* | 7,92 | *SD* | 0.10 | 0.45 | 0.00 | 0.41 | 0.15 | 0.28 |
| MO3 | *Av.* | 14.89 | 0.69 | 6.94 | 1.81 | 0.01 | 2.66 | 0.86 | 1.08 |
| | *SD* | 1.71 | 0.35 | 0.76 | 0.28 | 0.01 | 0.47 | 0.08 | 0.30 |
| MEZ1 | *Av.* | 17.06 | 1.04 | 7.70 | 1.92 | 0.02 | 1.04 | 1.03 | 0.72 |
| | *SD* | 2.17 | 0.54 | 0.15 | 0.52 | 0.01 | 0.39 | 0.38 | 0.10 |
| MEZ2 | *Av.* | 18.75 | 1.01 | 7.44 | 1.59 | 0.03 | 0.57 | 1.19 | 0.58 |
| | *SD* | 1.54 | 0.08 | 0.14 | 0.17 | 0.00 | 0.07 | 0.33 | 0.06 |
| MEZ3 | *Av.* | 17.70 | 1.95 | 7.00 | 2.09 | 0.03 | 6.43 | 0.80 | 0.81 |
| | *SD* | 2.30 | 1.36 | 0.37 | 0.79 | 0.02 | 0.51 | 0.10 | 0.14 |
| RA1 | *Av.* | 23.22 | 1.35 | 6.43 | 2.10 | 0.02 | 0.73 | 0.71 | 0.72 |
| | *SD* | 2.25 | 0.25 | 0.66 | 0.11 | 0.00 | 0.20 | 0.06 | 0.16 |
| RA2 | *Av.* | 28.81 | 0.78 | 6.81 | 2.36 | 0.02 | 1.43 | 0.76 | 1.06 |
| | *SD* | 2.71 | 0.16 | 0.21 | 0.33 | 0.01 | 0.46 | 0.12 | 0.13 |

| *Tomato* | | Ca | Fe | K | Mg | Mn | Na | P | S |
|---|---|---|---|---|---|---|---|---|---|
| MO1 | *Av.* | 0.93 | 0.04 | 7.08 | 1.15 | 0.01 | 2.98 | 2.06 | 1.06 |
| | *SD* | 0.12 | 0.00 | 0.20 | 0.16 | 0.00 | 1.20 | 0.29 | 0.07 |
| MO2 | *Av.* | 1.73 | 0.05 | 6.48 | 1.20 | 0.01 | 0.51 | 2.39 | 1.19 |
| | *SD* | 0.42 | 0.01 | 0.56 | 0.22 | 0.00 | 0.05 | 0.49 | 0.08 |
| MO3 | *Av.* | 1.67 | 0.06 | 6.49 | 1.21 | 0.01 | 0.59 | 2.14 | 1.06 |
| | *SD* | 0.53 | 0.01 | 0.87 | 0.17 | 0.00 | 0.19 | 0.33 | 0.17 |
| MEZ1 | *Av.* | 0.98 | 0.06 | 7.12 | 1.05 | 0.01 | 0.77 | 1.99 | 1.09 |
| | *SD* | 0.12 | 0.02 | 0.41 | 0.05 | 0.00 | 0.09 | 0.33 | 0.16 |
| MEZ2 | *Av.* | 0.77 | 0.05 | 6.70 | 1.24 | 0.01 | 0.73 | 2.50 | 1.18 |
| | *SD* | 0.15 | 0.00 | 0.78 | 0.08 | 0.00 | 0.09 | 0.13 | 0.09 |
| MEZ3 | *Av.* | 0.96 | 0.05 | 6.48 | 1.21 | 0.01 | 1.38 | 1.95 | 1.13 |
| | *SD* | 0.07 | 0.01 | 0.62 | 0.02 | 0.00 | 0.60 | 0.14 | 0.10 |
| RA1 | *Av.* | 0.67 | 0.04 | 6.77 | 1.16 | 0.01 | 1.04 | 2.18 | 1.00 |
| | *SD* | 0.15 | 0.01 | 0.38 | 0.08 | 0.00 | 0.59 | 0.15 | 0.05 |
| RA2 | *Av.* | 1.05 | 0.04 | 6.29 | 1.17 | 0.01 | 0.55 | 2.22 | 0.93 |
| | *SD* | 0.20 | 0.01 | 0.62 | 0.02 | 0.00 | 0.07 | 0.30 | 0.05 |

| *Stem* | | Ca | Fe | K | Mg | Mn | Na | P | S |
|---|---|---|---|---|---|---|---|---|---|
| MO1 | *Av.* | 16.01 | 0.08 | 7.03 | 3.11 | 0.00 | 8.56 | 0.61 | 1.24 |
| | *SD* | 1.78 | 0.02 | 0.21 | 0.49 | 0.00 | 1.93 | 0.19 | 0.28 |
| MO2 | *Av.* | 12.08 | 0.03 | 7.72 | 1.49 | 0.01 | 0.53 | 1.32 | 1.56 |
| | *SD* | 1.51 | 0.00 | 0.15 | 0.31 | 0.00 | 0.00 | 0.25 | 0.04 |
| MO3 | *Av.* | 13.39 | 0.06 | 7.61 | 2.34 | 0.01 | 0.98 | 0.74 | 0.94 |
| | *SD* | 4.00 | 0.02 | 0.22 | 1.14 | 0.01 | 0.55 | 0.26 | 0.22 |
| MEZ1 | *Av.* | 16.96 | 0.08 | 7.42 | 2.26 | 0.01 | 1.51 | 0.88 | 1.86 |
| | *SD* | 3.64 | 0.03 | 0.47 | 0.14 | 0.01 | 0.25 | 0.41 | 0.53 |
| MEZ2 | *Av.* | 11.52 | 0.07 | 6.82 | 2.23 | 0.01 | 1.58 | 1.14 | 1.75 |
| | *SD* | 1.22 | 0.01 | 0.63 | 0.13 | 0.00 | 0.42 | 0.31 | 0.16 |
| MEZ3 | *Av.* | 9.41 | 0.10 | 7.48 | 2.40 | 0.00 | 2.28 | 0.55 | 1.70 |
| | *SD* | 1.01 | 0.04 | 0.47 | 0.09 | 0.00 | 1.01 | 0.04 | 0.35 |
| RA1 | *Av.* | 11.29 | 0.06 | 7.81 | 3.64 | 0.01 | 1.89 | 1.41 | 1.65 |
| | *SD* | 2.12 | 0.02 | 0.04 | 0.55 | 0.00 | 1.21 | 0.11 | 0.19 |
| RA2 | *Av.* | 14.93 | 0.06 | 7.79 | 3.32 | 0.01 | 0.78 | 1.68 | 1.20 |
| | *SD* | 0.15 | 0.00 | 0.07 | 0.62 | 0.00 | 0.08 | 0.33 | 0.19 |

**S 7 - Correlation matrix showing Pearson correlation coefficients ($r^2$) of physicochemical and biochemical parameters. ** means correlation sig. $p < 0.01$; * means correlation sig. $p < 0.05$.**

| | pH | EC | CaCO3 | OC | NT | SOM | C/N | $\delta^{13}C$ | Cbas | Labile-C | Labile-N | Cmic | Nmic | Cmic/Nmic | qCO2 | qM | CSC | Ca exch | K exch | Mg exch | Na exch | Cmic/OC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **pH** | 1 | | | | | | | | | | | | | | | | | | | | | |
| **EC** | -.892** | 1 | | | | | | | | | | | | | | | | | | | | |
| **CaCO3** | .743** | -.736** | 1 | | | | | | | | | | | | | | | | | | | |
| **OC** | -.802** | .829** | -.775** | 1 | | | | | | | | | | | | | | | | | | |
| **NT** | -.814** | .849** | -.775** | .987** | 1 | | | | | | | | | | | | | | | | | |
| **SOM** | -.806** | .816** | -.777** | .984** | .977** | 1 | | | | | | | | | | | | | | | | |
| **C/N** | -.585** | .669** | -.633** | .760** | .712** | .757** | 1 | | | | | | | | | | | | | | | |
| **$\delta^{13}C$** | .200 | -.295* | -.023 | -.367** | -.367** | -.379** | .028 | 1 | | | | | | | | | | | | | | |
| **Cbas** | -.570** | .591** | -.639** | .609** | .621** | .602** | .700** | -.083 | 1 | | | | | | | | | | | | | |
| **Labile-C** | -.734** | .784** | -.663** | .819** | .835** | .821** | .735** | -.320** | .615** | 1 | | | | | | | | | | | | |
| **Labile-N** | -.779** | .773** | -.641** | .682** | .698** | .688** | .614** | -.217 | .688** | .707** | 1 | | | | | | | | | | | |
| **Cmic** | -.284* | .298* | -.120 | .386** | .283* | .399** | .093 | .077 | .044 | .254* | .281* | 1 | | | | | | | | | | |
| **Nmic** | -.190 | .252* | -.217 | .387** | .479** | .410** | .335** | -.140 | .309** | .408** | .299* | .458** | 1 | | | | | | | | | |
| **Cmic/Nmic** | -.156 | .059 | .088 | -.026 | -.181 | -.035 | -.272* | .120 | -.274* | -.150 | -.021 | .371** | -.581** | 1 | | | | | | | | |
| **qCO2** | -.146 | .140 | -.337** | .121 | .222 | .107 | .401** | -.101 | .658** | .165 | .277* | -.632** | -.014 | -.605** | 1 | | | | | | | |
| **qM** | .804** | -.836** | .735** | -.886** | -.870** | -.883** | -.680** | .283* | -.354** | -.767** | -.665** | -.272* | -.229 | -.051 | -.020 | 1 | | | | | | |
| **CEC** | -.864** | .872** | -.763** | .890** | .880** | .890** | .643** | -.062 | .543** | .763** | .718** | .374* | .124 | .391* | .093 | -.869** | 1 | | | | | |
| **Ca exch.** | -.814** | .864** | -.816** | .874** | .866** | .875** | .659** | -.107 | .585** | .774** | .705** | .497** | .296 | .245 | -.011 | -.829** | .893** | 1 | | | | |
| **K exch.** | -.812** | .799** | -.661** | .798** | .799** | .807** | .521** | .038 | .399** | .734** | .703** | .546** | .222 | .518** | -.173 | -.781** | .831** | .773** | 1 | | | |
| **Mg exch.** | -.818** | .881** | -.769** | .863** | .862** | .859** | .582** | -.100 | .495** | .749** | .650** | .485** | .261 | .297 | -.082 | -.852** | .903** | .875** | .910** | 1 | | |
| **Na exch.** | -.493** | .541** | -.536** | .553** | .551** | .559** | .210 | -.282 | .368* | .435** | .345* | .313* | .239 | .073 | -.031 | -.542** | .517** | .525** | .472** | .674** | 1 | |
| **Cmic/OC** | .633** | -.671** | .753** | -.702** | -.720** | -.691** | -.673** | .247* | -.592** | -.641** | -.544** | .313** | .004 | .263* | -.588** | .675** | -.709** | -.678** | -.504** | -.638** | -.426** | 1 |

## Historical evolution of a reclaimed valley in Italy (Valle Mezzano, Ferrara, North-East Italy) and implications on soil sustainability

The site condition of a reclaimed wetland transformed to farmland face big changes. According to studies conducted in many pedoclimatic regions of the world, these changes were reflected in variation of soils pH, salinity, heavy metals mobility, fertility, biochemical activities etc. For example, wetland OC could be subjected to rapid decomposition once exposed to air if it was not stabilized by soil minerals. The grades of changes were strictly related to pedoclimatic conditions, however the main risks identified for these lands were: soil pollution, and eutrophication of channels and sea-shore closed to the wetlands (Li et al., 2014). Moreover, accelerated circulation of carbon and nitrogen, increases greenhouse gasses (GHG) emissions ($CO_2$, $N_2O$ and $CH_4$) to the air, making reclaimed wetlands one of the important reasons for global warming and an essential issue in the field of agro-environment and climate change (WANG et al., 2012).

The Mezzano Valley is a recently reclaimed wetland part of the Natura 2000 network (IT4060008, "Mezzano Valley" Special Protection Area, 18886Ha; Fig.21). The reclamation processes started in 1957 and were completed by 1974, but in 1964 part of the Valley was available for agricultural purposes. It consists of two hydrologically independent basins, Mezzano North West and Mezzano South East, both with high organic matter content (SOM) and high salinity level. The density of population of the area is low (79 inhabitants/kmq against 200 inhabitants/kmq of Italian national average), thus the land-use of the valley has been mainly arable till nowadays, with basically no change during last 40 years. Lately, with increasing anthropic pressure on the environment and resources demand, the valley started to reveal its weak points: (-) the high costs to maintain fields dry and suitable for cultivation, (-) the decrease of natural fertility, (-) most of its extension lays below the sea level and, being closed to the sea, is exposed to several risks related to sea level rise, (-) the presence of buried organic material results in $CH_4$ emission from subsoils, which may happen to burn (sometimes for many day consecutively) and disrupts crops, endangers worker and fauna, and increases greenhouse gasses emission. Moreover, studies made on near reclaimed valley (Goro area, Ferrara, Italy) clearly demonstrated that economical incomes to local communities decreased with the switch from wetland to farmland (Breber, 1993). Apparently, these changes were not consistent with what found in other reclaimed wetlands all over the world, but strangely deepened studies on soil of Mezzano Valley don’t exist and specific quality indicators were never developed.

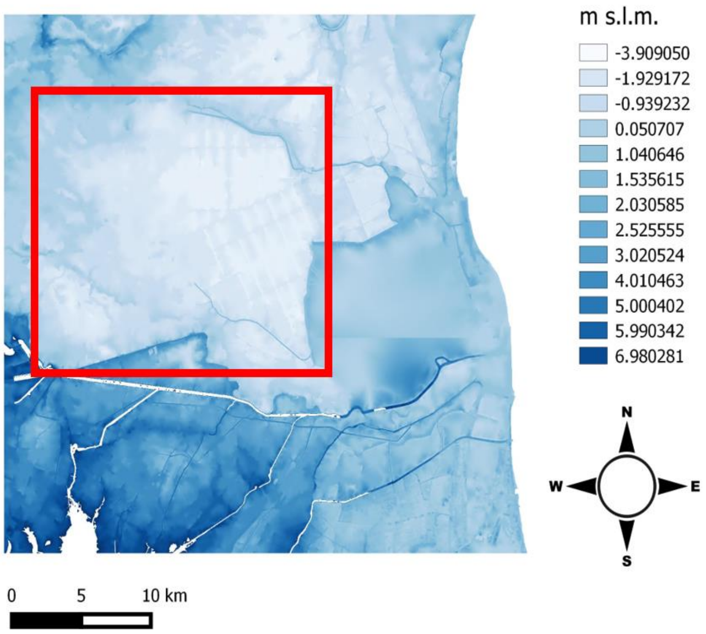



**Figure 21– Map of surface altitude elaborated from a DEM image with QGIS 2.16.3. In the red square there is the Mezzano Valley.**

The first survey on the reclaimed area is dated in the end of 60’s, carried on by the Istituto Sperimentale Agronomico - Modena Section (Boschi and Spallacci, 1974). They investigated many characteristics of soils: pH, $CaCO_3$, SOM, salinity, total nitrogen, potassium and phosphorous, available phosphorous and potassium, texture and many other physical characteristics of soils. Samples were collected in 145 different points at two depths, for a total of 290 samples: 0-50cm (surficial layer) and 50-100cm (deep layers). They provided maps of each measured parameter, both for surficial and deep horizons. In this work, QGIS 2.16.3 was used to reconstruct some of the maps with their data, which are displayed in the supplementary materials at the end of the chapter. They also deepened knowledges on humic substances and available P in 10 representative profiles and monitored the variation of some characteristics during the period 1967-1974: pH, salinity, $CaCO_3$, CEC and exchangeable cations, gypsum content, boron and some soluble anions and cations.

They estimated that about 42% of the surficial layers and 63% of the deep ones contained more than 20% of organic matter (SOM; in the report, they refer to the organic matter as "torba", which means "peat"). SOM resulted from the accumulation during thousands of years of plants residues in anoxic conditions, mainly Phragmites. The organic matter was more concentrated in the central part of the valley and always mixed with sediments in different proportions. These last characteristics created problem in the determination of soil texture and they did not provide texture data for those layers with SOM > 20%. In the marginal sections of the valley, where the waves and the sediments contribution from channel tributaries did not allow Phragmites to grow in great quantity, mainly non-organic layers were found. Along-together with SOM, total nitrogen (NT) was always high, being always > 0.6% in most layers, either surficial or deep. The C/N ratio was also high in most of the valley, except for the marginal areas where SOM decreased. They were confident that the oxidative processes would have increased availability of nutrients and enhance SOM humification with the beginning of agricultural activities.

The greats amount of organic matter resulted in acid pH in about 50% of surficial horizon and about 75% of deep ones. The acidity of surficial horizon was sufficiently buffered thanks to the diffuse presence of shells (mainly Bivalvia), which accounted for the most of $CaCO_3$ of the area.

Phosphorous contents, either total (Ptot) or available (Pav), were always very low: Ptot < 1permill in about 50% of surficial soils and about 57% of deep ones; Pav < 30ppm ($P_2O_5$) in about 55% of surficial soils and about 48% of deep ones. Pav was in equal parts represented by organic and inorganic fractions, the former more concentrated in surface horizon while the latter in the deep ones.

Salinity was inherited from the former brackish water. More than 50% of surface horizon and 75% of deep ones presented concentration of NaCl > 25‰, and most of the area presented concentration > 5‰. Soluble Na positively correlated with soluble S, Ca, Mg and K, but also gypsum. Different was for the total contents: total S was related to SOM, K to clay, Ca to $CaCO_3$, Mg not defined. Total K and Na were inversely related because of the great influence of salinity on total Na, which preferentially accumulated in the organic horizon. NaCl (and other salts) contents decreased during the seven years of monitoring, with different grades and velocity according to depth and texture of soils. After three years NaCl decreased to half, considering average of both surface and depth layers (1.41‰ per 100mm of rainwater), while during the following four years the average desalinization rhythm was lower: 0.46‰ per 100mm of rainwater. The highest rhythm of desalinization was found for non-organic horizons. Effectively, natural oscillation of groundwater and related variation of salinity had a direct impact on soil salinity: during spring and winter the groundwater raised and its salinity decreased (so did soil's salinity), while starting from summer to the beginning of the rainy season, groundwater level was low and its salinity raised (so did soil's salinity). Together with salinity, also pH and $CaCO_3$ content decreased during the seven years, while stable was gypsum. Boron was raising concerns because was very slowly washed out remaining at concentration over 5ppm (toxicity threshold at that time). All the other cations and anions decreased during the 7 years of monitoring, but in different percentages, as shown in Figure 22. Exchangeable Na and K decreased, while Ca and Mg increased (even if the latter were always absent in acid horizons).

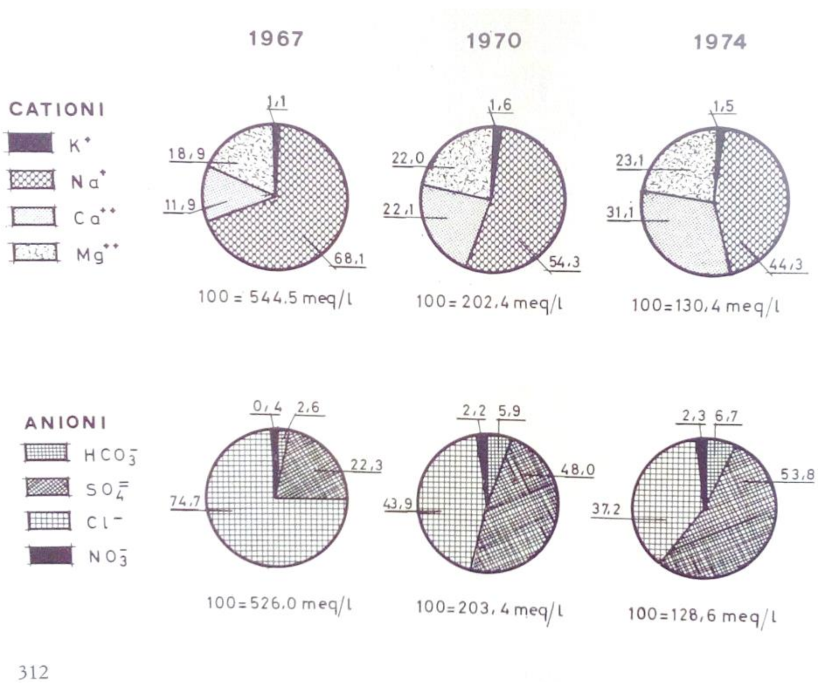



**Figure 22 - Original graphs taken from Boschi and Spallacci (1974) – p. 312 - representing the variation with time of main soluble cations and anions in Mezzano Valley.**

They concluded that the management of the area would cost much efforts in order to keep these lands dry, either from rainwater accumulation or from salty groundwater rise, and to maintain acceptable levels of salts in the cultivated layers. Notwithstanding the fast loss of $CaCO_3$, presence of gypsum and shells' fragments provided necessary calcium to replace sodium and hydrogen in soils. Potential fertility was very high to the point that authors were excluding the needing to add N and K fertilizers (N advised just in particular cases), and P was definitively the limiting element, which would have become just slightly more available with oxidative processes of organic matter. Nevertheless, many management and agricultural issues derived from such high SOM contents. In fact, SOM played a strong influence on hydrological characteristics, such as capillarity, water holding capacity and permeability (and subsequently wilting-point): capillarity was low, permeability and maximum water holding capacity were high, and wilting-point was high. The combination of these hydrological features created problems because caused delays in restart of spring activities and limited sweet water availability to plants during summer. Even the marginal areas presented some problems, such as clay deflocculation, but the fast wash out of salts from these areas allowed them to think that the problem would have quit soon. The suggestions for crops were directed to those tolerant to salts and resistant to high water contents, such as chard and some kind of (not specified) cereals, and slowly would have been possible to introduce alfalfa. Anyway crops suggestions were just general and redirected to regional survey for deepening knowledges.

This probably was the best characterization of the area and for many years no survey in the area were conducted (it is possible to find some brief communication in agronomic symposium). A nice study on $CH_4$ emission from deep layers was published by Cremonini et al. (2008): aimed to understand whether methane is produced by peat layers or seeps from deeper natural gas reservoirs, because the emission often results in fire which disrupt crops, endanger worker and fauna and increase greenhouse gasses emission.

Nowadays, Emilia-Romagna region published the regional database of soils, where is possible to find management advises and it is clear that many of the issues found by Boschi and Spallacci (1974) are still existing. According to the Soil Map 1:50.000 by Emilia Romagna region (Fig.23), eight different groups of soil delineations occur in the Mezzano Valley: Valle Mezzano, Canale Specchio, Mottalunga, Burano, Argine Agosta, Le Contane, Canale del Sole silty loam and Canale del Sole clayey silty loam. Hereafter, some references maps (and data) extracted by Emilia-Romagna database will be presented.

The latter three delineation represents the marginal area of the valley and some thin paleochannel that cross the valley, while all the other soil delineations represent those parts of the valley with high SOM contents.

**Le Contane clayey silty (LCO1) - Sulfic Endoaquept fine, mixed (calcareous), mesic (Soil Taxonomy, 1994).**

High clayey surficial horizons overlying organic deep ones endow to the profiles good natural fertility, but also salinity, risk of waterlogging, difficulty of work during either wet or dry seasons. Water drainage is poor and soil stability is weak. Short cycle herbaceous crops are suggested. Forests advised just for naturalistic purposes.

| Depth | Horizon | Sand | Silt | Clay | Texture | $CaCO_3$ % | | SOM | CEC | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | Somma | EC 1:5 | Ece* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS m^-1^* | *dS m^-1^* |
| 0-45 | *Ap* | 8 | 43 | 49 | Silty Clay | 9.0 | 6.7 | 4.8 | 29.0 | 25.0 | 2.8 | 0.0 | 0.3 | 28.1 | 0.2 | 0.8 |
| 45-65 | *Bg* | 4 | 46 | 49 | Silty Clay | 8.0 | 6.5 | 4.4 | 28.0 | 28.4 | 4.0 | 0.0 | 0.3 | 32.7 | 0.6 | 2.3 |
| 65-85 | *OB* | 61 | 26 | 13 | Sandy Loam | 0.0 | 0.0 | 30.6 | 37.4 | 56.5 | 6.8 | 0.0 | 0.1 | 63.4 | 1.3 | 3.6 |
| 85-100 | *Oa* | 88 | 12 | 0 | Sand | 0.0 | 0.0 | 49.7 | 36.2 | 55.3 | 7.3 | 0.0 | 0.4 | 63.0 | 2.2 | 15.7 |
| 100-120 | *Oe* | 82 | 13 | 5 | Loamy Sand | 0.0 | 0.0 | 41.7 | 37.8 | 30.8 | 3.7 | 0.0 | 0.1 | 34.6 | 3.1 | 21.9 |
| 120-140 | *Cg* | 48 | 41 | 12 | Loam | 1.0 | 0.5 | 11.0 | 30.4 | 10.4 | 2.8 | 0.0 | 0.2 | 13.3 | 3.4 | 8.1 |

**Canale del Sole silty loam (CSD1) - Typic Fluvaquents fine silty, mixed, active, calcareous, mesic (Soil Taxonomy, 2010).**

Silt provide good aeration but during rainy season permeability and oxygen content decrease. Typical is the formation of crusts on soil surface. Main problem is the presence of sodium in the surface layers that cause deflocculation of clay weakening soil structure. Sodium also may reach toxic levels and increase pH limiting the availability of nutrients to plants.  Water drainage is poor. Short cycle herbaceous crops tolerant to high salt levels are suggested, unless of availability of great amounts of water for irrigation. Forests advised just for naturalistic purposes.

| Depth | Horizon | Sand | Silt | Clay | Texture | $CaCO_3$ % | | SOM | CEC | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | Somma | EC 1:5 | Ece* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS m^-1^* | *dS m^-1^* |
| 0-45 | Ap | 17 | 58 | 26 | Silty Loam | 8.0 | 3.5 | 2.5 | 12.9 | 8.3 | 3.2 | 0.0 | 0.3 | 11.8 | 2.3 | 5.8 |
| 45-100 | Cg1 | 33 | 54 | 13 | Silty Loam | 16.0 | 6.5 | 0.5 | 7.8 | 4.6 | 1.9 | 0.0 | 0.3 | 6.9 | 1.0 | 3.0 |
| 100-150 | Cg2 | 89 | 7 | 4 | Clayey sandy loam | 14.0 | 2.0 | 0.2 | 3.7 | 3.1 | 1.3 | 0.1 | 0.1 | 4.6 | 3.7 | 8.8 |

**Canale del Sole clayey silty loam (CSD2) - Typic Fluvaquents fine silty, mixed, active, calcareous, mesic (Soil Taxonomy, 2010).**

Physcochemical charcteristics are hardly available. Problems and suggestions are somewhat the same of the CSD1.

**Canale Specchio, with humified material (CSP1) - Terric Sulfisaprists loamy, mixed, euic, mesic (Soil Taxonomy, 2010).**

High SOM and salts contents, and low oxygen availability characterize the delineation. Soils are kept dry mechanically and presents a gradual subsidence that obliges farmer to reset the lands every few years. The content of organic matter that may prevent water infiltration during irrigation. Not many plants are adequate to this kind of environment: soy, corn, wheat, melon and watermelon. Forests advised just for naturalistic purposes.

| **Depth** | **Horizon** | **Sand** | **Silt** | **Clay** | **Texture** | **$CaCO_3$ %** | | **SOM** | **CEC** | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **Somma** | **EC 1:5** | **Ece*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS $m^{-1}$* | *dS $m^{-1}$* |
| 0-55 | | | | | | 4.0 | 2.0 | 40.7 | 38.4 | 51.2 | 35.0 | 38.0 | 0.5 | 124.7 | | |
| 55-70 | | | | | | 1.0 | 0.0 | 60.8 | 38.4 | 51.2 | 35.0 | 38.0 | 0.5 | 124.7 | 16.5 | 39.0 |
| 70-90 | | | | | | 0.0 | 0.0 | 17.0 | 34.3 | 18.0 | 49.4 | 72.8 | 2.4 | 142.6 | 24.6 | 58.1 |
| 110-140 | Cg | 10 | 64 | 26 | Silty Loam | 0.0 | 0.0 | 16.4 | 28.5 | 11.1 | 20.6 | 25.0 | 1.7 | 58.3 | 12.9 | 28.6 |

**Valle Mezzano, with humified material (VME1) - Typic Sulfisaprists, euic, mesic (Soil Taxonomy, 2010).**

Problems and suggestions are somewhat the same of the CSP1 and AGO1.

| **Depth** | **Horizon** | **Sand** | **Silt** | **Clay** | **Texture** | **$CaCO_3$ %** | | **SOM** | **CEC** | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **Somma** | **EC 1:5** | **Ece*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS $m^{-1}$* | *dS $m^{-1}$* |
| 0-55 | Op | 66 | 26 | 9 | Sandy Loam | 8.0 | 5.0 | 35.1 | 65.2 | 61.0 | 5.1 | 1.1 | 0.5 | 67.7 | 5.8 | 13.6 |
| 55-68 | Oa | 78 | 16 | 6 | Loamy Sand | 0.0 | 0.0 | 22.6 | 56.8 | 14.4 | 7.2 | 1.4 | 1.7 | 24.6 | 19.1 | 45.1 |
| 68-75 | Cg | 11 | 36 | 53 | Clay | 0.0 | 0.0 | 6.3 | 26.3 | 8.2 | 9.0 | 11.1 | 0.9 | 29.1 | 7.8 | 30.4 |
| 75-91 | Oe | 80 | 3 | 17 | Sandy Loam | 0.0 | 0.0 | 29.5 | 73.0 | 14.1 | 6.6 | 2.7 | 1.2 | 24.7 | 23.4 | 55.2 |
| 91-118 | OCg | 56 | 33 | 12 | Sandy Loam | 0.0 | 0.0 | 18.1 | 45.9 | 6.7 | 9.2 | 14.9 | 1.3 | 32.2 | 18.6 | 43.9 |
| 118-150 | Oej | 64 | 15 | 22 | Sandy Clayey Loam | 0.0 | 0.0 | 29.6 | 75.9 | 44.5 | 3.8 | 0.0 | 0.5 | 48.8 | 31.4 | 74.1 |

**Argine Agosta, with humified material (AGO1) - Terric Sulfisaprists loamy, mixed, euic, mesic (Soil Taxonomy, 2010).**

Problems and suggestions are somewhat the same of the CSP1 and VM1.

| **Depth** | **Horizon** | **Sand** | **Silt** | **Clay** | **Texture** | **$CaCO_3$ %** | | **SOM** | **CEC** | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **Somma** | **EC 1:5** | **Ece*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS $m^{-1}$* | *dS $m^{-1}$* |
| 0-60 | Op | 66 | 25 | 9 | Sandy Loam | 1.0 | 0.0 | 32.4 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 60-80 | Bg | 23 | 49 | 28 | Clayey Loam | 1.0 | 0.0 | 8.6 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 80-110 | 2Cg1 | 44 | 46 | 10 | Loam | 13.0 | 2.0 | 2.0 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 110-150 | 2Cg2 | 83 | 13 | 4 | Loamy Sand | 13.0 | 1.0 | 0.8 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |

**Mottalunga, fine sandy loam (MOT1) - Histic Humaquepts sandy, mixed, active, nonacid, mesic (Soil Taxonomy, 2010).**

SOM is mixed with coarse sediments, characteristics that enhance oxygen availability while nutrients content is good. Soils are kept dry mechanically and do not present great problem for irrigation. These kinds of soils are not very diffuse and do not allow specific homogeneous cultivation. Usually they are found in combination with Burano delineation (BUR1).

| **Depth** | **Horizon** | **Sand** | **Silt** | **Clay** | **Texture** | **$CaCO_3$ %** | | **SOM** | **CEC** | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **Somma** | **EC 1:5** | **Ece*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS $m^{-1}$* | *dS $m^{-1}$* |
| 0-60 | Ap | 83 | 12 | 5 | Sandy Loam | 1.0 | 0.0 | 16.8 | 30.4 | 48.0 | 6.4 | 0.7 | 0.3 | 55.3 | 2.8 | 20.0 |
| 60-74 | Bg1 | 91 | 6 | 3 | Sandy Loam | 0.0 | 0.0 | 1.5 | 9.5 | 16.3 | 3.5 | 0.6 | 0.0 | 20.5 | 2.4 | 17.2 |
| 74-100 | | | | | | n.d. | n.d. | n.d. | 7.06 | 34.31 | 1.65 | 0.7 | 0.07 | 36.73 | 2.1 | 4.96 |
| 100-115 | Cg | 91 | 6 | 3 | Sandy Clayey Loam | 9.0 | 3.0 | 0.7 | 6.1 | 26.6 | 1.4 | 1.0 | 0.1 | 29.0 | 1.4 | 10.0 |

**Burano, fine sandy loam (BUR1) - Aquic Ustipsamments, mixed, mesic (Soil Taxonomy, 2010).**

SOM is mixed with coarse sediments, characteristics that enhance oxygen availability. In this case nutrients availability in not optimal. Water availability to plants also may become a problem. CaCO3 is higher compared to other organic soils and pH is usually alkaline. Not many plants are adequate to this kind of environment: soy, corn, wheat, melon, watermelon and few others.

| **Depth** | **Horizon** | **Sand** | **Silt** | **Clay** | **Texture** | **$CaCO_3$ %** | | **SOM** | **CEC** | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **Somma** | **EC 1:5** | **Ece*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *cm* | | *(%)* | | | | *Total* | *Active* | *%* | *Meq/100 gr* | | | | | | *dS $m^{-1}$* | *dS $m^{-1}$* |
| 0-35 | Ap1 | 86 | 8 | 6 | Sandy Loam | 1.0 | 0.0 | 6.6 | 21.5 | 26.3 | 2.5 | 0.4 | 0.1 | 29.3 | 0.4 | 2.9 |
| 35-60 | Ap2 | 87 | 9 | 4 | Sandy Loam | 1.0 | 0.0 | 5.0 | 19.2 | 21.1 | 1.9 | 0.5 | 0.1 | 23.5 | 0.3 | 2.1 |
| 60-76 | C1 | 95 | 4 | 1 | Sandy Clayey Loam | 0.0 | 0.0 | 0.4 | 6.0 | 4.1 | 0.9 | 0.3 | 0.0 | 5.3 | 0.2 | 1.4 |
| 83-140 | Cg | 94 | 4 | 2 | Sandy Clayey Loam | 8.0 | 1.0 | 0.3 | 5.5 | 30.2 | 0.6 | 0.4 | 0.1 | 31.2 | 1.7 | 12.2 |

* ECe presented in the tables was calculated by the author using math-formula given by Emilia-Romagna Region:

-*Clay and Silty Clay* - ECe = 3.889 * EC1:5 $r^2$=0.939

-*Clayey silty loam, silty loam, loam, clayey loam, silt and sandy silt* - ECe = 0.871 + 2.150 * EC1:5 $r^2$=0.726

-*Sand and Loamy sand* - ECe = 7.149 * EC1:5 $r^2$=0.969

-*Histosol* - ECe = 2.361 * EC1:5 $r^2$=0.933

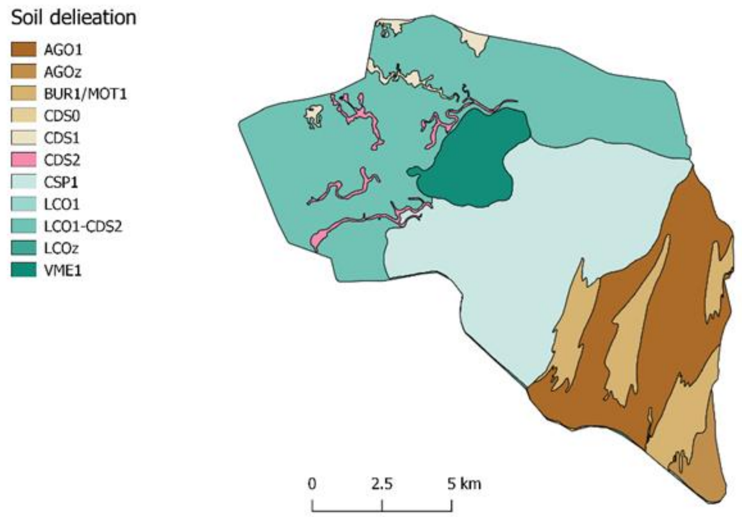



**Figure 23 - Soil delineation by the geological, seismic and soil survey of Emilia-Romagna region.**

The geological, seismic and soil survey of Emilia-Romagna region provides also maps of salinity levels (Fig.24), organic carbon contents (Fig.25) and natural background of certain elements: Cr, Cu, V, Zn, Ni and Pb (soil sample at the depth 90-130cm). In Fig.26 and Fig.27 is possible to see how the southern part of the valley presents always lower concentration of all heavy metals. Notwithstanding, the concentration agree with Po river sediments fingerprints (Bianchini et al., 2002, 2012, 2013)

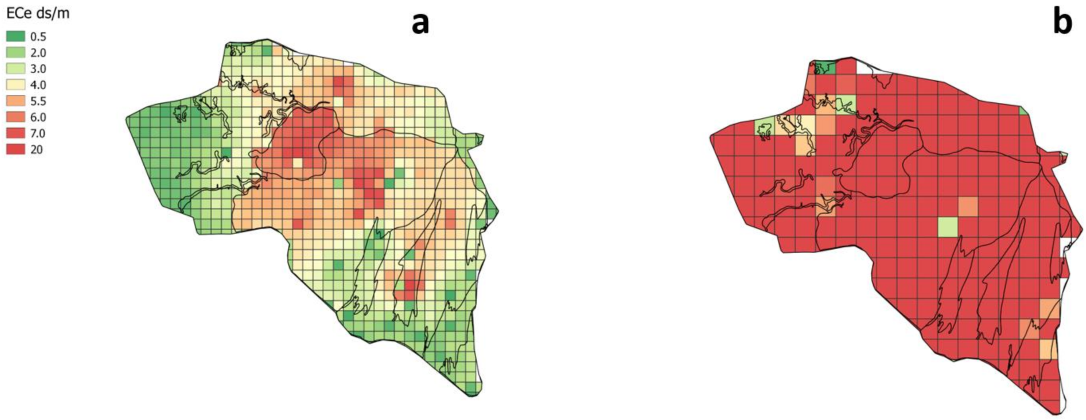



**Figure 24 - ECe of Mezzano Valley (a) surficial layers, (b) deep layers.**

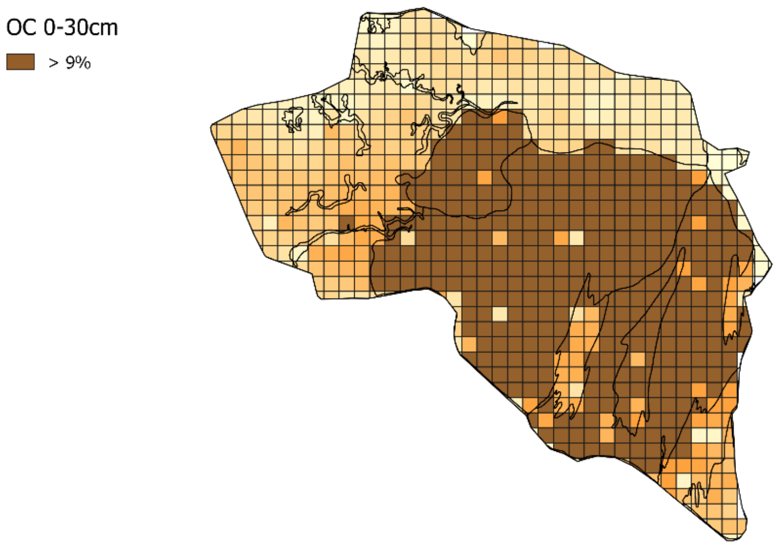



**Figure 25 - OC content of the first 30cm of Mezzano Valley's soils.**

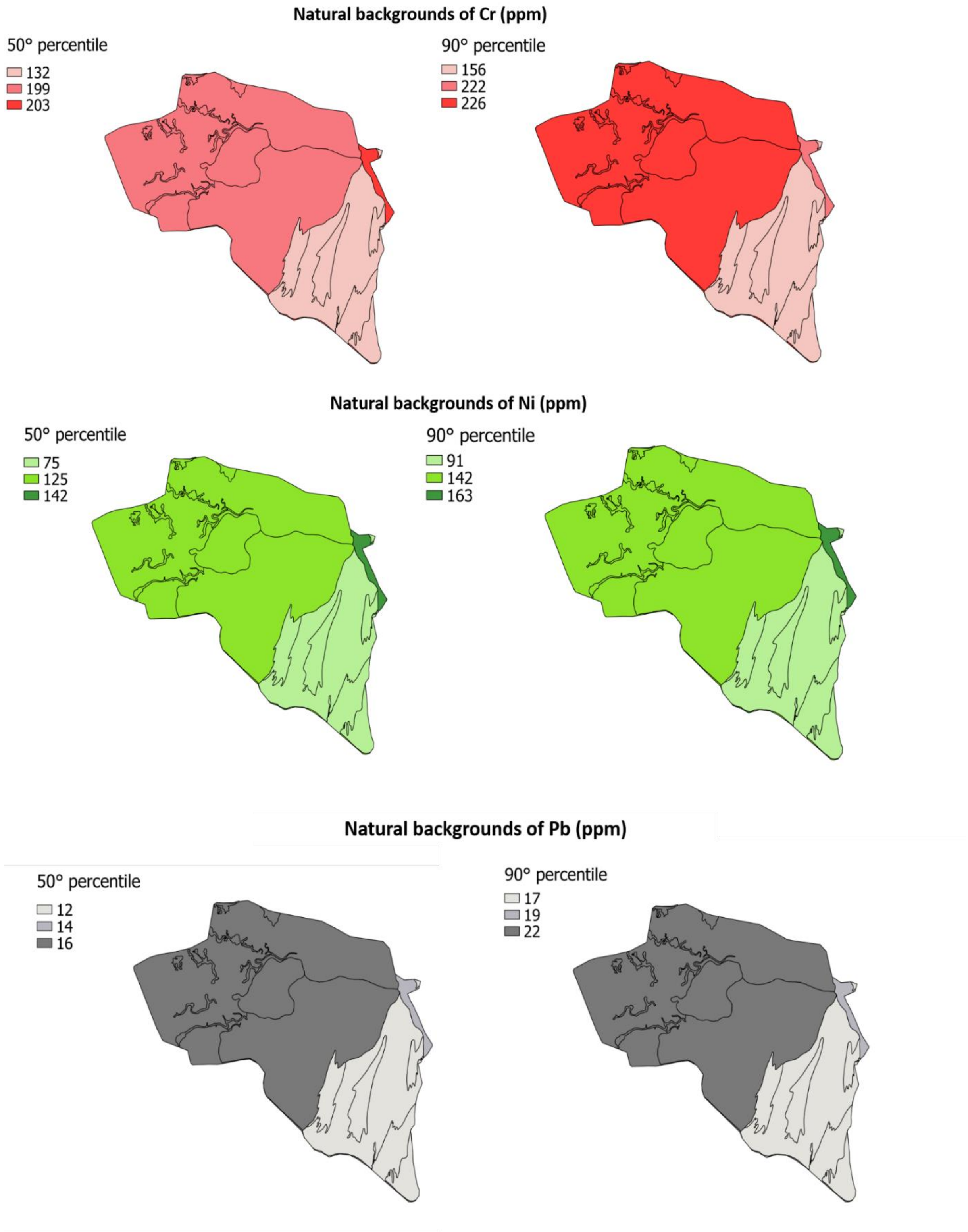



**Figure 26 - Natural backgrounds of Cr, Ni and Pb in Mezzano Valley (ppm).**

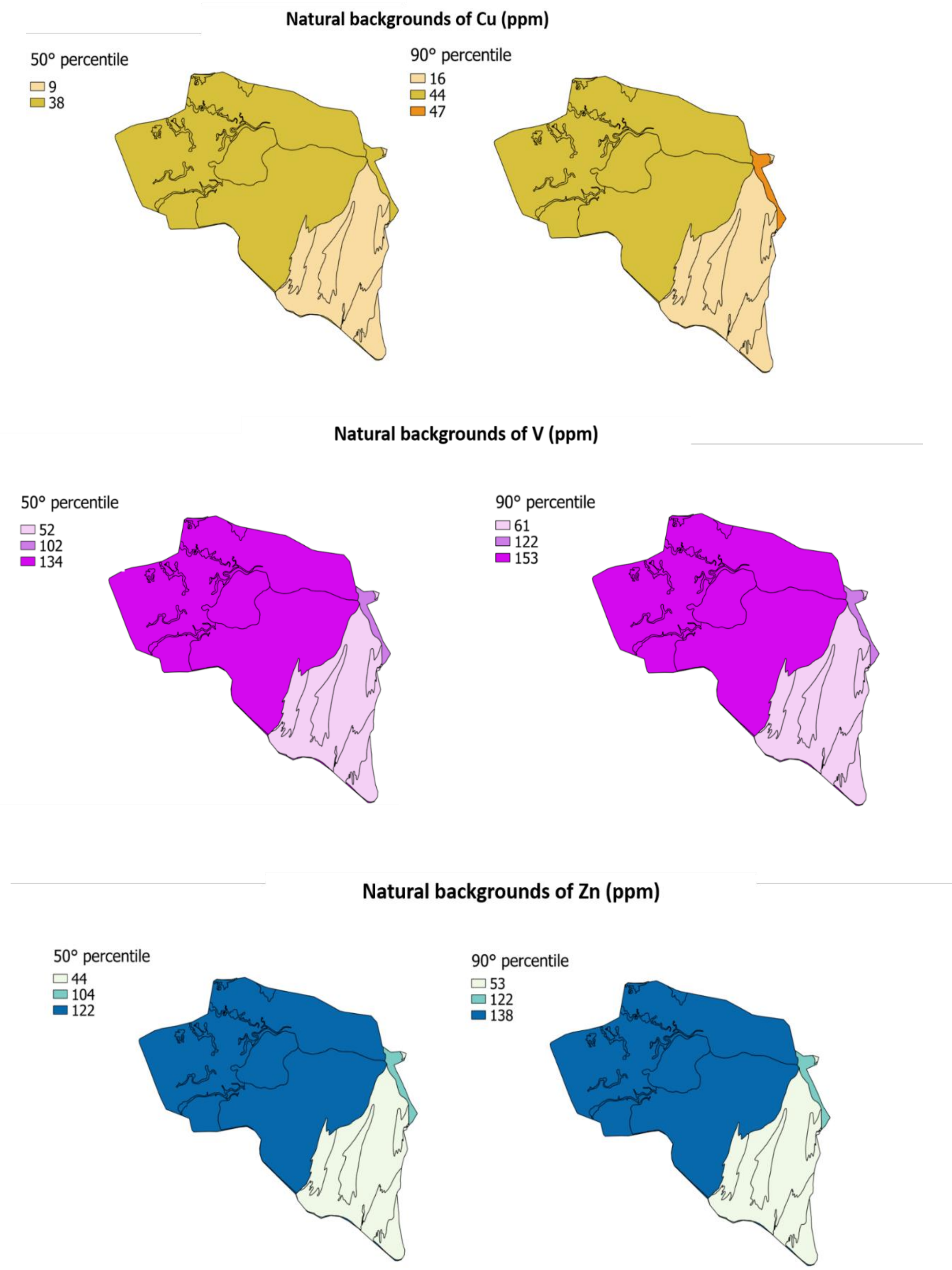



**Figure 27 - Natural backgrounds of Cu, V and Zn in Mezzano Valley (ppm).**

Another survey of the valley is found in Di Giuseppe et al. (2014). The aim of the study was to "give background information on possible geochemical risks". The work strengthen what was already known from the previous studies: (-) non-organic soil profiles were found in the marginal areas of the valley, while the rest of the valley presented high SOM contents, (-) lack of correlation of calcium with other elements, meaning that shell fragments consisted of most of it, (-) high salinity increasing with depth, (-) Na was the main soluble cation, SO4 and Cl the main anions, (-) presence of metal-rich phyllosilicates inherited by Po river sediments deposition.

The study also investigated dynamic aspect of some elements, giving interesting insights of potential risks. The total concentration of some elements, such as Cr and Ni, was higher compared to the rest of Po alluvial valley, but also higher compared to industrialized areas, such as Grugliasco (Turin, Italy) (Poggio et al., 2009). Total Ni concentration reached the threshold of 120mg $kg^{-1}$ defined by Italian Legislation for "green areas" (the Italian Legislative Decree 152, 03/04/2006). Surficial layers presented Top Enrichment Factors (TEF) > 1 (calculated as the ratio between the concentration of the surficial layers to the concentration of the deep ones) for the following potentially toxic elements: Co, Cr, Ni, Pb, V, Zn and Cu. It was interpreted as human-derived pollution. Using Ethylenediaminetetraacetic acid (EDTA), the mobility of these elements was assessed: Pb, Zn, Cu > Co, Ni > Cr, V. Thus, Cr and V were mainly in the mineral form, posing a low geochemical risk. Finally, lettuce was used as further indicator of elements mobility. Lettuce tissues were found to be enriched in Zn (up to 49mg $kg^{-1}$), Ni (up to 2.38mg $kg^{-1}$) an As (1.23mg $kg^{-1}$), slightly enriched in Cd (0.74mg $kg^{-1}$), Sb (0.06mg $kg^{-1}$) and Hg (0,09mg $kg^{-1}$), while no enrichment was detected for Pb, C, V and Co.

For the *purpose of this study*, three surveys were conducted in the area: 2014, 2015 and 2016.

Survey 2014 was used to classify soils, measure physicochemical and biochemical parameters, and determine total soluble content of element in soils. Soil were sampled according to soil map 1:50.000 of Soil Survey of Emilia-Romagna region. Survey season 2015 was conducted as explained in the first section of this work. During winter 2016, selected soil's profiles were sampled and analysed at the IIAG-CSIC (Instituto de Investigacion Agrobiologica de Galicia, Santiago de Compostela) for pH, EC, enzymatic activities, available phosphorous, total nitrogen, total carbon, soluble carbon (total, carbohydrates and polyphenols).

The choice to use different biochemical parameters was driven by the will of verifying the different response of the soils to different treatments and seeing if potentiality detected were the same. Other reason was justified by the fact that we intended to try identify a set of indicators that may be the most accurate and the best for land management proper choices. All data were compared with previous studies in order to evaluate criticism of the area.

## *Material and Methods*

### *Surveys 2014-2015*

During 2014 eleven soil profiles were described and sampled: Masal1, Masal2, Masal3, Masal4, Masal5, Masal6, Masal7, Masal8, Masal9, Masal10, Masal11. The first two profiles were outside the valley and were sampled for exploratory purposes on the territory. However, the data of those two profiles will not be presented here.

The methodologies used in 2014 were the same presented in chapter "Soil quality and its influence on crop stoichiometry in intensive agricultural system". The only methodological difference was the determination of soil basal respiration (Cbas). Methodology of 2014 basal respiration were explained in Natale (2015).

Data of soil samples gathered in 2014 are shown in Tables 9, 10, 11 and 12 and soil classification are presented in Table 13.

*Surveys 2016*

Six profiles were selected: MEZ1, MEZ2, MEZ3, Masal3, Masal5 and Masal10 (in the area of Masal4 and Masal8 trucks were resetting the lands, thus the choice went to the most similar profiles to them among all). All data of survey 2016 are presented in Tables 14 and 15.

-*Total Organic Carbon* (OC).

-Enzymatic Activities: *arylsulfatase* (AR), *CM-cellulase* (CL), *invertase* (IN), *ß-glucosidase* (GL), *urease* (UR), *acid phosphomoesterease* (P6), *alkaline phosphomoesterease* (P10) and *dehydrogenase* (DHD).

- *Carbon soluble in hot water: total carbon* (TSC), *polyphenols polyphenolic carbon* (PLH) and *carbohydrates* (CRB).

- *Sodium bicarbonate extractable phosphorous*: total (Ptot), inorganic (Pin) and organic (Porg).

-*Total Inorganic Nitrogen* (NIT): total (NIT), ammoniacal ($NH_3$) and nitrates ($NO_3$).

Total Organic Carbon (OC)

The OC was determined following using the classic method of Sauerlandt and Berwecke (1952) modified by Guitián and Carballas (1976). Briefly, to 0.2-0.5g of finely ground soils samples were weighted in 250ml Erlenmeyer flasks and 50 ml of concentrated $H_2SO_4$ were added and left to stand for 10-15 min; afterwards, 25ml of 1.8 N $K_2Cr_2O_7$ were added and then heated at 110°C for 1h 30m. Once cold, the Erlenmeyers' content was passed quantitatively to 250 ml volumetric flasks with the help of distilled $H_2O$. Finally, the residual content of $K_2Cr_2O_7$ $Cr^{6+}$ was determined (after the addition of with 2-3 drops of $H_3PO_4$) by titration titrated with 0.2N Mohr salt [$(NH_4)2Fe(SO_4)2·6H_2O$], by using an automatic titrator, to 700mV end-point.

Enzymatic activities

Acid and alkaline phosphomonoesterase activities (P6 and P10, respectively) were determined following the method of Tabatabai and Bremner (1969), with some modifications. Soil samples were incubated for 30 min with 16mM p-nitrophenyl phosphate as substrate in Modified Universal Buffer (pH 6.0 and pH 10.0 for acid and alkaline activity, respectively). The method described by Trasar-Cepeda et al. (1985) was applied to ensure that the pH of the reaction mixture was maintained. Some horizons (the two deepest of MASAL5) could not reach pH 6.0 (optimal pH), and were thus buffered to pH 6.5. After the incubation period, 2M $CaCl_2$ was added (to prevent dispersal of soil colloids and to avoid the brown coloration caused by organic matter), and the p-nitrophenol released during enzymatic hydrolysis was extracted with 0.2M NaOH and thereafter measured by spectrophotometry at 400nm (Trasar-Cepeda et al., 2003). The enzymatic activities were quantified by reference to calibration curves corresponding to p-nitrophenol standards incubated with each soil under the same conditions as for the samples (Trasar-Cepeda et al., 2003), and the activities are expressed as µmol p-nitrophenol $g^{-1}$ $h^{-1}$. ß-glucosidase activity (GL) was determined as described for phosphomonoesterase activity except that the substrate was 25mM p-nitrophenyl-ß-D-glucopyranoside, the incubation time was 1h and the released p-nitrophenol was extracted with 0.1M (Tris(hydroxymethyl)aminomethane)-NaOH (THAM-NaOH), pH 12 (Eivazi and Tabatabai, 1988). The activity of arylsulphatase (AR) was measured by using the method of Tabatabai and Bremner (1970), with minor modifications. Briefly, arylsulphatase activity was determined with 5 mM p-nitrophenyl sulphate as substrate in 0.5M acetate buffer (pH 5.8). After incubating for 1 h at 37 ºC, 2M $CaCl_2$ was added and the liberated p-nitrophenol was extracted with 0.2M NaOH and measured by spectrophotometry at 400nm (Trasar-Cepeda et al., 2003). The enzymatic activity was quantified by reference to calibration curves corresponding to p-nitrophenol standards incubated with each soil under the same conditions as for the samples (Trasar-Cepeda et al., 2003), and the activity is expressed as µmol p-nitrophenol $g^{-1}$ $h^{-1}$.

The activity of urease (UR) was determined as described by Nannipieri et al. (1980). Briefly, urease activity was determined using 1065.6mM urea as substrate, incubating for 1.5h in 0.2M phosphate buffer (pH 7.0 for MASAL 5 and pH 8.0 for all the other soils), and measuring the $NH4^+$ released with an ammonia electrode, and the enzyme activity is expressed as µmol NH3 $g^{-1}$ $h^{-1}$. Invertase activity (IN) was determined by incubating the samples with 35.06mM saccharose in 2M acetate buffer (pH 5.5) for 3h, and measuring the released reducing sugars following the method of Schinner and von Mersi (1990). Carboxymethylcellulase activity (CL) was determined in a similar way, except that the substrate was 0.7% carboxymethyl-cellulose and the incubation time was 24h (Schinner and von Mersi, 1990). In both cases, the enzyme activities are expressed as µmol glucose $g^{-1}$ $h^{-1}$. Dehydrogenase activity (DHD) was determined with iodonitrotetrazolium violet (INT) 0.5% as substrate, incubating with 1M TRIS-HCl buffer pH 7.5 for 1h. The iodonitrotetrazolium formazan (INTF) produced was extracted with a 1:1 (v:v) mixture of ethanol and dimethylformamide and measured spectrophotometrically at 490nm (Camiña et al., 1998). Activity was quantified by reference to a calibration curve constructed using INTF standards incubated with soil under the same conditions described above, and is expressed in µmol INTF $g^{-1}$ $h^{-1}$.

All the enzyme activity determinations were performed in triplicate by using moist soil samples (equivalent to 1g of oven-dried soil) and the average values were expressed on an oven-dried soil basis (105 ºC).

Carbon soluble in hot water (80 ºC).

To determine the fraction of C soluble in hot water, 50mL of distilled water was added to an amount of moist soil equivalent to 5g of air-dried sample, and the mixture was maintained for 24h at 80°C in a shaking water bath. The extract was then centrifuged (3200 x g, 20 min) and filtered through a 0.45µm membrane filter (Huang et al., 2008). Aliquots of the filtrate were dried at 60°C, and the total C content (TSC) was measured in the dried extracts by oxidation with dichromate in acidic medium (Sauerlandt and Berwecke, 1952, modified by Guitián and Carballas, 1976). The results are expressed in mg C $kg^{-1}$. Total polyphenolic carbon (PLH) was determined in an aliquot of the extracts following the Folin method and using p-cumaric acid as the standard (Kuwatsova and Shindo, 1973; Ceccanti et al., 1993). Anthron-reactive compounds (hexose and hexose-derived sugars) in the extracts (CRB) were determined following the anthrone method, using glucose as the standard (Brink et al., 1960; Ceccanti et al., 1993).

Sodium bicarbonate extractable P: total, inorganic and organic.

Sodium extractable P (Ptot, Pin and Porg) was determined following the method described by Hedley et al. (1982). Briefly, moist soil was extracted for 16h with $NaHCO_3$ 0.5M (1:50 soil: solution ratio) in an end-over-end mechanical shaker and then centrifuged for 15 min at 4500rpm and filtered. To determine the inorganic P (Pin), the extracts were acidified to pH 1.5 with concentrated sulfuric acid, and after centrifugation (15min, 4500r.p.m.) the P content of the supernatants was quantified following the colorimetric method described by Murphy and Riley (1962). The total P content of the extracts (Ptot) was extracted determined as described in Davidescu and Davidescu (1982) and quantified as described in Murphy and Riley (1962). The organic P content of the extracts (Porg) was calculated as the difference between Ptot and Pin.

Inorganic nitrogen: total, ammoniacal and nitrate.

Total inorganic nitrogen was extracted for 30min with KCl 2M in an end-over-end mechanical shaker (1:10 soil:solution ratio). Total inorganic (NIT) and ammoniacal nitrogen (NH3) contents in the extracts were determined by steam distillation and titration with sulfuric acid following the method described by Bremner and Keeney (1965). The nitrates ($NO_3$) content in the extracts was calculated as the difference between NIT and $NH_3$ contents.

| | Depth | Horizon | Coordinates UTM-WGS84 | | | Altitude | pH | EC 1:2.5 | ECe | $CaCO_3$ | Sand | Silt | Clay | OC | NT | SOM | C/N | $\delta^{113}C$ | $\delta^{15}N$ | CEC | $Ca^{++}$ | $K^{+}$ | $Mg^{++}$ | $Na^{+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | | *zone* | *x* | *y* | *m a.s.l.* | | μS $cm^{-1}$ | μS $cm^{-1}$ | % | % | % | % | g $kg^{-1}$ | g $kg^{-1}$ | % | | ‰ | ‰ | | *Cmol*$_{(+)}$ *kg*$^{-1}$ | | | |
| ***Masal3*** | ***0 - 10*** | ***Oap1*** | 33T | 267788 | 4951807 | -3 | 6.8 | 2570 | 3904 | 0.2 | Peat | Peat | Peat | 138.9 | 9.1 | 31.4 | 15.2 | -27.2 | 1.2 | 98.2 | 37.8 | 0.5 | 4.4 | 0.4 |
| | ***10-40/50*** | ***Oap2*** | | | | | 6.8 | 2960 | 4496 | 0.2 | Peat | Peat | Peat | 145.6 | 9.6 | 32.2 | 15.1 | -26.9 | 1.5 | 93.9 | 38.9 | 0.6 | 5.3 | 1.2 |
| | ***40/50 - 80*** | ***Oe*** | | | | | 6.1 | 4190 | 6365 | 0.3 | Peat | Peat | Peat | 112.5 | 7.4 | 25.6 | 15.3 | -27.4 | 1.5 | 87.4 | 42.8 | 0.7 | 6.5 | 3.5 |
| | ***80-100*** | ***C*** | | | | | 7.0 | 4820 | 7322 | 0.3 | 30 | 61 | 9 | 48.8 | 2.6 | 9.7 | 18.8 | -21.0 | 1.0 | 44.6 | 15.3 | 0.7 | 4.6 | 3.7 |
| ***Masal4*** | ***0-10*** | ***Oap1*** | 33T | 264362 | 4951114 | -4 | 6.7 | 3550 | 5392 | 0.2 | Peat | Peat | Peat | 201.9 | 12.8 | 45.7 | 15.8 | -27.1 | 1.3 | 117.5 | 41.7 | 0.4 | 5.6 | 2.0 |
| | ***10 - 40*** | ***Oap2*** | | | | | 6.9 | 3750 | 5696 | 0.3 | Peat | Peat | Peat | 202.2 | 13.1 | 46.3 | 15.4 | -27.0 | 1.5 | 112.2 | 47.7 | 0.5 | 7.3 | 2.7 |
| | ***40 - 100*** | ***Oe*** | | | | | 5.3 | 21700 | 30034 | 1.9 | Peat | Peat | Peat | 135.4 | 7.7 | 32.7 | 17.6 | -27.6 | 1.0 | 79.8 | 30.0 | 1.2 | 15.4 | 5.2 |
| ***Masal5*** | ***0-7*** | ***Ap1*** | 33T | 269059 | 4955120 | -1 | 7.9 | 370 | 513 | 7.1 | 49 | 32 | 20 | 18.1 | 1.7 | 3.1 | 10.8 | | | 31.6 | 13.3 | 0.4 | 1.9 | 0.5 |
| | ***7 - 40*** | ***Ap2*** | | | | | 7.9 | 349 | 484 | 7.8 | 55 | 25 | 20 | 19.0 | 1.7 | 3.3 | 10.9 | | | 38.6 | 13.5 | 0.5 | 1.7 | 0.3 |
| | ***40 - 60*** | ***AC*** | | | | | 7.9 | 307 | 426 | 7.1 | 46 | 34 | 20 | 17.3 | 1.8 | 3.0 | 9.9 | | | 32.3 | 13.9 | 0.4 | 1.9 | 0.4 |
| | ***60 -80*** | ***Cg*** | | | | | 7.6 | 1363 | 1887 | 7.3 | 33 | 38 | 29 | 13.1 | 1.3 | 2.3 | 9.8 | | | 33.2 | 15.3 | 0.7 | 2.4 | 1.1 |
| | ***80 - 120*** | ***2Cg1*** | | | | | 7.9 | 2930 | 4056 | 5.8 | 12 | 48 | 40 | 9.0 | 0.9 | 1.6 | 9.6 | | | 42.8 | 15.5 | 0.9 | 4.0 | 4.7 |
| | ***120 - 140*** | ***2Cg2*** | | | | | 8.1 | 3020 | 4181 | 5.4 | 5 | 58 | 37 | 7.2 | 0.8 | 1.2 | 8.7 | | | 39.8 | 10.5 | 0.8 | 3.6 | 5.1 |
| ***Masal6*** | ***0 -8*** | ***Ap1*** | 33T | 268839 | 4955459 | -1 | 7.6 | 1211 | 1677 | 6.3 | 22 | 49 | 29 | 19.1 | 1.7 | 3.3 | 11.2 | | | 42.8 | 16.6 | 0.6 | 2.5 | 0.7 |
| | ***8 - 36*** | ***Ap2*** | | | | | 7.6 | 1163 | 1610 | 6.9 | 20 | 46 | 34 | 18.7 | 1.7 | 3.2 | 10.7 | | | 44.6 | 16.5 | 0.6 | 2.4 | 0.8 |
| | ***36 - 60*** | ***AC*** | | | | | 7.7 | 1200 | 1662 | 7.1 | 19 | 48 | 34 | 18.7 | 1.8 | 3.2 | 10.6 | | | 43.8 | 16.3 | 0.7 | 2.6 | 1.0 |
| | ***60- 80*** | ***2Cg1*** | | | | | 7.5 | 4350 | 6021 | 9.6 | 5 | 80 | 15 | 10.4 | 1.1 | 1.8 | 9.6 | | | 43.5 | 19.6 | 0.9 | 4.2 | 3.6 |
| | ***80 - 100*** | ***2Cg2*** | | | | | 7.7 | 5210 | 7211 | 10.4 | 5 | 89 | 7 | 10.1 | 1.1 | 1.7 | 9.6 | | | 39.8 | 15.5 | 1.0 | 4.5 | 4.9 |
| | ***100-140*** | ***2Cg3*** | | | | | 7.5 | 7270 | 16547 | 1.8 | 4 | 38 | 57 | 18.8 | 1.6 | 3.2 | 11.6 | | | 55.6 | 12.7 | 1.1 | 7.6 | 5.2 |
| ***Masal7*** | ***0 - 5*** | ***A1*** | 33T | 269026 | 4955346 | 1 | 7.5 | 427 | 592 | 4.3 | 75 | 19 | 6 | 57.4 | 4.6 | 9.9 | 12.4 | | | 59.0 | 20.5 | 0.6 | 2.8 | 0.1 |
| | ***5 - 22*** | ***A2*** | | | | | 7.8 | 284 | 394 | 5.6 | 70 | 21 | 9 | 17.9 | 1.2 | 3.1 | 15.5 | | | 24.1 | 11.6 | 0.5 | 0.9 | 0.1 |
| | ***22- 32*** | ***AC*** | | | | | 7.8 | 293 | 406 | 6.7 | 69 | 20 | 11 | 7.7 | 0.7 | 1.3 | 11.1 | | | 17.7 | 10.2 | 0.5 | 0.6 | 0.1 |
| | ***32 - 47*** | ***Cg1*** | | | | | 8.0 | 326 | 452 | 7.2 | 56 | 30 | 13 | 8.4 | 0.8 | 1.5 | 10.9 | | | 13.0 | 8.1 | 0.2 | 0.4 | 0.1 |
| | ***47 - 79*** | ***Cg2*** | | | | | 8.0 | 419 | 581 | 7.2 | 54 | 31 | 16 | 8.3 | 0.6 | 1.4 | 13.3 | | | 22.0 | 10.7 | 0.3 | 0.9 | 0.3 |
| | ***79 - 110*** | ***Cg3*** | | | | | 8.0 | 371 | 514 | 8.4 | 70 | 23 | 7 | 4.9 | 0.4 | 0.8 | 12.6 | | | 17.0 | 8.9 | 0.2 | 0.8 | 0.2 |
| | ***110 - 115*** | ***Oe*** | | | | | 7.7 | 1640 | 2271 | 17.5 | 40 | 37 | 23 | 26.8 | 2.5 | 4.6 | 10.7 | | | 37.2 | 14.2 | 0.9 | 3.4 | 1.4 |
| | ***115 - 155*** | ***2C*** | | | | | 7.7 | 3500 | 7966 | 0.7 | 11 | 41 | 48 | 13.0 | 1.4 | 2.2 | 9.6 | | | 45.4 | 13.2 | 1.1 | 4.5 | 4.6 |

**Table 9 - – Soil physicochemical characteristics in 2014, part A.**

| | Depth | Horizon | Coordinates UTM-WGS84 | | | Altitude | pH | EC 1:2.5 | ECe | $CaCO_3$ | Sand | Silt | Clay | OC | NT | SOM | C/N | $\delta^{113}C$ | $\delta^{15}N$ | CEC | $Ca^{++}$ | $K^{+}$ | $Mg^{++}$ | $Na^{+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | | *zone* | *x* | *y* | *m a.s.l.* | | μS $cm^{-1}$ | μS $cm^{-1}$ | % | % | % | % | g $kg^{-1}$ | g $kg^{-1}$ | % | | ‰ | ‰ | | *$Cmol_{(+)}$ $kg^{-1}$* | | | |
| ***Masal8*** | ***0-10*** | ***Oap1*** | 33T | 262739 | 4951695 | -4 | 6.8 | 2850 | 4329 | 4.9 | Peat | Peat | Peat | 222.4 | 14.7 | 52.6 | 15.1 | -26.7 | 1.2 | 105.8 | 39.0 | 0.3 | 7.3 | 2.1 |
| | ***10-30*** | ***Oap2*** | | | | | 6.6 | 4220 | 6410 | 4.2 | Peat | Peat | Peat | 219.8 | 14.6 | 53.4 | 15.1 | -26.8 | 1.0 | 33.6 | 34.5 | 0.5 | 10.0 | 5.2 |
| | ***30-40*** | ***Oe*** | | | | | | | | | Peat | Peat | Peat | 240.6 | 11.8 | 41.5 | 20.3 | -27.3 | 0.0 | | | | | |
| | ***40-70*** | ***Oe*** | | | | | 5.3 | 17850 | 27114 | 0.0 | Peat | Peat | Peat | 45.2 | 3.3 | 12.7 | 13.6 | -25.9 | 1.6 | 104.4 | 9.6 | 1.7 | 15.5 | 15.4 |
| ***Masal9*** | ***0-10*** | ***Oap1*** | 33T | 266564 | 4947258 | -2 | 7.0 | 934 | 1419 | 0.9 | Peat | Peat | Peat | 99.9 | 6.5 | 20.0 | 15.4 | -25.6 | 1.5 | 56.0 | 20.9 | 0.3 | 2.4 | 0.8 |
| | ***10-50*** | ***Oap2*** | | | | | 6.8 | 1013 | 1539 | 0.7 | Peat | Peat | Peat | 107.1 | 7.0 | 21.0 | 15.2 | -25.7 | 1.2 | 66.6 | 24.4 | 0.4 | 2.4 | 0.4 |
| | ***50-70*** | ***Oe*** | | | | | 6.6 | 2930 | 4451 | 2.1 | Peat | Peat | Peat | 117.8 | 7.6 | 27.0 | 15.6 | -26.2 | 1.1 | 51.5 | 39.1 | 0.4 | 2.7 | 0.8 |
| | ***70-80*** | ***Oe*** | | | | | 6.7 | 2810 | 4268 | 1.3 | Peat | Peat | Peat | 35.7 | 2.4 | 10.4 | 14.9 | -21.3 | 1.6 | 22.5 | 57.0 | 0.4 | 1.8 | 0.6 |
| ***Masal10*** | ***0-15*** | ***Oap1*** | 32T | 736621 | 4949144 | -3 | 6.9 | 807 | 1226 | 2.1 | Peat | Peat | Peat | 90.0 | 6.6 | 20.8 | 13.6 | -26.1 | 2.2 | 65.7 | 25.7 | 0.9 | 2.5 | |
| | ***15-60*** | ***Oap2*** | | | | | 6.9 | 459 | 697 | 3.4 | Peat | Peat | Peat | 84.2 | 6.2 | 18.5 | 13.5 | -26.1 | 2.2 | 65.4 | 26.1 | 0.7 | 2.6 | |
| | ***60-70*** | ***Oe*** | | | | | 6.8 | 1326 | 2014 | 3.7 | Peat | Peat | Peat | 77.8 | 5.4 | 19.9 | 14.3 | -25.9 | 1.6 | 65.8 | 23.0 | 0.3 | 2.8 | 0.1 |
| | ***70-100*** | ***Oe*** | | | | | 6.7 | 700 | 1063 | 1.4 | Peat | Peat | Peat | 101.8 | 7.0 | 21.5 | 14.6 | -27.0 | 1.6 | 58.4 | 26.7 | 0.3 | 3.0 | 0.2 |
| ***Masal11*** | ***0 - 0.5*** | ***Crust*** | 32T | 736733 | 4949168 | -3 | 6.9 | 1632 | 2479 | 5.8 | Peat | Peat | Peat | 32.4 | 1.9 | 20.1 | 17.2 | -19.0 | 1.7 | 64.0 | 28.3 | 0.4 | 1.6 | 0.0 |
| | ***0.5 - 15*** | ***Ap1*** | | | | | 7.0 | 900 | 1367 | 5.5 | Peat | Peat | Peat | 102.1 | 7.0 | 19.8 | 14.7 | -25.5 | 1.6 | 60.9 | 26.9 | 0.4 | 1.3 | |
| | ***15-50*** | ***Ap2*** | | | | | 7.1 | 579 | 880 | 6.7 | Peat | Peat | Peat | 92.5 | 6.4 | 22.8 | 14.5 | -25.3 | 1.4 | 61.1 | 26.0 | 0.3 | 1.2 | |
| | ***50-70*** | ***Oe*** | | | | | 4.8 | 2720 | 4132 | 0.9 | Peat | Peat | Peat | 96.8 | 6.5 | 27.6 | 14.9 | -24.6 | 1.4 | 48.5 | 57.2 | 0.2 | 2.1 | 0.2 |
| | ***70-90 (i)*** | ***Oe*** | | | | | 4.3 | 3060 | 4648 | 1.1 | Peat | Peat | Peat | 121.4 | 7.8 | 35.5 | 15.6 | -27.1 | 0.3 | 33.4 | 36.9 | 0.2 | 3.5 | 0.6 |
| | ***70-90 (ii)*** | ***Oe*** | | | | | 4.9 | 4140 | 6289 | 1.1 | Peat | Peat | Peat | 160.7 | 11.0 | 13.5 | 14.7 | -27.4 | 1.3 | 35.1 | 23.9 | 0.6 | 9.1 | 1.2 |
| | ***90-100*** | ***C*** | | | | | 6.5 | 4070 | 5634 | 8.4 | 6 | 70 | 24 | 60.9 | 4.2 | 7.7 | 14.6 | -27.8 | 1.0 | 28.9 | 18.2 | 0.8 | 6.7 | 1.3 |

**Table 9 – Soil physicochemical characteristics in 2014, part B.**

| | Depth | Cbas | Labile-C | Labile-N | Cmic | Nmic | Cmic/Nmic | $qCO_2$ | qM | Cmic/OC |
|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | *(mg C_CO$_2$ kg$^{-1}$)* | *mg kg$^{-1}$* | *mg kg$^{-1}$* | *mg kg$^{-1}$* | *mg kg$^{-1}$* | | | *%* | *%* |
| ***Masal3*** | ***0 - 10*** | 12.3 | 362.5 | 69.1 | 442.9 | 18.1 | 24.5 | 0.12 | 0.06 | 0.3 |
| | ***10-40/50*** | 4.5 | 329.3 | 63.0 | 360.6 | 15.7 | 23.0 | 0.05 | 0.07 | 0.2 |
| | ***40/50 - 80*** | 3.8 | 341.3 | 55.8 | 181.4 | 6.9 | 26.1 | 0.09 | 0.07 | 0.2 |
| | ***80-100*** | 5.1 | 141.1 | 27.9 | 137.2 | 18.5 | 7.4 | 0.15 | 0.32 | 0.3 |
| ***Masal4*** | ***0-10*** | 8.5 | 623.7 | 62.7 | 403.5 | 37.1 | 10.9 | 0.09 | 0.04 | 0.2 |
| | ***10 - 40*** | 8.3 | 587.5 | 71.6 | 443.3 | 40.7 | 10.9 | 0.08 | 0.07 | 0.2 |
| | ***40 - 100*** | 10.4 | 365.4 | 103.4 | 119.4 | 10.2 | 11.7 | 0.36 | 0.11 | 0.1 |
| ***Masal5*** | ***0-7*** | 5.1 | 103.2 | 23.3 | 93.2 | 14.3 | 6.5 | 0.23 | 0.30 | 0.5 |
| | ***7 - 40*** | 6.3 | 98.5 | 21.7 | 123.1 | 17.6 | 7.0 | 0.21 | 0.29 | 0.6 |
| | ***40 - 60*** | 5.0 | 89.1 | 21.1 | 92.1 | 15.5 | 5.9 | 0.23 | 0.25 | 0.5 |
| | ***60 -80*** | 3.8 | 83.1 | 20.8 | 52.4 | 9.3 | 5.6 | 0.30 | 0.43 | 0.4 |
| | ***80 - 120*** | 4.5 | 73.6 | 15.4 | 17.7 | 2.0 | 8.8 | 1.07 | 0.20 | 0.2 |
| | ***120 - 140*** | 4.2 | 52.3 | 9.4 | 3.9 | 2.0 | 2.0 | 4.44 | 0.21 | 0.1 |
| ***Masal6*** | ***0 -8*** | 4.7 | 119.4 | 22.8 | 102.6 | 9.1 | 11.3 | 0.19 | 0.22 | 0.5 |
| | ***8 - 36*** | 5.3 | 94.7 | 22.0 | 122.3 | 16.9 | 7.2 | 0.18 | 0.25 | 0.7 |
| | ***36 - 60*** | 5.3 | 97.8 | 22.2 | 111.3 | 9.7 | 11.5 | 0.20 | 0.26 | 0.6 |
| | ***60- 80*** | 4.3 | 88.6 | 21.0 | 45.6 | 12.4 | 3.7 | 0.39 | 0.38 | 0.4 |
| | ***80 - 100*** | 4.9 | 81.1 | 17.9 | 19.9 | 2.4 | 8.3 | 1.02 | 0.36 | 0.2 |
| | ***100-140*** | 7.3 | 132.2 | 19.8 | 0.9 | 2.0 | 0.5 | 32.50 | 0.25 | 0.0 |
| ***Masal7*** | ***0 - 5*** | 48.7 | 379.3 | 111.4 | 842.8 | 126.9 | 6.6 | 0.24 | 0.95 | 1.5 |
| | ***5 - 22*** | 20.2 | 100.5 | 39.0 | 223.4 | 33.4 | 6.7 | 0.38 | 1.26 | 1.3 |
| | ***22- 32*** | 10.3 | 28.6 | 19.5 | 63.6 | 8.4 | 7.6 | 0.68 | 1.91 | 0.8 |
| | ***32 - 47*** | 10.2 | 22.0 | 11.1 | 49.0 | 7.5 | 6.5 | 0.87 | 1.71 | 0.6 |
| | ***47 - 79*** | 13.8 | 24.1 | 12.0 | 53.6 | 7.2 | 7.5 | 1.07 | 1.53 | 0.6 |
| | ***79 - 110*** | 11.5 | 10.2 | 8.1 | 22.6 | 3.9 | 5.9 | 2.12 | 2.55 | 0.5 |
| | ***110 - 115*** | 18.0 | 71.9 | 51.7 | 159.7 | 14.7 | 10.9 | 0.47 | 0.71 | 0.6 |
| | ***115 - 155*** | 10.6 | 27.7 | 24.4 | 61.5 | 5.8 | 10.6 | 0.72 | 1.17 | 0.5 |

**Table 10 - Biochemical characteristics of selected soil's profiles in 2014.**

| | Depth | Al | As | B | Ba | Be | Ca | Ce | Co | Cr | Cu | Fe | K | Li | Mg | Mn | Mo | Na | Ni | P | Pb | S | Si | Sn | Sr | Ti | Tl | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | *g kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *g kg-1* | *Mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *g kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* |
| ***Masal 3*** | ***0 - 10*** | 44.1 | 8.7 | 83.0 | 215.9 | 1.8 | 18.8 | 16.2 | 12.6 | 103.4 | 74.6 | 25.4 | 10.5 | 63.1 | 9.3 | 0.24 | 5.3 | 1.4 | 92.4 | 0.79 | 14.8 | 9.22 | 306.9 | 2.5 | 172.0 | 635.1 | 7.09 | 80.3 | 72.7 |
| | ***10-40/50*** | 43.3 | 8.5 | 83.1 | 213.0 | 1.7 | 20.5 | 16.5 | 12.8 | 101.9 | 72.5 | 25.1 | 10.4 | 62.4 | 9.4 | 0.24 | 5.3 | 1.8 | 91.4 | 0.81 | 14.6 | 10.75 | 444.1 | 2.2 | 180.3 | 618.6 | 7.77 | 78.8 | 90.3 |
| | ***40/50 - 80*** | 38.2 | 6.6 | 60.3 | 159.0 | 1.5 | 33.8 | 41.6 | 14.2 | 96.2 | 38.1 | 24.7 | 10.1 | 58.0 | 12.9 | 0.42 | 1.4 | 1.6 | 79.4 | 0.44 | 11.1 | 9.69 | 349.9 | 2.2 | 177.2 | 803.3 | 7.04 | 67.8 | 85.8 |
| | ***80-100*** | 44.9 | 6.4 | 81.9 | 204.8 | 1.8 | 20.5 | 0.0 | 11.4 | 98.6 | 60.5 | 26.6 | 10.9 | 65.4 | 9.7 | 0.19 | 4.3 | 2.9 | 78.8 | 0.58 | 13.0 | 13.83 | 502.3 | 2.3 | 151.9 | 537.4 | 6.39 | 80.7 | 76.5 |
| ***Masal 4*** | ***0-10*** | 33.9 | 8.0 | 75.6 | 154.2 | 1.4 | 24.9 | 0.0 | 10.0 | 76.9 | 39.4 | 20.3 | 8.3 | 48.7 | 7.0 | 0.20 | 6.8 | 2.0 | 72.9 | 0.77 | 15.1 | 12.71 | 417.1 | 1.9 | 219.5 | 489.7 | 7.56 | 64.2 | 108.0 |
| | ***10 - 40*** | 32.5 | 8.2 | 86.8 | 154.9 | 1.4 | 36.0 | 0.0 | 9.6 | 70.8 | 37.1 | 19.1 | 8.2 | 46.8 | 7.1 | 0.21 | 7.0 | 2.6 | 70.1 | 0.82 | 15.0 | 15.88 | 358.3 | 2.0 | 310.1 | 488.3 | 8.21 | 61.2 | 81.8 |
| | ***40 - 100*** | 37.9 | 8.3 | 86.7 | 134.4 | 1.5 | 12.8 | 0.0 | 10.6 | 92.2 | 37.3 | 23.1 | 10.3 | 57.7 | 9.9 | 0.15 | 5.7 | 11.3 | 71.3 | 0.45 | 6.2 | 18.33 | 546.7 | 2.0 | 130.8 | 509.6 | 8.28 | 72.3 | 112.9 |
| ***Masal 5*** | ***0-7*** | 32.2 | 6.1 | 42.3 | 176.3 | 1.2 | 36.8 | 42.3 | 13.5 | 108.6 | 34.9 | 20.1 | 7.9 | 52.7 | 12.8 | 0.43 | 0.8 | 1.7 | 89.0 | 0.53 | 13.5 | 0.99 | 452.8 | 2.0 | 210.9 | 949.5 | 8.29 | 59.1 | 75.0 |
| | ***7 - 40*** | 33.2 | 5.8 | 41.5 | 180.4 | 1.2 | 35.7 | 42.2 | 13.3 | 107.1 | 34.6 | 19.9 | 7.9 | 52.7 | 12.6 | 0.42 | 0.8 | 1.6 | 86.5 | 0.51 | 12.8 | 0.88 | 216.5 | 2.0 | 208.7 | 989.4 | 8.48 | 59.6 | 71.7 |
| | ***40 - 60*** | 31.6 | 5.7 | 40.5 | 168.7 | 1.2 | 35.5 | 41.7 | 13.6 | 104.2 | 34.2 | 20.0 | 7.3 | 52.6 | 12.7 | 0.43 | 0.9 | 1.4 | 87.9 | 0.45 | 13.1 | 0.88 | 270.9 | 2.1 | 205.2 | 951.7 | 6.91 | 57.1 | 71.1 |
| | ***60 -80*** | 40.2 | 6.1 | 50.5 | 223.9 | 1.5 | 33.4 | 46.1 | 15.9 | 122.3 | 38.1 | 23.8 | 9.6 | 61.4 | 14.3 | 0.51 | 0.8 | 2.0 | 104.3 | 0.43 | 13.3 | 1.11 | 159.8 | 2.3 | 189.2 | 1024.8 | 7.12 | 71.2 | 79.6 |
| | ***80 - 120*** | 46.3 | 5.8 | 61.2 | 235.0 | 1.8 | 29.7 | 43.4 | 18.5 | 139.4 | 48.4 | 37.1 | 10.8 | 70.7 | 15.7 | 1.09 | 0.0 | 0.0 | 124.7 | 0.44 | 15.7 | 1.23 | 270.5 | 2.4 | 154.1 | 878.5 | 7.39 | 82.8 | 90.0 |
| | ***120 - 140*** | 45.9 | 4.9 | 58.0 | 229.9 | 1.8 | 28.8 | 46.5 | 18.6 | 137.1 | 44.7 | 28.3 | 10.8 | 69.8 | 16.5 | 0.64 | 0.0 | 0.0 | 121.1 | 0.43 | 14.7 | 0.50 | 235.9 | 2.3 | 147.8 | 915.9 | 7.81 | 82.1 | 91.6 |
| ***Masal 6*** | ***0 -8*** | 44.4 | 7.1 | 60.6 | 238.8 | 1.7 | 34.1 | 44.7 | 16.9 | 127.0 | 46.8 | 24.9 | 10.7 | 69.6 | 15.2 | 0.49 | 0.8 | 1.9 | 109.9 | 0.61 | 15.2 | 1.41 | 222.1 | 2.3 | 200.5 | 905.8 | 6.35 | 78.8 | 91.1 |
| | ***8 - 36*** | 43.1 | 7.2 | 59.4 | 222.8 | 1.7 | 34.4 | 44.5 | 17.0 | 124.2 | 46.6 | 24.8 | 10.1 | 68.3 | 15.2 | 0.49 | 0.8 | 1.9 | 109.8 | 0.52 | 15.1 | 1.31 | 224.0 | 2.3 | 201.0 | 919.4 | 7.13 | 76.6 | 89.1 |
| | ***36 - 60*** | 46.5 | 7.4 | 63.4 | 251.6 | 1.8 | 34.2 | 47.6 | 17.3 | 129.0 | 46.3 | 25.4 | 11.2 | 70.6 | 15.6 | 0.49 | 0.8 | 2.2 | 110.8 | 0.52 | 15.2 | 1.41 | 210.1 | 2.6 | 204.1 | 960.2 | 6.89 | 81.9 | 89.1 |
| | ***60- 80*** | 46.4 | 4.7 | 61.8 | 262.3 | 1.8 | 40.6 | 44.7 | 18.3 | 138.1 | 46.8 | 26.1 | 11.1 | 72.7 | 16.9 | 0.58 | 0.0 | 0.0 | 118.9 | 0.41 | 15.4 | 2.53 | 222.5 | 2.4 | 200.2 | 940.8 | 6.47 | 81.6 | 90.8 |
| | ***80 - 100*** | 46.2 | 3.9 | 64.9 | 251.9 | 1.8 | 40.9 | 46.0 | 17.3 | 131.5 | 42.3 | 29.8 | 11.3 | 69.5 | 16.2 | 0.88 | 0.0 | 0.0 | 110.8 | 0.47 | 14.3 | 2.06 | 245.1 | 2.4 | 207.7 | 916.5 | 4.07 | 80.9 | 85.3 |
| | ***100-140*** | 61.4 | 7.7 | 91.2 | 315.9 | 2.4 | 12.8 | 45.4 | 20.8 | 151.8 | 54.8 | 32.3 | 14.3 | 84.0 | 16.6 | 0.51 | 0.0 | 5.0 | 129.5 | 0.44 | 17.2 | 2.08 | 206.4 | 2.8 | 110.3 | 818.4 | 4.20 | 109.9 | 105.2 |
| ***Masal 7*** | ***0 - 5*** | 21.2 | 3.0 | 42.7 | 109.4 | 0.8 | 28.2 | 40.1 | 10.3 | 95.9 | 21.2 | 15.3 | 5.2 | 32.4 | 10.4 | 0.41 | 0.0 | 0.9 | 63.8 | 0.56 | 10.5 | 0.79 | 352.3 | 1.7 | 147.8 | 889.4 | 6.20 | 39.1 | 60.4 |
| | ***5 - 22*** | 20.5 | 3.9 | 24.0 | 96.6 | 0.8 | 30.3 | 36.4 | 10.9 | 94.3 | 18.3 | 16.1 | 4.8 | 33.8 | 11.0 | 0.43 | 0.6 | 0.8 | 69.3 | 0.40 | 9.2 | 0.44 | 332.5 | 1.6 | 142.0 | 937.2 | 3.74 | 38.8 | 54.2 |
| | ***22- 32*** | 22.5 | 4.2 | 22.0 | 110.0 | 0.8 | 32.3 | 38.7 | 11.5 | 108.0 | 19.4 | 16.9 | 5.2 | 36.3 | 11.6 | 0.46 | 0.0 | 1.0 | 72.1 | 0.35 | 8.8 | 0.37 | 289.4 | 1.5 | 152.6 | 1037.3 | 3.50 | 42.1 | 54.9 |
| | ***32 - 47*** | 23.9 | 4.6 | 24.3 | 120.4 | 0.9 | 33.7 | 43.9 | 12.2 | 96.4 | 22.1 | 18.0 | 5.4 | 39.4 | 12.0 | 0.47 | 0.0 | 1.1 | 79.4 | 0.36 | 9.5 | 0.35 | 171.6 | 1.6 | 157.2 | 1026.8 | 3.23 | 44.3 | 53.9 |
| | ***47 - 79*** | 25.9 | 4.9 | 27.2 | 128.3 | 1.0 | 33.8 | 38.7 | 12.5 | 110.0 | 23.1 | 18.6 | 6.1 | 41.4 | 12.3 | 0.50 | 0.0 | 1.1 | 79.9 | 0.36 | 10.0 | 0.43 | 180.8 | 1.7 | 165.3 | 1064.6 | 7.40 | 47.4 | 55.1 |
| | ***79 - 110*** | 19.5 | 3.6 | 18.5 | 95.6 | 0.7 | 38.8 | 37.1 | 10.8 | 85.3 | 17.1 | 16.2 | 4.4 | 33.3 | 11.5 | 0.48 | 0.0 | 0.9 | 67.0 | 0.39 | 7.3 | 0.26 | 380.6 | 1.5 | 180.8 | 1065.5 | 7.14 | 36.7 | 49.1 |
| | ***110 - 115*** | 33.5 | 7.4 | 59.0 | 183.8 | 1.2 | 61.0 | 38.0 | 11.8 | 100.7 | 36.0 | 18.6 | 9.1 | 56.5 | 11.5 | 0.38 | 1.7 | 2.8 | 78.6 | 0.35 | 14.4 | 2.03 | 186.6 | 1.9 | 459.4 | 837.9 | 6.45 | 60.2 | 63.7 |
| | ***115 - 155*** | 50.0 | 7.7 | 70.9 | 262.4 | 2.0 | 12.5 | 47.3 | 20.0 | 153.4 | 45.1 | 26.6 | 11.7 | 77.9 | 16.0 | 0.29 | 0.9 | 0.0 | 135.3 | 0.34 | 17.5 | 1.43 | 217.3 | 2.5 | 111.4 | 944.8 | 3.50 | 89.5 | 101.9 |

**Table 11 - Soil total content of elements in 2014 – part A.**

| | Depth | Al | As | B | Ba | Be | Ca | Ce | Co | Cr | Cu | Fe | K | Li | Mg | Mn | Mo | Na | Ni | P | Pb | S | Si | Sn | Sr | Ti | Tl | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | *g kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *g kg-1* | *Mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *g kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *g kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* | *mg kg-1* |
| ***Masal8*** | ***0-10*** | 28.9 | 7.3 | 77.8 | 165.0 | 1.0 | 29.8 | 20.1 | 7.6 | 67.9 | 31.1 | 16.1 | 7.2 | 37.8 | 6.4 | 0.16 | 8.1 | 2.7 | 54.6 | 0.68 | 13.6 | 11.16 | n.d. | 2.0 | 261.5 | 461.2 | n.d. | 52.1 | 66.3 |
| | ***10-30*** | 24.8 | 7.3 | 83.9 | 119.5 | 0.7 | 8.9 | 14.2 | 4.6 | 61.2 | 31.1 | 20.4 | 8.5 | 29.5 | 6.2 | 0.06 | 8.4 | 11.7 | 33.3 | 0.33 | 8.8 | 29.68 | n.d. | 1.4 | 98.9 | 364.3 | n.d. | 49.1 | 60.4 |
| | ***30-40*** | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | ***40-70*** | 38.5 | 8.8 | 60.2 | 129.7 | 1.3 | 6.8 | 38.6 | 13.3 | 119.4 | 26.3 | 28.2 | 10.2 | 59.2 | 14.8 | 0.36 | 3.0 | 9.4 | 71.6 | 0.40 | 12.9 | 14.72 | n.d. | 2.0 | 63.3 | 975.9 | n.d. | 67.7 | 92.3 |
| ***Masal9*** | ***0-10*** | 24.4 | 8.5 | 36.7 | 99.2 | 0.8 | 19.6 | 33.0 | 8.7 | 93.7 | 44.2 | 18.0 | 5.9 | 32.9 | 8.4 | 0.31 | 3.1 | 1.7 | 50.1 | 0.62 | 10.3 | 4.69 | n.d. | 1.4 | 133.0 | 775.4 | n.d. | 44.9 | 58.6 |
| | ***10-50*** | 22.6 | 7.7 | 34.9 | 89.3 | 0.7 | 19.4 | 25.9 | 8.3 | 90.9 | 34.3 | 17.4 | 5.5 | 32.0 | 8.1 | 0.29 | 3.4 | 1.0 | 48.9 | 0.60 | 13.2 | 4.80 | n.d. | 1.4 | 129.1 | 710.5 | n.d. | 42.6 | 59.6 |
| | ***50-70*** | 25.6 | 7.3 | 42.8 | 102.4 | 0.8 | 27.2 | 24.7 | 9.2 | 87.3 | 27.9 | 18.3 | 6.4 | 36.4 | 9.0 | 0.31 | 4.0 | 1.6 | 54.3 | 0.61 | 11.4 | 10.00 | n.d. | 1.3 | 184.9 | 665.8 | n.d. | 48.2 | 58.1 |
| | ***70-80*** | 26.2 | 7.9 | 34.5 | 88.0 | 0.9 | 32.2 | 28.0 | 10.3 | 90.3 | 19.3 | 22.5 | 6.8 | 41.3 | 13.1 | 0.55 | 2.7 | 1.4 | 50.9 | 0.32 | 10.1 | 15.32 | n.d. | 1.5 | 135.9 | 791.4 | n.d. | 47.5 | 61.7 |
| ***Masal10*** | ***0-15*** | 48.8 | 13.0 | 74.2 | 243.5 | 1.6 | 19.0 | 33.8 | 11.2 | 131.2 | 51.6 | 24.1 | 11.7 | 70.9 | 10.6 | 0.23 | 3.8 | 1.6 | 81.2 | 0.78 | 19.7 | 3.30 | n.d. | 2.3 | 162.6 | 697.9 | n.d. | 88.0 | 77.8 |
| | ***15-60*** | 50.7 | 12.9 | 76.6 | 252.8 | 1.8 | 18.7 | 34.1 | 11.5 | 134.8 | 50.6 | 25.1 | 12.1 | 71.5 | 11.2 | 0.24 | 3.8 | 1.7 | 83.3 | 0.74 | 20.4 | 3.21 | n.d. | 2.6 | 162.7 | 743.6 | n.d. | 90.1 | 75.3 |
| | ***60-70*** | 39.6 | 10.2 | 54.6 | 195.3 | 1.3 | 16.2 | 32.9 | 12.4 | 121.7 | 39.9 | 25.2 | 9.2 | 59.5 | 10.9 | 0.26 | 5.4 | 1.2 | 78.5 | 0.57 | 15.6 | 3.45 | n.d. | 2.0 | 132.0 | 778.2 | n.d. | 73.4 | 71.7 |
| | ***70-100*** | 46.3 | 9.4 | 63.8 | 240.3 | 1.5 | 15.1 | 36.3 | 11.7 | 126.1 | 40.4 | 25.3 | 11.2 | 63.0 | 10.5 | 0.25 | 6.2 | 1.8 | 74.7 | 0.54 | 15.3 | 4.50 | n.d. | 2.4 | 129.3 | 794.7 | n.d. | 84.9 | 68.9 |
| ***Masal11*** | ***0 - 0.5*** | 40.0 | 10.6 | 64.0 | 200.1 | 1.4 | 26.5 | 30.9 | 11.5 | 111.9 | 41.7 | 23.2 | 10.1 | 59.9 | 10.0 | 0.31 | 4.5 | 1.5 | 74.4 | 0.72 | 16.0 | 4.58 | n.d. | 2.2 | 194.6 | 672.9 | n.d. | 72.1 | 67.4 |
| | ***0.5 - 15*** | 40.7 | 11.3 | 62.7 | 204.9 | 1.4 | 29.9 | 32.8 | 12.1 | 112.8 | 41.2 | 23.5 | 10.0 | 60.2 | 10.2 | 0.34 | 4.4 | 1.5 | 76.1 | 0.69 | 16.0 | 4.31 | n.d. | 2.2 | 207.3 | 716.2 | n.d. | 72.0 | 65.7 |
| | ***15-50*** | 40.1 | 10.5 | 61.7 | 203.9 | 1.4 | 29.3 | 30.6 | 11.6 | 109.9 | 41.7 | 23.3 | 9.8 | 59.4 | 10.0 | 0.33 | 4.6 | 1.5 | 76.2 | 0.70 | 16.0 | 4.47 | n.d. | 2.2 | 206.3 | 672.7 | n.d. | 71.5 | 67.3 |
| | ***50-70*** | 43.1 | 9.1 | 70.2 | 252.4 | 1.3 | 22.5 | 34.2 | 8.5 | 107.8 | 32.0 | 22.8 | 12.2 | 56.7 | 7.9 | 0.13 | 8.4 | 1.7 | 50.3 | 0.44 | 14.0 | 17.25 | n.d. | 2.2 | 149.4 | 617.3 | n.d. | 84.7 | 51.8 |
| | ***70-90 (i)*** | 32.1 | 7.9 | 51.7 | 166.3 | 1.0 | 11.6 | 23.5 | 8.0 | 92.0 | 27.5 | 19.6 | 8.2 | 38.6 | 6.5 | 0.11 | 15.4 | 1.5 | 58.1 | 0.37 | 12.3 | 13.19 | n.d. | 1.6 | 92.0 | 547.5 | n.d. | 61.4 | 55.5 |
| | ***70-90 (ii)*** | 48.7 | 9.6 | 61.6 | 214.4 | 1.8 | 10.0 | 35.0 | 23.8 | 154.6 | 45.1 | 34.3 | 11.6 | 70.1 | 16.2 | 0.37 | 3.1 | 2.7 | 131.0 | 0.39 | 16.6 | 15.62 | n.d. | 2.4 | 82.1 | 856.7 | n.d. | 83.7 | 105.2 |
| | ***90-100*** | 41.8 | 7.9 | 49.4 | 171.2 | 1.5 | 28.8 | 33.9 | 18.7 | 148.1 | 42.4 | 32.5 | 10.4 | 68.6 | 18.2 | 0.58 | 1.4 | 2.5 | 112.6 | 0.36 | 16.1 | 13.46 | n.d. | 2.3 | 137.7 | 838.9 | n.d. | 70.5 | 96.3 |

**Table 11 - Soil total content of elements in 2014 – part B – n.d. stays for not detected; n.a. stays for not analysed.**

| | Depth | As | B | Ba | Be | Ca | Ca | Co | Cr | Cu | Fe | K | Li | Mg | Mg | Mn | Mo | Na | Ni | P | Pb | S | Sr | Ti | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | g kg$^{-1}$ | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | µg kg$^{-1}$ | g kg$^{-1}$ | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | µg kg$^{-1}$ | g kg$^{-1}$ | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | g kg$^{-1}$ | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* | *mg kg-$^{-1}$* |
| ***Masal3*** | ***0 - 10*** | 0.1 | 1.1 | 0.1 | 0.0 | 0.1 | 93.6 | 0.0 | 0.0 | 0.1 | 4.7 | 42.0 | 39.4 | 0.0 | 19.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 0.6 | 0.3 | 0.0 | 0.0 |
| | ***10-40/50*** | 0.1 | 1.2 | 0.2 | 0.0 | 0.1 | 100.3 | 0.0 | 0.0 | 0.1 | 3.0 | 55.6 | 44.8 | 0.0 | 22.6 | 0.1 | 38.6 | 0.0 | 0.0 | 1.1 | 0.0 | 0.0 | 0.7 | 0.2 | 0.0 | 0.0 |
| | ***40/50 - 80*** | 0.0 | 1.4 | 0.1 | 0.0 | 0.1 | 73.3 | 0.0 | 0.0 | 0.1 | 0.7 | 22.0 | 39.9 | 0.0 | 24.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 |
| | ***80-100*** | 0.1 | 1.5 | 0.1 | 0.0 | 0.1 | 122.0 | 0.0 | 0.0 | 0.2 | 2.3 | 99.1 | 48.0 | 0.0 | 35.7 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.6 | 0.3 | 0.0 | 0.0 |
| ***Masal4*** | ***0-10*** | 0.1 | 1.4 | 0.1 | 0.0 | 0.1 | 127.5 | 0.0 | 0.0 | 0.2 | 1.7 | 48.1 | 45.7 | 0.0 | 36.2 | 0.0 | 43.5 | 0.0 | 0.0 | 2.4 | 0.0 | 0.0 | 0.6 | 0.3 | 0.0 | 0.0 |
| | ***10 - 40*** | 0.1 | 2.4 | 0.1 | 0.0 | 0.1 | 116.5 | 0.0 | 0.0 | 0.2 | 0.6 | 62.7 | 71.7 | 0.0 | 37.5 | 0.0 | 114.0 | 0.1 | 0.0 | 1.1 | 0.0 | 0.0 | 0.8 | 0.2 | 0.0 | 0.0 |
| | ***40 - 100*** | 0.0 | 3.3 | 0.2 | 0.1 | 2.7 | 2671.3 | 0.1 | 0.0 | 0.9 | 0.4 | 85.4 | 103.8 | 0.3 | 280.0 | 0.9 | 404.7 | 0.1 | 0.1 | 1.2 | 0.0 | 2.5 | 14.2 | 0.0 | 0.1 | 0.3 |
| ***Masal5*** | ***0-7*** | 0.0 | 6.0 | 0.2 | 0.1 | 3.0 | 2979.1 | 0.1 | 0.0 | 0.7 | 0.4 | 108.2 | 107.7 | 0.4 | 369.4 | 1.6 | 125.4 | 0.5 | 0.2 | 0.9 | 0.2 | 3.1 | 16.3 | 0.0 | 0.1 | 0.3 |
| | ***7 - 40*** | 0.0 | 4.4 | 0.1 | 0.1 | 1.5 | 1498.0 | 0.1 | 0.0 | 0.8 | 0.0 | 222.7 | 222.2 | 0.4 | 434.5 | 3.4 | 112.5 | 1.5 | 0.1 | 0.9 | 0.0 | 2.0 | 8.4 | 0.0 | 0.1 | 0.3 |
| | ***40 - 60*** | 0.0 | 4.8 | 0.1 | 0.1 | 2.8 | 2808.8 | 0.1 | 0.0 | 1.8 | 0.8 | 163.8 | 135.0 | 0.5 | 498.0 | 6.9 | 12.4 | 1.1 | 0.1 | 0.7 | 0.0 | 3.4 | 16.6 | 0.0 | 0.1 | 0.2 |
| | ***60 -80*** | 0.0 | 4.3 | 0.2 | 0.1 | 2.9 | 2864.9 | 0.1 | 0.0 | 0.8 | 0.8 | 71.5 | 96.3 | 0.3 | 346.1 | 3.0 | 129.8 | 0.5 | 0.1 | 1.4 | 0.0 | 2.6 | 17.8 | 0.0 | 0.1 | 0.4 |
| | ***80 - 120*** | 0.0 | 6.3 | 0.2 | 0.1 | 3.1 | 3100.2 | 0.1 | 0.0 | 0.8 | 0.7 | 91.8 | 109.6 | 0.5 | 464.3 | 5.0 | 222.9 | 0.7 | 0.1 | 1.6 | 0.2 | 3.0 | 22.0 | 0.0 | 0.1 | 0.2 |
| | ***120 - 140*** | 0.0 | 15.8 | 0.2 | 0.1 | 3.4 | 3381.6 | 0.7 | 0.0 | 0.9 | 9.2 | 694.3 | 794.2 | 1.9 | 1903.1 | 19.1 | 0.0 | 14.8 | 1.1 | 5.2 | 0.0 | 5.5 | 28.5 | 0.0 | 0.1 | 7.1 |
| ***Masal6*** | ***0 -8*** | 0.1 | 1.8 | 0.1 | 0.0 | 0.1 | 123.4 | 0.0 | 0.0 | 0.2 | 1.3 | 46.5 | 33.1 | 0.0 | 23.0 | 0.0 | 48.7 | 0.2 | 0.0 | 2.7 | 0.0 | 0.1 | 0.7 | 0.3 | 0.0 | 0.0 |
| | ***8 - 36*** | 0.0 | 1.5 | 0.2 | 0.0 | 0.1 | 111.8 | 0.0 | 0.0 | 0.2 | 3.2 | 58.4 | 36.8 | 0.0 | 19.3 | 0.1 | 0.0 | 0.1 | 0.1 | 1.4 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.1 |
| | ***36 - 60*** | 0.0 | 1.8 | 0.2 | 0.0 | 0.1 | 116.1 | 0.0 | 0.0 | 0.2 | 3.1 | 63.5 | 37.3 | 0.0 | 20.1 | 0.1 | 59.5 | 0.1 | 0.0 | 0.9 | 0.0 | 0.0 | 0.7 | 0.5 | 0.0 | 0.1 |
| | ***60- 80*** | 0.0 | 2.4 | 0.1 | 0.0 | 0.5 | 512.9 | 0.0 | 0.0 | 0.3 | 0.1 | 172.8 | 56.8 | 0.1 | 79.2 | 0.1 | 0.0 | 0.3 | 0.0 | 0.2 | 0.0 | 0.7 | 2.3 | 0.0 | 0.0 | 0.0 |
| | ***80 - 100*** | 0.0 | 2.1 | 0.3 | 0.1 | 0.6 | 642.4 | 0.1 | 0.0 | 0.9 | 0.1 | 136.5 | 123.0 | 0.1 | 145.9 | 0.0 | 0.0 | 1.4 | 0.0 | 0.6 | 0.0 | 1.2 | 2.9 | 0.0 | 0.1 | 0.4 |
| | ***100-140*** | 0.0 | 1.9 | 0.1 | 0.1 | 0.1 | 99.3 | 0.1 | 0.0 | 0.7 | 0.0 | 76.8 | 100.8 | 0.1 | 50.4 | 0.1 | 21.7 | 1.7 | 0.0 | 0.5 | 0.0 | 0.5 | 0.7 | 0.0 | 0.1 | 0.1 |
| ***Masal7*** | ***0 - 5*** | 0.0 | 2.9 | 0.2 | 0.0 | 0.5 | 548.4 | 0.0 | 0.0 | 0.1 | 0.0 | 88.2 | 53.8 | 0.1 | 80.8 | 0.0 | 0.0 | 0.2 | 0.0 | 1.6 | 0.0 | 0.6 | 2.7 | 0.0 | 0.0 | 0.0 |
| | ***5 - 22*** | 0.0 | 2.7 | 0.2 | 0.0 | 0.4 | 416.2 | 0.0 | 0.0 | 0.1 | 0.7 | 102.3 | 60.9 | 0.1 | 63.4 | 0.1 | 0.0 | 0.2 | 0.0 | 0.5 | 0.0 | 0.5 | 2.2 | 0.0 | 0.0 | 0.0 |
| | ***22- 32*** | 0.0 | 3.0 | 0.2 | 0.0 | 0.6 | 621.3 | 0.0 | 0.0 | 0.1 | 0.1 | 123.8 | 71.1 | 0.1 | 94.4 | 0.1 | 0.0 | 0.3 | 0.0 | 0.4 | 0.0 | 0.7 | 2.9 | 0.0 | 0.0 | 0.1 |
| | ***32 - 47*** | 0.0 | 2.8 | 0.2 | 0.1 | 2.1 | 2105.8 | 0.1 | 0.0 | 0.8 | 0.2 | 178.1 | 154.2 | 0.3 | 342.8 | 0.2 | 0.0 | 1.2 | 0.0 | 0.4 | 0.3 | 2.7 | 8.0 | 0.0 | 0.1 | 0.1 |
| | ***47 - 79*** | 0.0 | 3.4 | 0.1 | 0.1 | 1.3 | 1334.3 | 0.0 | 0.0 | 0.7 | 0.0 | 231.6 | 140.9 | 0.3 | 335.8 | 0.1 | 0.0 | 1.9 | 0.0 | 0.3 | 0.0 | 2.1 | 5.9 | 0.0 | 0.1 | 0.2 |
| | ***79 - 110*** | 0.0 | 4.1 | 0.2 | 0.1 | 0.6 | 562.2 | 0.1 | 0.0 | 0.8 | 0.1 | 308.5 | 122.9 | 0.3 | 308.5 | 1.0 | 23.4 | 4.2 | 0.0 | 0.6 | 0.0 | 1.7 | 3.6 | 0.0 | 0.1 | 0.3 |
| | ***110 - 115*** | 0.1 | 4.3 | 0.2 | 0.0 | 0.2 | 183.8 | 0.0 | 0.0 | 0.2 | 5.3 | 111.1 | 35.7 | 0.0 | 34.7 | 0.3 | 0.0 | 0.0 | 0.1 | 12.8 | 0.0 | 0.0 | 0.9 | 0.2 | 0.0 | 0.1 |
| | ***115 - 155*** | 0.0 | 2.1 | 0.2 | 0.0 | 0.1 | 118.3 | 0.0 | 0.0 | 0.2 | 8.9 | 84.3 | 39.0 | 0.0 | 17.3 | 0.2 | 0.0 | 0.0 | 0.1 | 1.8 | 0.0 | 0.0 | 0.5 | 0.4 | 0.0 | 0.1 |

**Table 12 - Soil dissolved elements in 2014 – part A.**

| | Depth | As | B | Ba | Be | Ca | Ca | Co | Cr | Cu | Fe | K | Li | Mg | Mg | Mn | Mo | Na | Ni | P | Pb | S | Sr | Ti | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | g kg⁻¹ | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | µg kg⁻¹ | g kg⁻¹ | *mg kg-⁻¹* | *mg kg-⁻¹* | µg kg⁻¹ | g kg⁻¹ | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | g kg⁻¹ | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* | *mg kg-⁻¹* |
| ***Masal8*** | ***0-10*** | 0.0 | 1.4 | 0.2 | 0.0 | 0.1 | 103.8 | 0.0 | 0.0 | 0.2 | 6.3 | 66.1 | 33.0 | 0.0 | 11.3 | 0.1 | 0.0 | 0.0 | 0.1 | 0.5 | 0.0 | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 |
| | ***10-30*** | 0.0 | 1.6 | 0.1 | 0.0 | 0.1 | 108.0 | 0.0 | 0.0 | 0.2 | 7.8 | 90.0 | 31.6 | 0.0 | 11.8 | 0.1 | 0.0 | 0.1 | 0.0 | 0.5 | 0.0 | 0.0 | 0.5 | 0.3 | 0.0 | 0.0 |
| | ***30-40*** | 0.0 | 1.8 | 0.2 | 0.0 | 0.1 | 111.9 | 0.0 | 0.0 | 0.2 | 6.2 | 60.3 | 34.2 | 0.0 | 14.9 | 0.2 | 0.0 | 0.1 | 0.1 | 0.4 | 0.0 | 0.0 | 0.5 | 0.2 | 0.0 | 0.1 |
| | ***40-70*** | 0.0 | 1.8 | 0.1 | 0.0 | 0.1 | 94.0 | 0.0 | 0.0 | 0.1 | 2.4 | 35.9 | 23.9 | 0.0 | 14.3 | 0.1 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.5 | 0.2 | 0.0 | 0.1 |
| ***Masal9*** | ***0-10*** | 0.0 | 3.0 | 0.2 | 0.1 | 0.4 | 359.3 | 0.0 | 0.0 | 0.9 | 0.8 | 140.2 | 132.2 | 0.1 | 107.4 | 0.2 | 119.3 | 0.5 | 0.2 | 1.2 | 0.3 | 0.5 | 2.5 | 0.0 | 0.1 | 0.2 |
| | ***10-50*** | 0.0 | 3.9 | 0.2 | 0.1 | 0.4 | 403.5 | 0.1 | 0.0 | 0.8 | 0.2 | 200.3 | 165.7 | 0.1 | 134.0 | 0.2 | 35.5 | 1.4 | 0.0 | 0.6 | 0.0 | 1.1 | 2.4 | 0.0 | 0.1 | 0.1 |
| | ***50-70*** | 0.0 | 7.0 | 0.2 | 0.0 | 0.8 | 788.7 | 0.0 | 0.0 | 0.1 | 0.8 | 96.2 | 26.4 | 0.2 | 155.8 | 0.2 | 580.4 | 0.6 | 0.1 | 1.0 | 0.0 | 0.7 | 5.7 | 0.0 | 0.0 | 0.0 |
| | ***70-80*** | 0.0 | 7.2 | 0.3 | 0.1 | 1.0 | 991.3 | 0.1 | 0.0 | 0.8 | 2.8 | 123.9 | 138.0 | 0.3 | 301.3 | 0.7 | 381.2 | 1.5 | 0.0 | 1.6 | 0.3 | 1.5 | 7.3 | 0.0 | 0.1 | 0.4 |
| ***Masal10*** | ***0-15*** | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a |
| | ***15-60*** | 0.0 | 11.2 | 0.4 | 0.0 | 1.4 | 1366.3 | 0.5 | 0.0 | 0.1 | 0.2 | 494.6 | 1043.1 | 1.9 | 1890.3 | 34.2 | 21.1 | 11.5 | 0.8 | 0.5 | 0.0 | 4.2 | 10.9 | 0.0 | 0.0 | 1.0 |
| | ***60-70*** | 0.1 | 2.9 | 0.1 | 0.0 | 0.2 | 247.8 | 0.0 | 0.0 | 0.3 | 7.4 | 78.0 | 35.2 | 0.0 | 36.3 | 0.1 | 162.4 | 0.3 | 0.2 | 1.8 | 0.0 | 0.2 | 1.3 | 0.3 | 0.0 | 0.2 |
| | ***70-100*** | 0.0 | 2.8 | 0.1 | 0.0 | 0.4 | 354.3 | 0.0 | 0.0 | 0.4 | 4.1 | 103.0 | 28.9 | 0.0 | 44.7 | 0.1 | 160.9 | 0.2 | 0.1 | 1.3 | 0.0 | 0.3 | 2.0 | 0.2 | 0.0 | 0.1 |
| ***Masal11*** | ***0 - 0.5*** | 0.0 | 3.5 | 0.2 | 0.0 | 2.6 | 2619.5 | 0.0 | 0.0 | 0.1 | 0.2 | 163.5 | 44.0 | 0.2 | 240.0 | 0.2 | 209.8 | 0.4 | 0.0 | 0.3 | 0.0 | 2.9 | 17.8 | 0.0 | 0.0 | 0.0 |
| | ***0.5 - 15*** | 0.0 | 2.8 | 0.1 | 0.0 | 2.9 | 2863.5 | 0.0 | 0.0 | 0.1 | 1.1 | 141.5 | 98.7 | 0.2 | 230.4 | 0.7 | 0.0 | 0.3 | 0.0 | 0.2 | 0.0 | 2.9 | 16.4 | 0.0 | 0.0 | 0.1 |
| | ***15-50*** | 0.0 | 2.2 | 0.3 | 0.0 | 0.3 | 281.3 | 0.0 | 0.1 | 0.2 | 5.5 | 101.2 | 31.7 | 0.0 | 31.1 | 0.1 | 109.6 | 0.0 | 0.2 | 1.9 | 0.0 | 0.1 | 1.8 | 0.5 | 0.0 | 0.1 |
| | ***50-70*** | 0.0 | 2.6 | 0.2 | 0.0 | 0.3 | 259.9 | 0.1 | 0.0 | 0.2 | 1.3 | 54.3 | 20.4 | 0.0 | 34.9 | 0.0 | 171.4 | 0.0 | 0.2 | 2.1 | 0.0 | 0.1 | 1.5 | 0.3 | 0.0 | 0.0 |
| | ***70-90 (i)*** | 0.0 | 2.2 | 0.1 | 0.0 | 0.3 | 324.6 | 0.0 | 0.0 | 0.2 | 2.4 | 46.6 | 18.2 | 0.0 | 42.7 | 0.0 | 180.8 | 0.1 | 0.1 | 0.8 | 0.0 | 0.2 | 1.8 | 0.2 | 0.0 | 0.1 |
| | ***70-90 (ii)*** | 0.0 | 2.1 | 0.1 | 0.0 | 0.4 | 360.5 | 0.0 | 0.0 | 0.2 | 3.2 | 48.2 | 17.7 | 0.0 | 45.1 | 0.0 | 131.6 | 0.1 | 0.1 | 0.8 | 0.0 | 0.2 | 1.8 | 0.2 | 0.0 | 0.1 |
| | ***90-100*** | 0.0 | 3.0 | 0.3 | 0.0 | 0.9 | 898.3 | 0.0 | 0.0 | 0.1 | 0.5 | 81.4 | 24.3 | 0.1 | 57.3 | 0.0 | 185.6 | 0.1 | 0.1 | 1.0 | 0.0 | 0.5 | 5.0 | 0.0 | 0.0 | 0.1 |

**Table 12 – Soil dissolved elements in 2014 – part B.**

| **Sampled soils** | **Soil Taxonomy (2014)** | **WRB (2014)** | **Soil Survey of Emilia Romagna Region** |
|---|---|---|---|
| **Masal3** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Canale Specchio |
| **Masal4** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Canale Specchio |
| **Masal5** | Ustorthents | Gleyic Fluvisol (Loamic) | Le Contane/Canale del Sole |
| **Masal6** | Ustorthents | Gleyic Fluvisol | Le Contane/Canale del Sole |
| **Masal7** | Ustorthents | Gleyic Fluvisol | Le Contane/Canale del Sole |
| **Masal8** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Canale Specchio |
| **Masal9** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Burano/Mottalunga |
| **Masal10** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Canale Specchio |
| **Masal11** | Typic Sulfisaprists, euic, mesic | Thionic Sapric Histosols (Sulfidic) | Canale Specchio |

**Table 13 - Soil delineations of sampled soils in 2014, according to Soil Taxonomy 2014, WRB 2014 and geological, seismic and soil survey of Emilia-Romagna region.**

| Samples | *pH* | ECe | OC | *PLH* | *CRB* | *TSC* | *CRB+PLH* | Ptot | | | Pin | | | *NIT* | *Ammoniacal* | *Nitrates* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *µS cm⁻¹* | *g kg⁻¹* | | *hot-water* | | *%wt of TSC* | *µg g⁻¹* | | | *µg g⁻¹* | | | | *mgN kg⁻¹* | |
| | | | | | *mgC kg⁻¹* | | | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | | | |
| | 6.74 | 486 | 134.1 | 157.1 | 150.9 | 1461.5 | 21.1 | 46.6 | 5.3 | 11.3 | 38.8 | 1.2 | 3.2 | 12.5 | 1.4 | 11.2 |
| | 6.56 | 2051 | 131.4 | 116.4 | 124.2 | 1093.4 | 22.0 | 36.0 | 1.7 | 4.8 | 37.2 | 0.6 | 1.7 | 19.9 | 1.4 | 18.6 |
| **MEZ1** | 6.49 | 3067 | 140.4 | 100.1 | 104.2 | 966.1 | 21.1 | 43.6 | 9.0 | 20.6 | 33.1 | 0.7 | 2.1 | 32.8 | 1.4 | 31.4 |
| | 5.62 | 3494 | 167.8 | 152.5 | 212.8 | 1547.8 | 23.6 | 45.2 | 1.7 | 3.7 | 18.0 | 0.4 | 2.4 | 42.9 | 2.0 | 40.9 |
| | 4.76 | 3494 | 86.8 | 88.1 | 123.1 | 622.3 | 33.9 | 24.8 | 1.7 | 7.5 | 9.2 | 0.0 | 0.2 | 11.8 | 2.0 | 9.8 |
| | 6.89 | 2886 | 159.6 | 134.3 | 137.6 | 1206.0 | 22.5 | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a |
| | 6.54 | 3129 | 144.9 | 80.7 | 73.7 | 768.3 | 20.1 | 32.2 | 5.2 | 16.1 | 49.5 | 1.8 | 3.7 | 14.9 | 1.0 | 13.9 |
| | 6.8 | 3342 | 148.5 | 68.4 | 70.9 | 691.5 | 20.2 | 47.0 | 17.0 | 36.1 | 55.3 | 5.1 | 9.3 | 23.7 | 2.4 | 21.3 |
| **MEZ2** | 6.79 | 3646 | 155.4 | 84.0 | 84.7 | 751.9 | 22.4 | 47.6 | 13.1 | 27.5 | 61.6 | 2.2 | 3.5 | 44.0 | 3.0 | 40.9 |
| | 6.56 | 5013 | 223.0 | 141.9 | 230.4 | 1513.3 | 24.6 | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a |
| | 5.72 | 6015 | 106.9 | 80.1 | 69.3 | 730.9 | 20.4 | 20.1 | 3.6 | 17.9 | 14.3 | 3.1 | 21.6 | 23.0 | 2.4 | 20.6 |
| | 3.35 | 13671 | 84.4 | 54.7 | 88.5 | 741.7 | 19.3 | 18.9 | 1.4 | 7.6 | 12.2 | 2.2 | 18.2 | 8.1 | 7.1 | 1.0 |
| | 7.71 | 699 | 46.5 | 47.1 | 59.6 | 468.3 | 22.8 | 54.7 | 5.1 | 9.2 | 54.4 | 4.0 | 7.4 | 3.0 | 0.7 | 2.4 |
| **MEZ3** | 7.41 | 965 | 45.7 | 43.8 | 61.9 | 456.8 | 23.1 | 28.2 | 3.5 | 12.4 | 27.1 | 4.3 | 15.9 | 5.7 | 0.0 | 5.7 |
| | 6.77 | 3494 | 20.9 | 25.8 | 41.1 | 215.3 | 31.1 | 12.6 | 1.6 | 12.3 | 12.0 | 1.4 | 11.3 | 7.1 | 0.0 | 7.1 |
| | 6.8 | 4253 | 17.6 | 17.7 | 15.2 | 208.4 | 15.8 | 10.3 | 2.0 | 19.3 | 8.7 | 0.2 | 2.1 | 7.1 | 2.7 | 4.4 |
| | 7.43 | 3038 | 159.9 | 83.2 | 87.9 | 681.3 | 25.1 | 61.9 | 1.3 | 2.0 | 57.9 | 1.7 | 2.9 | 10.8 | 4.73 | 6.1 |
| **Masal3** | 6.89 | 3463 | 155.2 | 77.6 | 99.6 | 703.7 | 25.2 | 60.6 | 4.4 | 7.2 | 56.1 | 2.6 | 4.7 | 19.6 | 3.38 | 16.2 |
| | 5.58 | 6046 | 74.5 | 72.2 | 68.5 | 565.0 | 24.9 | 26.6 | 5.9 | 22.3 | 22.1 | 1.5 | 6.9 | 19.6 | 2.70 | 16.9 |
| | 8.02 | 264 | 12.4 | 23.9 | 38.8 | 230.9 | 27.2 | 18.6 | 2.7 | 14.8 | 22.0 | 3.1 | 14.2 | 8.1 | 0.3 | 7.8 |
| | 7.55 | 599 | 12.7 | 22.0 | 38.0 | 222.7 | 27.0 | 16.7 | 2.7 | 16.2 | 18.8 | 2.9 | 15.3 | 15.2 | 3.0 | 12.2 |
| **Masal5** | 7.76 | 900 | 12.7 | 22.9 | 35.2 | 250.8 | 23.2 | 10.5 | 2.3 | 21.7 | 16.4 | 1.7 | 10.7 | 12.5 | 3.0 | 9.5 |
| | 7.74 | 3101 | 14.2 | 20.5 | 34.7 | 245.8 | 22.4 | 9.0 | 7.2 | 79.2 | 14.2 | 5.3 | 37.4 | 15.2 | 2.4 | 12.8 |
| | 7.97 | 8535 | 6.2 | 10.8 | 23.1 | 199.3 | 17.0 | 4.7 | 0.8 | 17.8 | 6.1 | 0.1 | 2.0 | 3.7 | 4.4 | -0.7 |
| | 8.23 | 3322 | 3.5 | 7.0 | 14.7 | 182.7 | 11.9 | 5.2 | 3.2 | 61.9 | 4.4 | 0.4 | 9.5 | 3.0 | 3.0 | 0.0 |
| | 7.64 | 516 | 85.1 | 66.5 | 81.2 | 676.4 | 21.8 | 66.9 | 22.3 | 33.4 | 84.4 | 7.1 | 8.4 | 27.0 | 1.35 | 25.7 |
| **Masal10** | 7.51 | 805 | 103.8 | 89.0 | 104.7 | 939.1 | 20.6 | 38.8 | 7.8 | 20.1 | 65.4 | 7.1 | 10.9 | 56.1 | 2.03 | 54.1 |
| | 7.35 | 2127 | 110.9 | 76.6 | 96.2 | 822.7 | 21.0 | 59.8 | 1.4 | 2.3 | 53.2 | 0.5 | 0.9 | 69.0 | 2.70 | 66.3 |

**Table 14 - pH, ECe and nutrients contents of soils sampled in 2016.**

| Samples | DHD µmol INTF $g^{-1}$ $h^{-1}$ | | | DHD/OC | | | CL µmol glucose $g^{-1}$ $h^{-1}$ | | | CL/OC | | | IN µmol glucose $g^{-1}$ $h^{-1}$ | | | IN/OC | | | GL µmol p-nitrofenol $g^{-1}$ $h^{-1}$ | | | GL/OC | | | AR µmol p-nitrofeno $g^{-1}$ $h^{-1}$ | | | AR/OC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* |
| | 0,377 | 0,009 | 2 | 2,811 | 0,064 | 2 | 0,039 | 0,015 | 39 | 0,289 | 0,112 | 39 | 2,216 | 0,033 | 1 | 16,526 | 0,246 | 1 | 0,633 | 0,048 | 8 | 4,722 | 0,357 | 8 | 0,084 | 0,006 | 7 | 0,629 | 0,043 | 7 |
| | 0,305 | 0,014 | 4 | 2,322 | 0,103 | 4 | 0,078 | 0,009 | 11 | 0,594 | 0,067 | 11 | 2,036 | 0,054 | 3 | 15,491 | 0,409 | 3 | 0,610 | 0,067 | 11 | 4,639 | 0,507 | 11 | 0,064 | 0,004 | 7 | 0,486 | 0,032 | 7 |
| **MEZ1** | 0,432 | 0,021 | 5 | 4,613 | 0,146 | 3 | 0,124 | 0,010 | 8 | 0,886 | 0,069 | 8 | 2,258 | 0,163 | 7 | 16,086 | 1,158 | 7 | 0,511 | 0,014 | 3 | 3,644 | 0,097 | 3 | 0,087 | 0,004 | 5 | 0,619 | 0,032 | 5 |
| | 0,257 | 0,028 | 11 | 1,529 | 0,168 | 11 | 0,175 | 0,024 | 14 | 1,044 | 0,145 | 14 | 0,879 | 0,072 | 8 | 5,875 | 1,145 | 19 | 0,391 | 0,059 | 15 | 2,331 | 0,349 | 15 | 0,068 | 0,023 | 33 | 0,406 | 0,135 | 33 |
| | 0,216 | 0,020 | 9 | 2,490 | 0,235 | 9 | 0,117 | 0,041 | 35 | 1,102 | 0,265 | 24 | 0,141 | 0,191 | 135 | 0,035 | 0,049 | 141 | 0,133 | 0,042 | 31 | 1,262 | 0,125 | 10 | 0,016 | 0,004 | 25 | 0,189 | 0,047 | 25 |
| | 0,401 | 0,010 | 2 | 2,510 | 0,060 | 2 | 0,038 | 0,006 | 17 | 0,238 | 0,039 | 17 | 2,442 | 0,302 | 12 | 15,301 | 1,890 | 12 | 0,452 | 0,039 | 9 | 2,830 | 0,244 | 9 | 0,157 | 0,010 | 6 | 0,987 | 0,060 | 6 |
| | 0,261 | 0,007 | 3 | 1,801 | 0,050 | 3 | 0,057 | 0,004 | 7 | 0,391 | 0,029 | 7 | 2,817 | 0,115 | 4 | 17,814 | 2,863 | 16 | 0,473 | 0,064 | 14 | 3,262 | 0,440 | 14 | 0,163 | 0,009 | 5 | 1,124 | 0,061 | 5 |
| | 0,378 | 0,022 | 6 | 2,547 | 0,147 | 6 | 0,035 | 0,003 | 7 | 0,239 | 0,017 | 7 | 2,550 | 0,236 | 9 | 17,174 | 1,592 | 9 | 0,471 | 0,002 | 0 | 3,173 | 0,011 | 0 | 0,165 | 0,002 | 1 | 1,112 | 0,013 | 1 |
| **MEZ2** | 0,309 | 0,028 | 9 | 1,989 | 0,179 | 9 | 0,045 | 0,039 | 87 | 0,434 | 0,040 | 9 | 4,000 | 0,113 | 3 | 25,733 | 0,727 | 3 | 0,607 | 0,018 | 3 | 3,903 | 0,117 | 3 | 0,186 | 0,003 | 2 | 1,194 | 0,021 | 2 |
| | 0,435 | 0,035 | 8 | 1,952 | 0,155 | 8 | 0,101 | 0,010 | 10 | 0,452 | 0,045 | 10 | 2,966 | 0,191 | 6 | 13,300 | 0,858 | 6 | 0,297 | 0,053 | 18 | 1,330 | 0,236 | 18 | 0,172 | 0,001 | 1 | 0,773 | 0,006 | 1 |
| | 0,140 | 0,030 | 21 | 1,312 | 0,281 | 21 | 0,051 | 0,001 | 3 | 0,475 | 0,012 | 3 | 0,741 | 0,030 | 4 | 6,929 | 0,278 | 4 | 0,174 | 0,010 | 6 | 1,628 | 0,098 | 6 | 0,056 | 0,008 | 13 | 0,525 | 0,071 | 13 |
| | 0,298 | 0,081 | 27 | 3,043 | 0,600 | 20 | 0,125 | 0,006 | 5 | 1,479 | 0,070 | 5 | 0,194 | 0,126 | 65 | 1,458 | 0,453 | 31 | 0,093 | 0,030 | 32 | 1,293 | 0,157 | 12 | 0,019 | 0,007 | 38 | 0,227 | 0,085 | 38 |
| | 0,243 | 0,007 | 3 | 5,997 | 1,348 | 22 | 0,051 | 0,004 | 7 | 1,098 | 0,081 | 7 | 2,374 | 0,067 | 3 | 51,092 | 1,440 | 3 | 0,417 | 0,036 | 9 | 8,971 | 0,773 | 9 | 0,028 | 0,003 | 11 | 0,992 | 0,166 | 17 |
| **MEZ3** | 0,215 | 0,021 | 10 | 4,701 | 0,461 | 10 | 0,034 | 0,007 | 21 | 0,738 | 0,155 | 21 | 2,070 | 0,177 | 9 | 45,257 | 3,872 | 9 | 0,349 | 0,0380 | 11 | 7,628 | 0,831 | 11 | 0,048 | 0,001 | 2 | 1,053 | 0,022 | 2 |
| | 0,136 | 0,011 | 8 | 6,533 | 0,512 | 8 | 0,051 | 0,008 | 16 | 2,438 | 0,402 | 16 | 0,632 | 0,112 | 18 | 30,252 | 5,345 | 18 | 0,086 | 0,020 | 23 | 4,630 | 0,497 | 11 | 0,036 | 0,003 | 9 | 1,729 | 0,154 | 9 |
| | 0,081 | 0,012 | 15 | 4,608 | 0,674 | 15 | 0,049 | 0,002 | 4 | 2,787 | 0,125 | 4 | 0,090 | 0,008 | 9 | 5,124 | 0,483 | 9 | 0,038 | 0,002 | 6 | 2,185 | 0,125 | 6 | 0,019 | 0,002 | 12 | 1,105 | 0,132 | 12 |
| | 0,415 | 0,024 | 6 | 2,593 | 0,149 | 6 | 0,101 | 0,013 | 13 | 0,629 | 0,081 | 13 | 1,864 | 0,195 | 10 | 11,657 | 1,222 | 10 | 0,525 | 0,0768 | 15 | 3,286 | 0,481 | 15 | 0,057 | 0,004 | 8 | 0,355 | 0,027 | 8 |
| **Masal3** | 0,312 | 0,006 | 2 | 2,009 | 0,039 | 2 | 0,103 | 0,004 | 3 | 0,545 | 0,201 | 37 | 2,128 | 0,039 | 2 | 13,708 | 0,248 | 2 | 0,333 | 0,0393 | 12 | 4,116 | 0,253 | 6 | 0,105 | 0,002 | 2 | 0,677 | 0,015 | 2 |
| | 0,172 | 0,001 | 1 | 2,041 | 0,470 | 23 | 0,092 | 0,002 | 2 | 1,389 | 0,272 | 20 | 0,492 | 0,246 | 50 | 6,602 | 3,302 | 50,0 | 0,059 | 0,0004 | 1 | 1,579 | 0,006 | 0 | 0,057 | 0,018 | 31 | 0,762 | 0,235 | 31 |
| | 0,150 | 0,013 | 9 | 12,112 | 1,058 | 9 | 0,001 | 0,000 | 0 | 0,101 | n.d | n.d | 1,620 | 0,008 | 1 | 130,691 | 0,685 | 1 | 0,267 | 0,025 | 9 | 21,519 | 2,006 | 9 | 0,043 | 0,002 | 4 | 3,455 | 0,154 | 4 |
| | 0,120 | 0,016 | 13 | 9,456 | 1,229 | 13 | 0,014 | 0,005 | 35 | 1,106 | 0,382 | 35 | 2,028 | 0,153 | 8 | 159,547 | 12,016 | 8 | 0,216 | 0,013 | 6 | 16,957 | 1,051 | 6 | 0,024 | 0,003 | 13 | 1,884 | 0,237 | 13 |
| | 0,124 | 0,022 | 18 | 9,763 | 1,724 | 18 | 0,013 | 0,001 | 10 | 1,059 | 0,105 | 10 | 1,161 | 0,165 | 14 | 91,534 | 13,045 | 14 | 0,140 | 0,038 | 27 | 9,353 | 1,311 | 14 | 0,033 | 0,009 | 26 | 2,229 | 0,261 | 12 |
| **Masal5** | 0,121 | 0,006 | 5 | 8,508 | 0,423 | 5 | 0,000 | 0,000 | 0 | 0,000 | 0,000 | 0 | 0,604 | 0,102 | 17 | 42,406 | 7,178 | 17 | 0,070 | 0,012 | 17 | 7,372 | 0,850 | 12 | 0,037 | 0,001 | 2 | 2,573 | 0,046 | 2 |
| | 0,020 | 0,002 | 9 | 3,228 | 0,289 | 9 | 0,012 | 0,004 | 34 | 1,874 | 0,645 | 34 | 0,153 | 0,021 | 14 | 24,793 | 3,437 | 14 | 0,019 | 0,010 | 56 | 2,064 | 0,003 | 0 | 0,001 | 0,002 | 173 | 0,531 | 0,000 | 0 |
| | 0,017 | 0,012 | 69 | 6,202 | 3,011 | 49 | 0,000 | 0,000 | 0 | 0,000 | 0,000 | 0 | 0,015 | 0,004 | 28 | 4,252 | 1,203 | 28 | 0,011 | 0,005 | 46 | 2,295 | 0,687 | 30 | 0,001 | 0,001 | 204 | 0,606 | 0,000 | 0 |
| | 0,310 | 0,019 | 6 | 3,648 | 0,227 | 6 | 0,106 | 0,017 | 16 | 1,244 | 0,197 | 16 | 2,703 | 0,140 | 5 | 34,512 | 4,884 | 14 | 0,708 | 0,0716 | 10 | 8,327 | 0,842 | 10 | 0,116 | 0,021 | 18 | 1,365 | 0,246 | 18 |
| **Masal10** | 0,384 | 0,011 | 3 | 3,698 | 0,109 | 3 | 0,120 | 0,019 | 16 | 1,259 | 0,034 | 3 | 2,874 | 0,297 | 10 | 27,696 | 2,862 | 10 | 0,552 | 0,0996 | 18 | 5,320 | 0,960 | 18 | 0,107 | 0,001 | 1 | 1,543 | 0,006 | 0 |
| | 0,401 | 0,018 | 5 | 3,619 | 0,165 | 5 | 0,046 | 0,033 | 72 | 0,412 | 0,295 | 72 | 1,362 | 0,000 | 0 | 15,189 | 5,030 | 33 | 0,422 | 0,0268 | 6 | 3,806 | 0,241 | 6 | 0,202 | 0,006 | 3 | 1,818 | 0,054 | 3 |

**Table 15 - Enzymatic activities of soil sampled in 2016, measured at IIAG-CSIC (Santiago de Compostela, Spain) – part A.**

| Samples | UR μmol $NH_3$ $g^{-1}$ $h^{-1}$ | | | UR/OC | | | P6 μmol p-nitrofenol $g^{-1}$ $h^{-1}$ | | | P6/OC | | | P10 μmol p-nitrofenol $g^{-1}$ $h^{-1}$ | | | P10/OC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* | *Average* | *ST.D* | *%err* |
| **MEZ1** | 2,868 | 0,126 | 4 | 21,388 | 0,938 | 4 | 0,757 | 0,059 | 8 | 5,645 | 0,441 | 8 | 1,582 | 0,152 | 10 | 11,794 | 1,132 | 10 |
| | 3,175 | 0,301 | 9 | 24,156 | 2,288 | 9 | 1,085 | 0,058 | 5 | 8,251 | 0,445 | 5 | 1,835 | 0,036 | 2 | 13,959 | 0,273 | 2 |
| | 2,696 | 0,266 | 10 | 19,204 | 1,895 | 10 | 1,204 | 0,089 | 7 | 8,578 | 0,635 | 7 | 2,275 | 0,154 | 7 | 15,193 | 1,915 | 13 |
| | 1,867 | 0,176 | 9 | 11,123 | 1,048 | 9 | 1,678 | 0,007 | 0 | 9,998 | 0,042 | 0 | 0,940 | 0,123 | 13 | 5,603 | 0,734 | 13 |
| | 0,784 | 0,093 | 12 | 9,032 | 1,070 | 12 | 1,400 | 0,147 | 11 | 16,131 | 1,699 | 11 | 0,208 | 0,025 | 12 | 2,399 | 0,283 | 12 |
| **MEZ2** | 4,870 | 0,180 | 4 | 30,512 | 1,130 | 4 | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a | n.a |
| | 5,156 | 0,188 | 4 | 35,575 | 1,298 | 4 | 0,931 | 0,089 | 10 | 6,422 | 0,617 | 10 | 2,059 | 0,059 | 3 | 14,203 | 0,410 | 3 |
| | 5,342 | 0,302 | 6 | 35,977 | 2,033 | 6 | 1,066 | 0,052 | 5 | 7,181 | 0,350 | 5 | 2,384 | 0,097 | 4 | 17,603 | 2,714 | 15 |
| | 3,988 | 0,298 | 7 | 25,657 | 1,915 | 7 | 1,153 | 0,126 | 11 | 7,420 | 0,810 | 11 | 2,217 | 0,200 | 9 | 14,264 | 1,289 | 9 |
| | 4,991 | 0,173 | 3 | 22,382 | 0,777 | 3 | 0,898 | 0,105 | 12 | 4,029 | 0,469 | 12 | 1,940 | 0,198 | 10 | 8,699 | 0,890 | 10 |
| | 2,776 | 0,315 | 11 | 25,955 | 2,950 | 11 | 1,292 | 0,061 | 5 | 12,078 | 0,573 | 5 | 1,126 | 0,104 | 9 | 10,533 | 0,976 | 9 |
| | 0,891 | 0,491 | 55 | 10,558 | 5,819 | 55 | 0,615 | 0,079 | 13 | 8,738 | 2,590 | 30 | 0,034 | 0,004 | 12 | 0,466 | 0,115 | 25 |
| **MEZ3** | 4,109 | 0,478 | 12 | 88,436 | 10,277 | 12 | 0,470 | 0,012 | 3 | 10,109 | 0,265 | 3 | 2,518 | 0,212 | 8 | 49,492 | 8,765 | 18 |
| | 4,066 | 0,452 | 11 | 88,891 | 9,885 | 11 | 0,573 | 0,063 | 11 | 12,538 | 1,381 | 11 | 2,658 | 0,160 | 6 | 58,121 | 3,506 | 6 |
| | 1,589 | 0,114 | 7 | 84,110 | 14,444 | 17 | 0,414 | 0,014 | 3 | 19,824 | 0,664 | 3 | 1,003 | 0,161 | 16 | 48,010 | 7,705 | 16 |
| | 0,585 | 0,067 | 11 | 33,326 | 3,787 | 11 | 0,082 | 0,005 | 6 | 4,683 | 0,275 | 6 | 0,134 | 0,008 | 6 | 7,657 | 0,460 | 6 |
| **Masal3** | 3,019 | 0,261 | 9 | 18,878 | 1,632 | 9 | 0,876 | 0,137 | 16 | 5,480 | 0,855 | 16 | 0,866 | 0,160 | 18 | 6,230 | 1,578 | 25 |
| | 2,215 | 0,114 | 5 | 21,623 | 4,713 | 22 | 0,241 | 0,061 | 25 | 1,550 | 0,390 | 25 | 0,552 | 0,036 | 7 | 3,555 | 0,233 | 7 |
| | 1,406 | 0,055 | 4 | 16,924 | 3,399 | 20 | 0,830 | 0,123 | 15 | 11,137 | 1,656 | 15 | 0,179 | 0,049 | 27 | 2,404 | 0,659 | 27 |
| **Masal5** | 0,592 | 0,032 | 5 | 47,791 | 2,550 | 5 | 0,331 | 0,032 | 10 | 26,666 | 2,572 | 10 | 1,167 | 0,012 | 1 | 94,151 | 0,996 | 1 |
| | 0,436 | 0,030 | 7 | 37,782 | 6,250 | 17 | 0,235 | 0,005 | 2 | 16,377 | 3,626 | 22 | 1,390 | 0,070 | 5 | 109,353 | 5,488 | 5 |
| | 0,481 | 0,068 | 14 | 37,885 | 5,342 | 14 | 0,295 | 0,014 | 5 | 23,269 | 1,108 | 5 | 1,210 | 0,072 | 6 | 95,378 | 5,686 | 6 |
| | 0,510 | 0,132 | 26 | 35,803 | 9,256 | 26 | 0,209 | 0,028 | 14 | 14,677 | 1,998 | 14 | 1,071 | 0,113 | 11 | 75,179 | 7,916 | 11 |
| | 0,082 | 0,007 | 8 | 2,221 | 0,457 | 21 | 0,049 | 0,052 | 107 | 7,876 | 8,455 | 107 | 0,023 | 0,027 | 115 | 5,658 | 3,994 | 71 |
| | 0,199 | 0,029 | 15 | 0,000 | 0,000 | 0 | 0,076 | 0,097 | 126 | 32,528 | 28,126 | 86 | 0,063 | 0,011 | 18 | 17,876 | 3,187 | 18 |
| **Masal10** | 4,620 | 0,472 | 10 | 57,574 | 6,883 | 12 | 0,767 | 0,054 | 7 | 9,011 | 0,636 | 7 | 2,455 | 0,035 | 1 | 28,860 | 0,407 | 1 |
| | 6,118 | 0,150 | 2 | 58,955 | 1,446 | 2 | 0,956 | 0,019 | 2 | 10,085 | 1,510 | 15 | 2,555 | 0,218 | 9 | 24,621 | 2,099 | 9 |
| | 6,635 | 0,380 | 6 | 59,841 | 3,427 | 6 | 1,569 | 0,132 | 8 | 14,150 | 1,188 | 8 | 2,994 | 0,008 | 0 | 27,006 | 0,075 | 0 |

**Table 15 - Enzymatic activities of soil sampled in 2016, measured at IIAG-CSIC (Santiago de Compostela, Spain) – part B.**

## *Results 2014-2015*

The two most peculiar characteristics of the area, SOM and salinity, were consistent with previous studies. SOM was higher in the central part of the valley and lower in the marginal part. SOM decreased with depth, presenting buried levels of partially undecomposed organic material found at different depths in different part of the valley. Boschi and Spallacci (1974) presented the opposite trend in most of the valley, but their profile consisted of just two layers, so it is possible that buried organic layers were included in the deeper layer (50-100cm). Soil Survey of Emilia-Romagna region database agreed with our data.

Masal5 and Masal6, the only two profiles representing the marginal section of the valley, showed discrepancies in soil textures. Our samples were mainly loamy and sometimes some clayey, while in Boschi and Spallacci (1974) were mainly sandy or silty clay.

Soil organic matter (SOM) of superficial horizons was reasonably comparable with historical data for organic layers (with some differences probably due to analytical methods) while extreme differences were found for Masal5, Masal6 and Masal7: our results showed about 3-4% of SOM, while 10-15% in 70s. The same area, in Emilia-Romagna region's database presented SOM ranging between 2.9 and 5.5% for the first 30cm, thus agreed with our results. Considering deep horizons (50-100cm), Masal10 and Masal11 showed double contents (5-10% in 70s against about 20% nowadays). Masal5, Masal6 and Masal7 had about 5.5% of SOM content in 70s, just about 2% nowadays.

Total Nitrogen (Ntot) of surficial layers showed reasonably comparable data with historical ones in organic layers (methods are considered comparable): our results showed Ntot > 6.5g $kg^{-1}$ while 70s results showed Ntot > 8g $kg^{-1}$. Exceptions were Masal11 (5g $kg^{-1}$) and MEZ3 (4.3g $kg^{-1}$). Extreme differences were found for Masal5, Masal6 and Masal7: our results showed about 1.7g kg-1, while 6-8 g $kg^{-1}$ in 70s. Deeper layers showed wider ranges of Ntot and not always in agreement with previous studies: MEZ2 and Masal4 7.60 and 7.71g $kg^{-1}$ (70s, Ntot > 8g $kg^{-1}$); MEZ1 3.48g $kg^{-1}$, Masal3 4.98g $kg^{-1}$, Masal9 4.98g $kg^{-1}$, Masal8 3.32g $kg^{-1}$ (about half of the Ntot detected in 70s, Ntot

> 8g $kg^{-1}$); Masal10 6.21g $kg^{-1}$ and Masal11 7.25g $kg^{-1}$ (Ntot < 4g $kg^{-1}$ in 70s). MEZ3 and MEZ4 and Masal7 showed extremely low values, much lower than 70s. Masal5 and Masal6 showed about 1g $kg^{-1}$, one point per-mill lower than 70s.

C/N presented results comparable to historical data for all superficial horizons. Deeper layers showed some differences in all horizons presenting slightly lower value nowadays, and big differences just for Masal5 and Masal6 (C/N about 9 nowadays against C/N 13-16 during 70s).

In correspondence of Masal7, very interesting was the presence of a thin dark buried layer (at depth 110-115cm) with a higher relative SOM (4.6%wt) and $CaCO_3$ (17%wt) contents compared to the rest of the profile.

Total P was consistent with Boschi and Spallaci (1974) in all analysed organic samples: P < 1‰ (just two horizons among all showed contents slightly above 1‰). Masal5 and Masal6 showed half content than 70s.

Salinity never reached high levels in the surficial horizons, with few exception: Masal3 and Masal4 presented ECe ranging between 3.9 and 5.6dS $m^{-1}$ in the cultivated horizons. Salinity always increased with depth and in certain horizons the extracted water solution reached concentration of salts very closed to those of average seawater (30dS $m^{-1}$).

Both salinity and SOM showed influences on pH levels: in fact, pH decreased generally with depth were organic layers were found. On the contrary, where the deep layers consisted of salty mineral horizons, pH tended to increase together with salinity.

Soluble cations always correlated positively to each other's, except for few cases. The most concentrated were generally S and Ca, while Na became the most represented in the deep layers.

$CaCO_3$ contents rarely exceeded 5%wt in the organic horizons, while non-organic horizons generally showed higher $CaCO_3$ contents, and just two samples presented values > 10%. These data are really different compared to 70s, when most of the surficial horizons presented contents > 10% (0-50cm; about 84.8% of surface). $CaCO_3$ just slightly decreased with depth, while in the 70s about 76.5% of the valley presented contents < 5%wt (Fig.28). Anyway, Boschi and Spallacci (1974) already identified a trend of $CaCO_3$ decrease reaching average values of 5%wt.

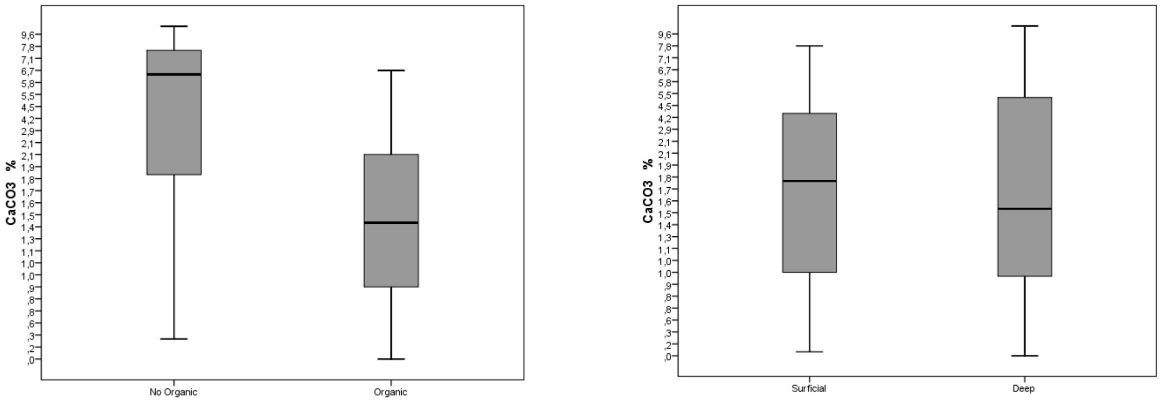



**Figure 28 - Box plots representing $CaCO_3$ contents in Organic and mineral layers, and in surficial and deep layers.**

CEC was high in organic layers and low in the mineral layers. $Ca^{2+}$ was the most represented among exchangeable cations, then $Mg^{2+}$, $Na^+$ and $K^+$. Potassium and sodium did slightly increment closed to water table. No exchangeable $H^+$ was detected. The ratios between exchangeable cations did confirm the trend already seen in 70s.

Total content of selected metals (Cr, Ni, V, Cu, Pb and Zn) in deep layers were comparable with those of Emilia-Romagna regions database, even no demonstrable differences were found among northern and southern sections of the valley. Just MEZ1 and MEZ3 showed always the lower content of metals except Pb and Cr. Data were also comparable with those of Di Giuseppe et al. (2014) except for V and Cr: our samples showed definitively lower concentrations. Generally total concentration of these elements was comparable with those found in other sediments deposited in the Po river basin. Notwithstanding, top enrichment factor was not a generalized trend for our samples.

In 2014, biochemical parameters were measured in selected profiles: Masal3 and Masal4 as “peaty” horizons, Masal5 and Masal6 as mineral horizons, and Masal7 as natural reference (even if it is a restored wood along the road on the side of the mineral layers).

Cmic was higher in natural reference just in the most superficial horizon, deeper layers showed contents lower compared to all others, while “peaty” horizons always presented higher contents compared to mineral ones. Nmic had similar patterns to Cmic in superficial horizons while in deep layers it was comparable for all profiles. Cmic/Nmic was very high at Masal4 (23 to 26.1, fungi composition) while much lower in all other profiles.

Labile-C and Labile-N of organic horizons were higher compared to mineral layers. Masal3 presented very high contents of Labile-C compared to others. The deep layers of Masal7 showed lower values than mineral cultivated profiles.

Cbas was always at its highest in the natural reference. Organic horizons also showed higher value than mineral cultivated layers, except for deep layers of Masal4. Ccum was always higher in organic profiles than in mineral ones, and sometimes even higher than the natural reference. Beside all, Cmic/OC, $qCO_2$ and qM were always higher in the natural reference, while “peaty” profiles presented the lowest values of all (Fig.29).

In 2015, the cultivated organic layers were also compared to a natural reference, a restored wood on organic soils along a channel. The results showed similar trends to those found in 2014: Cbas higher in natural reference, labile-C and labile-N higher only in the superficial horizon of natural reference, Cmic and Nmic uneven, Cmic/Nmic higher in cultivated layers, $qCO_2$ and qM higher in the natural reference, while exception was Cmic/OC that was lower in the natural reference (Fig.30).

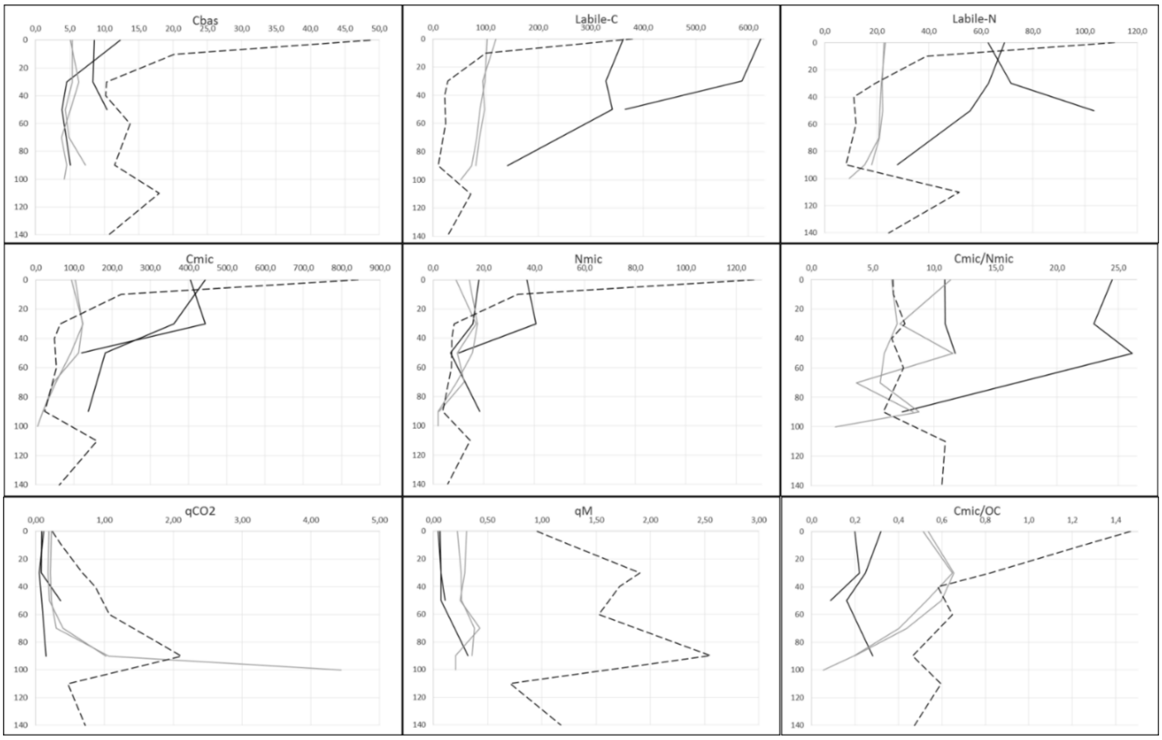



**Figure 29 – Variation with depth of biochemical parameters measured in 2014. Dashed lines referrer to natural reference (Masal7); black lines to Histosols (Masal3 and Masal4); grey lines to Entisols (Masal5 and Masal6).**

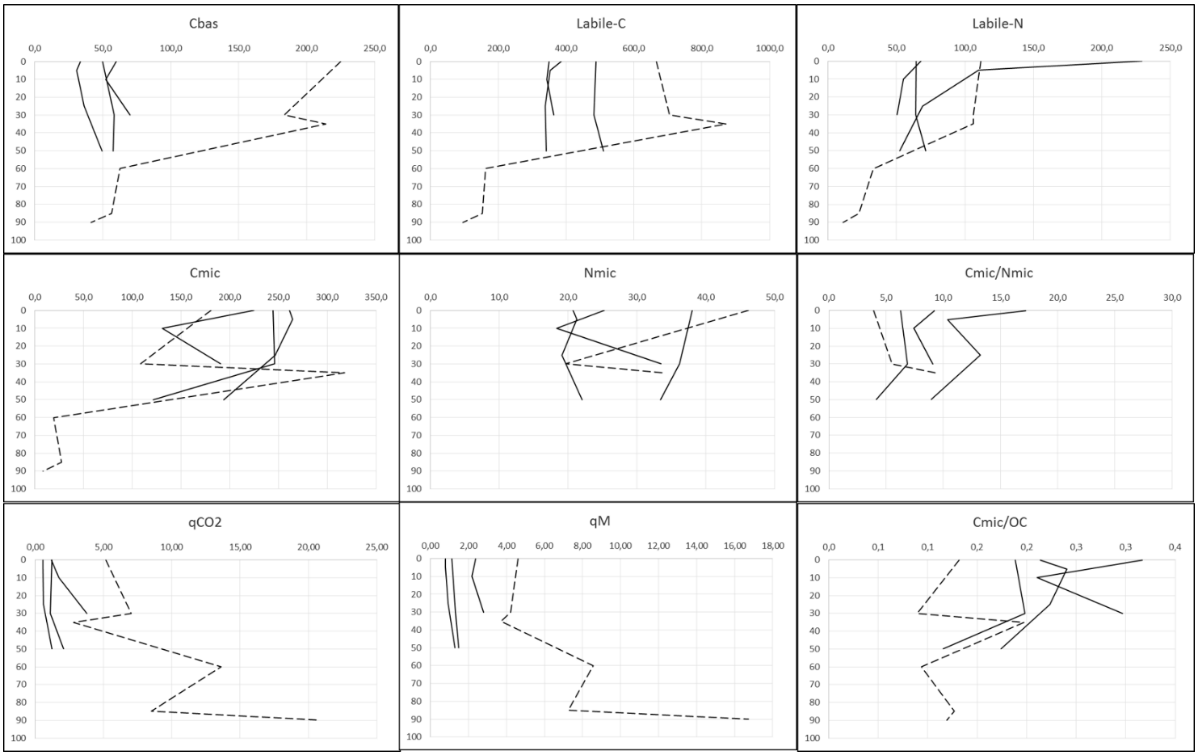



**Figure 30 - Variation of biochemical parameters measured in 2015. Dashed lines refer to natural reference (MEZ4); black lines to Histosols (MEZ1, MEZ2 and MEZ3).**

## *Results 2016*

The pH of soils was generally neutral or slightly acid on the surface horizons but decreasing with depth to very low values, with the only exceptions Masal5 that presented basic pH along all profile and increasing with depth. EC was quite variable, with common feature of increasing with depth in all profiles: MEZ1, MEZ2 and Masal3 presented ECe above 2dS $m^{-1}$ already in the surficial horizons, while other profiles reached those levels of conductivity below 40-60cm from the ground surface.

OC was high as expected in al profiles except Masal5, however data were not always consistent with those of the previous years, especially organic horizons. This probably because every year farmer must reset most of fields due to subsidence and mixing layers. Masal10 was the only profile where OC increased with depth. TSC, PLH and CRB were strictly related to OC ($r^2$ = 0.710, 0.771 and 0.685, $p < 0.01$, respectively) and follow the same trend with depth, even if in MASAL10 the highest contents were found in the middle horizon (15-60cm) and not in the deepest as for OC. Either OC or soluble fractions of carbon presented the lowest values in Masal5. NIT was mainly represented by $NO_3$ (in most of cases was the only fraction found): Masal10 presented the highest concentration of NIT among all, and MEZ3 the lowest. Concentration of NIT generally increased till a certain depth, variable from profile to profile, and started to decrease in deeper layers. However, this trend was found just for those profiles where groundwater level was deep at the time of sampling, for the others NIT just increased with depth. Ptot was higher in the organic horizons and decreased with depth drastically, except for Masal10. Concentration of Pin allowed to think that Porg was absent or extremely low in most of the horizons: just MEZ1 and few other horizons presented some detectable traces of Porg.

Data of phosphorous were compared with those presented in Boschi and Spallacci (1974). The sharpest differences were that samples of 2016 did not contained (or contained very low amounts) of Porg, moreover Pin did not increase with depth.

Enzymatic activities showed always lower values along Masal5 (except few isolated cases), generally decreased with depth and were positively correlated with OC and other nutrients.

UR ranged from 0 to 6.63μmol$NH_3$ $g^{-1}h^{-1}$, decreased with depth nut not always gradually and MASAL10 activity increased with depth.

DHD ranged from 0.017 to 0.556μmol INTF $g^{-1}h^{-1}$, gradually decreased with depth (except MASAL10, where increased) and positively correlated with OC and other nutrients.

AR ranged from 0 to 0.216μmol $g^{-1}h^{-1}$, generally decreased with depth (except Masal10, where increased) and positively correlated with OC and other nutrients.

CL ranged from 0 to 0.175μmol glucosio $g^{-1}h^{-1}$, variation with depth was uneven and correlation with OC and other nutrients was positive (with P fractions no correlation was found).

IN ranged from 0 to 4.07μmol glucosio $g^{-1}$ $h^{-1}$, gradually decreased with depth and positively correlated with OC and other nutrients.

GL ranged from 0.01 to 0.7μmol PNP $g^{-1}$ $h^{-1}$, gradually decreased with depth and positively correlated with OC and other nutrients.

P6 ranged from 0.08 to 1.68μmol PNP $g^{-1}$ $h^{-1}$, increased generally with depth were a decrese of pH was found (pH, $r^2 = -0.606$, $p < 0.01$), otherwise variation with depth was uneven, positively correlated with OC and other nutrients.

P10 ranged from 0.03 to 3.00μmol PNP $g^{-1}$ $h^{-1}$, generally decreased with depth (except Masal10, where increased), positive correlations with pH nor OC were not found, while other nutrients positively correlated with the activity.

Enzymatic activities were also expressed to OC contents, named as specific activity: activity/OC. It is a way to express the results that help to compare horizons with different OC. Figure 31 shows the variation with depth of specific activities of different enzymes in the various profiles.

Masal5 presented the highest values of all specific activities except for CL and UR: CL was uneven through al profiles, while UR was higher in MEZ3 and Masal10. Masal10 showed increasing of specific activities with depth similarly to effective activities: AR, UR and DHD. In all other profiles, generally specific activities decreased with depth, except for DHD and P6: DHD was homogeneous through profiles (in Masal5 decreased), P6 increased.

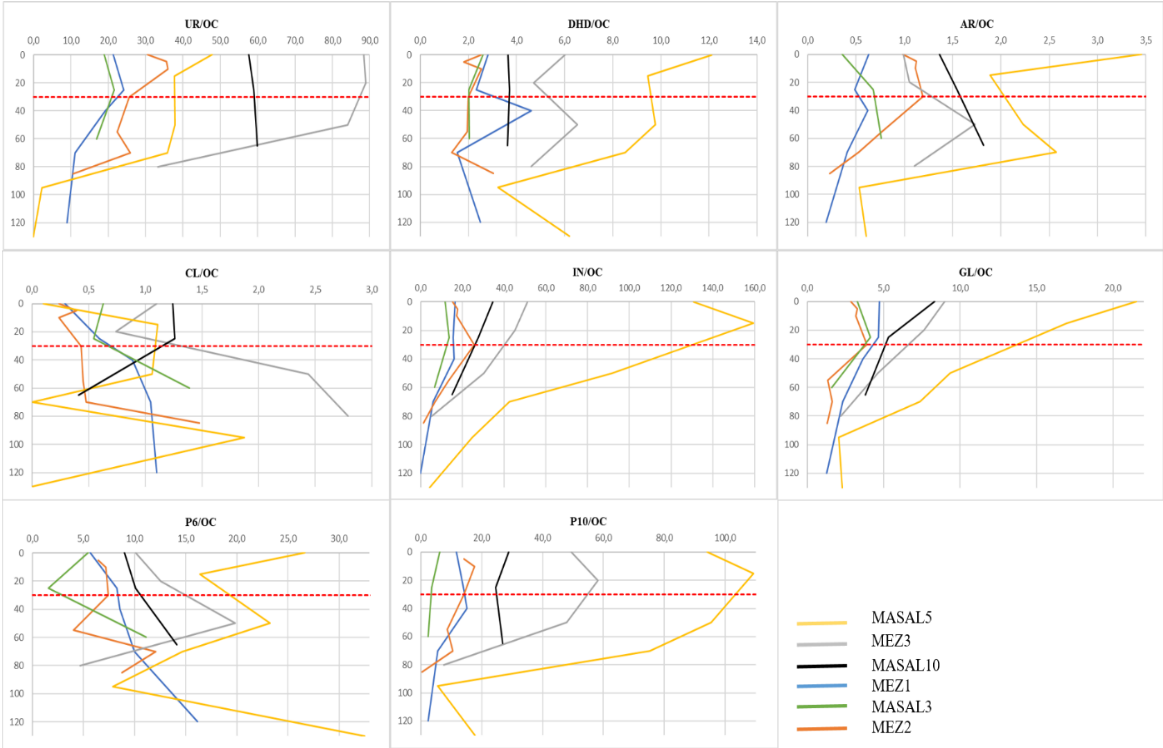



**Figure 31- Variation of enzymatic specific activities with depth. Dotted red lines represent 30cm depth, which is considered the base of cultivated layers.**

## *Data processing*

Considering all data-set, so both deep and cultivated layers, a correlation matrix was performed (Tab.16).

All nutrients showed a strong positive correlation to each other's. OC was strongly positively correlated with all nutrients (also Pin) and enzymatic activities except P10. pH was strongly negatively related to OC and relative soluble fraction, while among enzymatic activities just DHD, CL and P6 increased with decreasing pH, due to their uneven activity decrease with depth. ECe increased with decreasing pH and Pin, but no relation was found with NIT, OC and relative soluble fractions (slightly negative with PLH). Through enzymatic activities just AR, CL and P6 did not show relation with ECe. All enzymatic activities positive correlate through each other's, just CL, being the most variable, did not correlate with UR, P10 and IN.

| | *pH* | *Ece* | *OC* | *TSC* | *CRB* | *PLH* | *Pin* | *NIT* | *AR* | *CL* | *IN* | *GL* | *DHD* | *UR* | *P6* | *P10* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***pH*** | 1 | | | | | | | | | | | | | | | |
| ***Ece*** | -.511** | 1 | | | | | | | | | | | | | | |
| ***OC*** | -.413** | | 1 | | | | | | | | | | | | | |
| ***TSC*** | -.433** | | .471** | 1 | | | | | | | | | | | | |
| ***CRB*** | -.407** | | .602** | .792** | 1 | | | | | | | | | | | |
| ***PLH*** | -.293** | -.234* | .406** | .701** | .628** | 1 | | | | | | | | | | |
| ***Pin*** | | -.396** | .693** | .314** | .403** | .247* | 1 | | | | | | | | | |
| ***NIT*** | | | .498** | .421** | .288** | .347** | .499** | 1 | | | | | | | | |
| ***AR*** | | | .271* | .483** | .373** | .529** | .415** | .363** | 1 | | | | | | | |
| ***CL*** | -.650** | .258* | .435** | .466** | .535** | .333** | | .300** | | 1 | | | | | | |
| ***IN*** | | -.383** | .263* | .387** | .321** | .487** | .538** | .232* | .760** | | 1 | | | | | |
| ***GL*** | | -.444** | .421** | .559** | .539** | .629** | .613** | .445** | .673** | .247* | .766** | 1 | | | | |
| ***DHD*** | -.367** | | .406** | .624** | .519** | .636** | .382** | .328** | .681** | .441** | .629** | .622** | 1 | | | |
| ***UR*** | | -.223* | .296** | .470** | .345** | .431** | .486** | .307** | .886** | | .755** | .654** | .707** | 1 | | |
| ***P6*** | -.606** | | .535** | .650** | .582** | .669** | .300* | .531** | .633** | .480** | .367** | .471** | .630** | .611** | 1 | |
| ***P10*** | | -.525** | | .410** | | .340** | .566** | .409** | .701** | | .763** | .663** | .542** | .825** | .404** | 1 |

**Table 16 - Correlation matrix of all enzymatic activities, pH, EC and measured nutrients, in all soils' horizons.**

Instead, considering just cultivated layers to avoid the effect of decreased enzymatic activity with depth, some correlation changes were found (Tab. 17).

| | *pH* | *Ece* | *OC* | *TSC* | *CRB* | *PLH* | *Pin* | *NIT* | *AR* | *CL* | *IN* | *GL* | *DHD* | *UR* | *P6* | *P10* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***pH*** | 1 | | | | | | | | | | | | | | | |
| ***Ece*** | -.677** | 1 | | | | | | | | | | | | | | |
| ***OC*** | -.781** | .802** | 1 | | | | | | | | | | | | | |
| ***TSC*** | -.647** | | .649** | 1 | | | | | | | | | | | | |
| ***CRB*** | -.578** | | .632** | .896** | 1 | | | | | | | | | | | |
| ***PLH*** | -.601** | | .652** | .877** | .786** | 1 | | | | | | | | | | |
| ***Pin*** | | | .519** | | | .377* | 1 | | | | | | | | | |
| ***NIT*** | | | | | | | .515** | 1 | | | | | | | | |
| ***AR*** | -.502** | .558** | .617** | .391* | | .463** | .611** | .592** | 1 | | | | | | | |
| ***CL*** | | | .445** | .371* | .424** | | .679** | .502** | | 1 | | | | | | |
| ***IN*** | -.332* | .363* | .421** | | | .428** | .625** | .440** | .736** | | 1 | | | | | |
| ***GL*** | -.407** | | .383* | .593** | .521** | .564** | .556** | .415** | .501** | .315* | .527** | 1 | | | | |
| ***DHD*** | -.439** | .454** | .809** | .699** | .696** | .657** | .655** | .353* | .553** | .532** | .331* | .332* | 1 | | | |
| ***UR*** | -.353* | .345* | .464** | .330* | | | .660** | .476** | .741** | .446** | .574** | .358* | .597** | 1 | | |
| ***P6*** | -.580** | .501** | .676** | .579** | .442* | .588** | .450* | | .629** | | .535** | | .660** | .560** | 1 | |
| ***P10*** | | | | | | | | | .399* | | .470** | | | .687** | .452* | 1 |

**Table 17 - Correlation matrix of all enzymatic activities, pH, EC and measured nutrients, in cultivated layers.**

Deeper layers were not considered because enzymatic activities were often very low in these layers and depth of profiles was very different. Considering cultivated layers, again most of nutrients showed strong positive correlation to each other's. OC was strongly positively correlated with all nutrients (also Pin, but no NIT) and enzymatic activities. pH negatively correlated with ECe, OC and soluble fractions of C. Among enzymatic activities, AR, IN, GL, DHD, UR and P6 were negatively correlated. ECe was strongly positively correlated with OC (not with soluble fractions) and as a consequence the positive correlation was maintained with, AR, IN, DHD, UR and P6. TSC and CRB did not show correlation with Pin and NIT, while PLH showed positive correlation with Pin. TSC showed positive correlation with most of enzymatic activities except IN and P10. CRB showed positive correlation with most of enzymatic activities except AR, IN, UR and P10. PLH showed positive correlation with most of enzymatic activities except CL, UR and P10. Pin showed positive correlation with most of enzymatic activities except P10. NIT showed positive correlation with most of enzymatic activities except P6 and P10. Enzymatic activities showed positive correlation to each other's, with few exceptions.

To further understand data, were considered just the first 30cm (in case that there was no sharp horizon at 30cm, the horizon that contained the 30cm depth was considered as the bottom layer). First step was to perform a One-way ANOVA, Tuckey post-hoc ($p < 0.05$) between cultivated layers of all profiles, that leaded to statistical differences presented in Table 18.

| | *AR/OC* | *CL/OC* | *IN/OC* | *GL/OC* | *DHD/OC* | *UR/OC* | *P6/OC* | *P10/OC* | *TSC* | *CRB* | *PLH* | *OC* | *Pin* | *NIT* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***MEZ1*** | c | cd | d | cd | cd | e | bc | de | a | a | a | b | c | bc |
| ***MEZ2*** | bc | d | d | d | d | d | bc | d | b | bc | b | a | b | b |
| ***MEZ3*** | bc | ab | b | b | b | a | b | b | c | cd | cd | d | c | c |
| ***MASAL3*** | b | a | c | bc | c | b | b | c | b | b | b | c | a | a |
| ***MASAL5*** | a | bc | a | a | a | c | a | a | c | d | d | e | d | bc |
| ***MASAL10*** | c | bcd | d | d | cd | e | c | e | b | b | bc | a | b | bc |

**Table 18 - One-way ANOVA with Tuckey post-hoc test ($p < 0.05$) in cultivated layers. Different letteres refer to statistically different values, with decreasing values from "a" to "d".**

Specific activities of most of enzymes was higher in mineral layers of MASAL5, while nutrients content the opposite. The profiles did not always show comparable results; thus samples were grouped with different combination in order to evaluate better valley specificity.

- **Case1**. *Groundwater level.* Group 1: profiles with high groundwater level – depth 70-85cm - (MEZ3, Masal10, Masal3). Group 2: profiles with low groundwater level - depth > 85cm - (MEZ1, MEZ2, Masal5).
- **Case 2**. *Crop conduction of summer season 2015*. Group 1: profiles with tomato conduction (MEZ1, MEZ2 and MEZ3). Group 2: profiles with random conduction (Masal3, Masal5 and Masal10).
- **Case 3**. *Soil pH*. Group 1: acid pH (MEZ1, MEZ2 and Masal3). Group 2: basic pH (MEZ3, Masal5 and Masal10).
- **Case 4**. *Soil ECe*. Group 1: profiles with ECe > 2 dS $m^{-1}$ in cultivated layers (MEZ1, MEZ2 and Masal3). Group 2: profiles with ECe < 2 dS $m^{-1}$ in cultivated layers (MEZ3, Masal5 and Masal10) – Groups coincide with those of Case 3, so will be considered jointly.
- **Case 5**. *Soil delineation*. Group 1: Histosols (MEZ1, MEZ2, Masal3 and Masal10). Group 2: Other soils (MEZ3 and Masal5).

For each case, ANOVA was performed (sig., $p < 0.05$), averaging values of all groups horizons (Fig.32 shows boxplots of some selected variables with statistical differences between groups.

Case 1showed statistical differences just in Pin, CL/OC and UR/CT. All three highest in samples with high groundwater (GW) level.

Case 2 showed statistical differences in PLH, AR/OC, CL/OC, IN/OC, GL/OC and DHD/GLC. PLH were higher in fields with tomatoes conduction in summer 2015, while specific activities the opposite.

Case 3 and Case 4 showed statistical differences in all nutrients except NIT and Pin, and in all specific activities. OC and soluble fractions were higher in layers with acid pH, while specific activities were sharply higher in those with pH > 7.

Case 5 showed statistical differences in all nutrients and specific activities except for CL/OC. All nutrients were higher in histosols, while specific activities in other soils.

The same analyses were repeated eliminating Masal5 (so also Case 5), due to the fact that being a soil profile with completely different physicochemical characteristics from other soils, it may superimpose these differences on ANOVA analyses. Cases will be named: Case 1bis, 2bis, 3bis and 4bis.

Case 1bis showed statistical differences in all nutrients except Pin and NIT, and in all activities except AR/OC and P6/OC. OC and soluble fraction higher in group 2, and opposite the specific activities.

Case 2bis showed statistical differences in CL/OC, Pin and NIT. All three were higher in layers that were not conducted with tomatoes in summer 2015.

Case 3bis and 4bis showed statistical differences in all nutrients and specific activities, except Pin, being specific activities higher in soils with higher pH and lower salinity.

## *Discussion*

Mezzano Valley presented different soil delineations that despite the little extension of the area resulted in marked evolution-differences during time. The responses of soil profiles showed a generalized inability to sustain intensive agricultural management, nevertheless Histosols must be discussed separately from other soils (with only exception of MEZ3, that even if was not classified as Histosol, it showed some grades of either organic or mineral soils).

The valley showed a trend of desalinization classic of reclaimed wetland (Li et al., 2014). Most of soluble and exchangeable Na were lost in surficial layers, in fact following the trend already underlined in 70s, Ca was the most concentrated, either soluble or exchangeable. Notwithstanding, n deeper layers, closed to groundwater level, Na became the dominant cation. S had always high concentration, both for SOM concentration and salinity. The loss of $CaCO_3$ seemed to decrease respect the years very after the reclamation, probably because were applied strategies to buffer pH

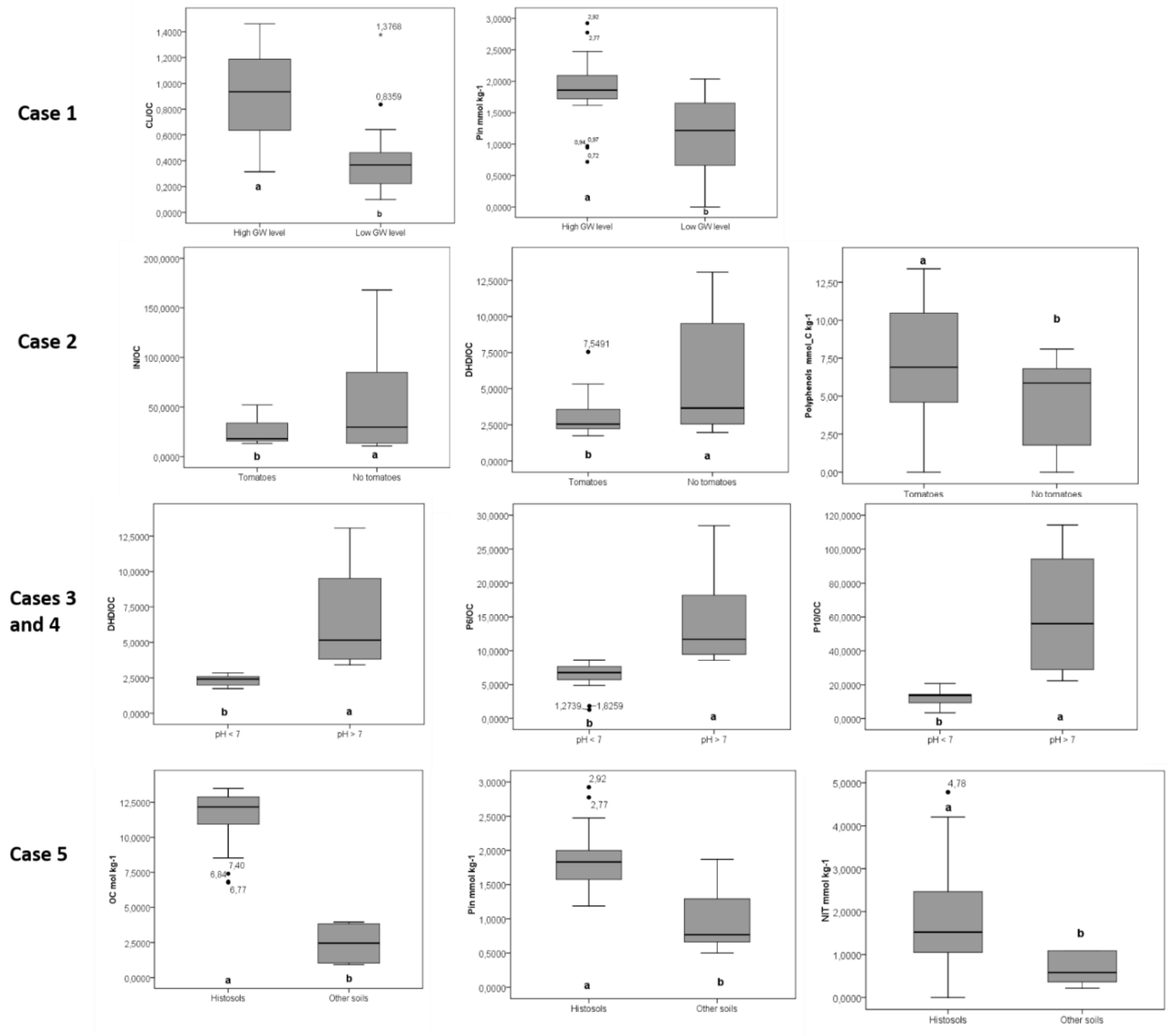



**Figure 32 - Boxplots showing variation of selected variables in the different presented cases. Different lettere refer to stistical differences of One-way ANOVA, "a" represent higher values, "b" lower values. Cases 3 and 4 grouped the same profiles, so pH < / is EC > 2 dS $m^{-1}$ of Case 4, and pH > 7 is EC < 2dS $m^{-1}$.**

decrease of the valley. In fact, a gradual pH decrease was not detected, thus the slow loss of $CaCO_3$ it was attributed to a gradual loss of carbonate shells during many years of land reworking. Although, considering the specific pedoclimatic condition of the area, temporal anoxic condition due to waterlogging (either rainfall or groundwater rise) may have temporary lower soil pH enhancing $CaCO_3$ leaching.

In Histosols, SOM, N and C/N of surficial layers did not show great variations, even if some localized discrepancies were found, these may be attributed to the constant land levelling that may have mixed deep layers with surficials, or SOM oxidation. Generally, the subsidence of reclaimed wetlands is considered a direct consequence of SOM oxidation (Verhoeven and Setter, 2010). In fact, deep organic layers showed big discrepancies in SOM and N, considering the double SOM contents described in 70s. The reasons of these discrepancies may due to soil compaction as a consequence of SOM oxidation, thus deeper mineral layers were found closer to the ground surface nowadays. Hence, C/N was generally lower in deeper layers. In soils other than Histosols, those found in the marginal sections of the valley, drastic SOM and N decreases were detected, both in surficial and deep layers, while C/N decreased just in deep layers. In this case, it is difficult to understand how was possible that such a great decrease of SOM and N may have maintained the same C/N in surficial layers. Therefore, the possibilities are that: (-) 70s data did have some mistaken localization for SOM, N and C/N, or (-) C and N have been decomposed at the same rate, thus C/N was maintained at least in the surficial layers, or (-) the surficial layers were removed or mixed with other sediments, so that the similar C/N is just a coincidence. Last option may fit with the fact that at Masal7, 110-115cm below the ground surface, a layer with relative higher SOM content (4.6%) and that has C/N of 10.6 was found. On the contrary, a similar horizon was not found in Masal5 and Masal6. Thus, probably land management reworked intensively and unevenly this part of the valley.

SOM oxidation and site specific pedological conditions were also the reasons of changes in available P contents through time. Moreover, high variability of soluble minerals content (in time and space) and the constant needing to buffer low pH, create quite inhospitable conditions for homogeneous P availability through the valley. De facto, if total P did not show considerable variation after 40 years in all organic layers, available P slightly increased: Porg was not detected nowadays, thus all available P was inorganic. Nevertheless, Pin was positively correlated with OC, either if all layers were considered or just cultivated ones. Interesting was the fact that Pin showed no correlation with pH. Hence, considering that needed available P to reach optimum levels for plant uptake is related to soil's CEC (higher CEC, higher available P in need) Pin content and its relation to OC were due to chemical fertilizers application. Masal5 showed a drastic decrease in Ptot and available P (Ptot showed decrease also in Masal6, while P available was not determined for this profile): in Boschi and

Spallacci (1974) the marginal sections of the valley presented higher content of Ptot and available P compared to the high SOM soils. Our results showed similar Ptot contents in all the valley, indicating that Ptot decreased in the North-East section of the valley, while available P was lower in Masal5 compared to Histosols, presenting results more similar to MEZ3. However, in MEZ3 nowadays contents were comparable to those of 70s (anyway Porg disappeared) while in Masal5, Pin was less than half of the content found in 70s. Thus, Masal5 lost a great amount of Ptot and given that the loss of its available Porg fraction cannot be imputed for such a decrease, the possibility of strong land reworking, as already discussed for SOM, N and C/N, is plausible. On the contrary, all other profiles, except MEZ3, increased their available P contents despite the loss of Porg. However, the increase of P contents and the decrease of Porg were a trend already detected in reclaimed wetland of other regions of the world, respectively due to fertilizer application and crop residues burial, and SOM oxidation (Li et al., 2014).

The fact that Masal5 and Masal6 showed thinner texture compared to 70s, was in agreement with normal decrease of soil particles size detected in other reclaimed wetlands (Li et al., 2013). Biochemical parameters of the valley were partially discussed in chapter "Soil quality and its influence on crop stoichiometry in intensive agricultural system". In addition to that discussion it was possible to compare the organic soils with natural references and mineral profiles found inside the valley. The natural references were not properly "natural", but implanted woods along channels or roads in the valley. In 2014, the wood was on mineral soils, in fact, they presented higher, Labile-N, Cmic and Nmic just in the first 10cm of the profile, while in the deepest layers were lower even compared to mineral layers. According to Cmic/OC and $qCO_2$, Masal7 pedological features did represent a good environment for microbial population just at the very top-surface, even if their mineralization ability was the highest along all profile. Possibly, the organic top-layer will grow in thickness with time, enhancing the development of more suitable environmental conditions for microbial populations. In 2015, natural reference was on organic soils, thus Labile-C and Cbas were way higher compared to cultivated organic layers. Nevertheless, Cmic and Nmic were comparable in all horizons, either natural or cultivated, $qCO_2$ and qM higher in natural, while Cmic/OC and Cmic/Nmic lower in natural soils, underlining what found in previous year: the restored wood did not help to create a more suitable environment for local microbial population, that is struggling to find a new equilibrium. Anyway, all these parameters should be monitored during next years in order to verify possible shifts in trends. Directly related to microbial activity is generally TSC. Interesting fact of studied soils was that TSC accounted for > 2% of OC in Masal5, while in all other profiles was always lower <1.1%. De facto, TSC is an indicator of the labile-C pool of soils stimulating microbial activity (Ghani et al. 1999), hence positively correlated with C of microbial biomass (Sparling et al. 1998). Our results showed low values compared to the dataset presented by Ghani et al. (2003), even with lower percentage of CRB (10% against 45%). Nevertheless, enzymatic activities were different from profile to profile increasing with increasing OC and all enzymatic activities were positively correlated with TSC, except IN and P10. On the contrary CRB and PLH presented weaker correlation with enzymatic activities. Moreover, specific enzymatic activities were lower in organic layers compared to Masal5, this could be attributed to salinity inhibition of activities or increasing recalcitrance of nutrients with increasing SOM. In fact, cultivated layers' specific activities were higher in those horizons with higher pH and lower salinity, independently from OC, so that it was possible to suppose a negative effect of low pH and high salinity an all groups of enzymes. In addition, PLH were positively correlated with available P, probably in relation to their role in preventing phosphorous precipitation (Hattenscwiler and Vitousek, 2000). Moreover, fields cultivated with tomatoes in 2015 showed statistically higher contents of PLH (not if Masal5 was excluded by the analyses), nevertheless tomatoes contain many phenolic compounds (Erba et al., 2013) thus it may be the reason for the higher values. DHD is considered an indicator of microbial activity (Gu et al., 2009; Salazar et al., 2011). DHD of organic layers was higher compared to other data presented in literature for agricultural soils, while Masal5 was comparable (Von Mersi and Schimer, 1991; Garcia et al., 1993). The high activity of organic layers was due to OC (Moeskops et al., 2010), high humidity (Zhoo et al., 2010) and frequent water-logging events that happen in these soils (Weaver et al., 2012), confirmed by the higher specific activity in profiles with GW level closer to the surface. Higher pH influenced positively specific activity in cultivated layers, probably due to the fact that these horizons had lower salinity, even if SOM was lower. The fact that DHD was higher in organic layers and specific activity higher in Masal5, agreed with microbial respiration and $qCO_2$ found the previous years. UR is not generally influenced by climatic conditions and literature offers quite wide activity values ranges. Specific activity was higher in MEZ3 compared to other all profiles, probably due to the fact that the enzyme is found mainly in microstructural units (< 50micron), tied to clay, and MEZ3 showed peaty horizon mixed with clayey sediments. AR is widespread in agricultural soils, nevertheless is never high in sulphate-rich environment (Oshrain and Wiebe, 1979), as Mezzano Valley. Nevertheless, it is usually related to C of microbial biomass (Klose et al., 1999), in fact our data showed positive relation of AR with OC, TSC and DHD. Giusquiniani et al. (1995) showed similar behaviour of AR to phosphate enzymes, which could be confirmed by the fact that P10 and P6 strongly positively correlated with AR, even if P10 did not positively correlated with any of the nutrients in cultivated layers. AR/OC was higher in mineral layers of Masal5, even if activity values were so low that many times estimation errors have passed acceptability. DHD, UR and AR decreased with depth in all profiles except in Masal10: Masal10 showed increasing OC and NIT with depth, and the highest Ptot values among all profiles, even at 60-70cm of depth. P10 and P6 also increased with depth in Masal10, probably because profile’s pH was rather constant with depth. Detected phosphomonoesterase activities were similar to those of other studies in agricultural sites (0.9 – 2.1, Bolton et al., 1985; 0.2 – 2.0, Frankenberger and Dick, 1983), with P10 always higher than P6. Moreover, in cultivated layers, P6 was always correlated to nutrient contents, while P10 never. Excluding Masal5 from data elaboration, GW level influenced P10/OC, being higher in profiles with higher GW level, while not P6/OC. P10/OC and P6/OC were both higher in cultivated layers with higher pH and lower salinity, probably indicating a negative effect of salinity that superimposes itself even on pH best of enzymatic groups. Hence, it seemed that P6 was more involved in all site-specific pedological dynamics, either human-induced or not, while P10 became active just “on request” with no influence of surrounding environment on it. In soils with such high content of recalcitrant SOM, important is the presence of microbial community able to depolymerize organic matter and produce exo-glucose so enhancing CL, that in analysed samples was always very low as typical in agricultural soils (Bruce AD Coldwell, 2005). It irregularly decreased with depth, but still positively correlated layers with Pin, NIT and OC when just cultivated were considered. Even if CL/OC was higher in cultivated layers of those profiles with high GW level, it was also higher in those horizons with higher pH and lower salinity, confirming probably the findings of Elmajdoub and Maschner (2013) that salinity inhibits the ability of soil microbes to utilise cellulose. Tomato fields conduction seemed to inhibit even more CL. IN and GL are generally positively correlated with OC and are really important in carbon cycle (Eyvazi and Tabatai, 1990). Our samples showed lower values compared to literature for IN (e.g. Chendrayan, Adhya and Sethunathan, 1979), while somehow comparable for GL (e.g. Pascual et al., 2000). Both activities drastically decreased with depth and positively correlated with all nutrients (IN did not with CRB and PLH). Specific activities were somehow inhibited by low pH and high salinity.

To conclude it must be said that microbial activity and enzymatic activities may be inhibited also by the high contents heavy metals and their bioavailability, as Pb, As, Cr and Cd (Su, 2014). Thus, for Mezzano Valley it may represent another obstacle to reach good environmental performances.

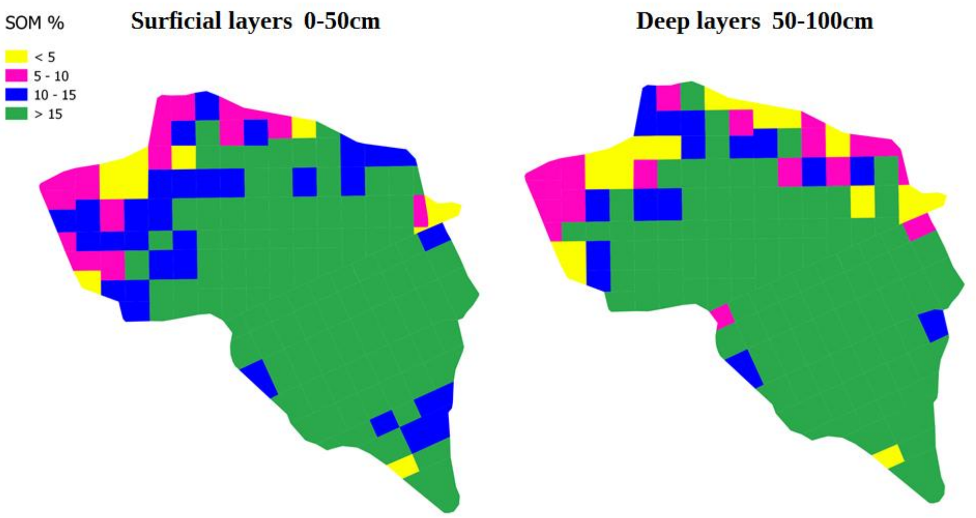
## *Conclusion*

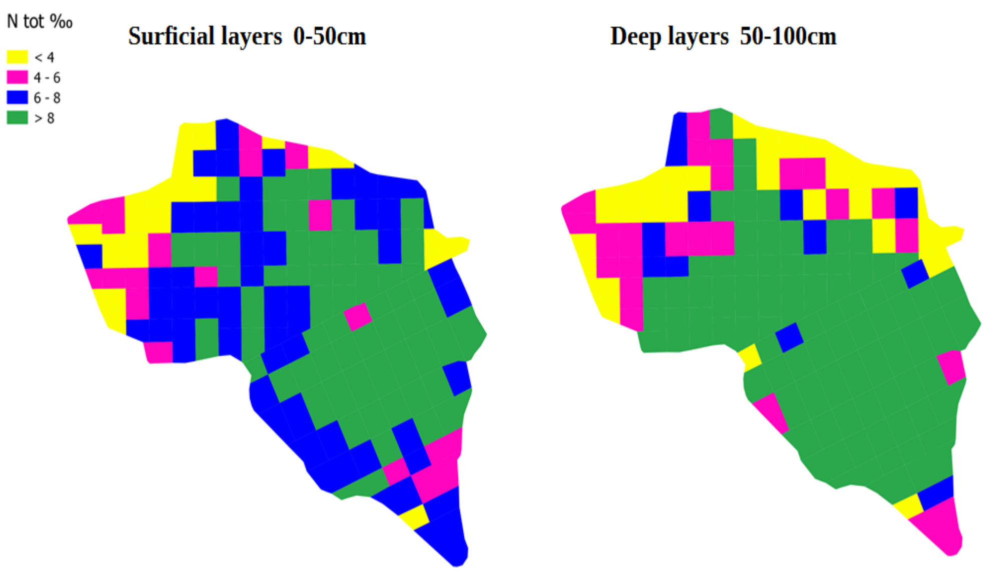
Considered the naturally high content of SOM in studied soils, the idea was that biochemical parameters could be higher than “usual” agricultural soils, and in authors hopes, comparable to other environments with similar contents. In this case, even if SOM had positive effect on potential activities, pH end ECe and GW level also played an influence on activities, differentiating soil profiles potential activities. Enzymatic activities data seemed to confirm the fear underlined by microbial biomass activity of previous section of the work. Surely enzymatic activities generally change very fast according to land management, but in our results even same management conditions seemed to lead to different response. It means that the Valley presents very diverse pedological features that must be better understood if intensive land management want to be preserved. Anyway, such a drastic change of environment combined to intensive land exploitation did not allow soils to perform as good as they could, becoming slowly inconvenient either environmentally speaking or economically.

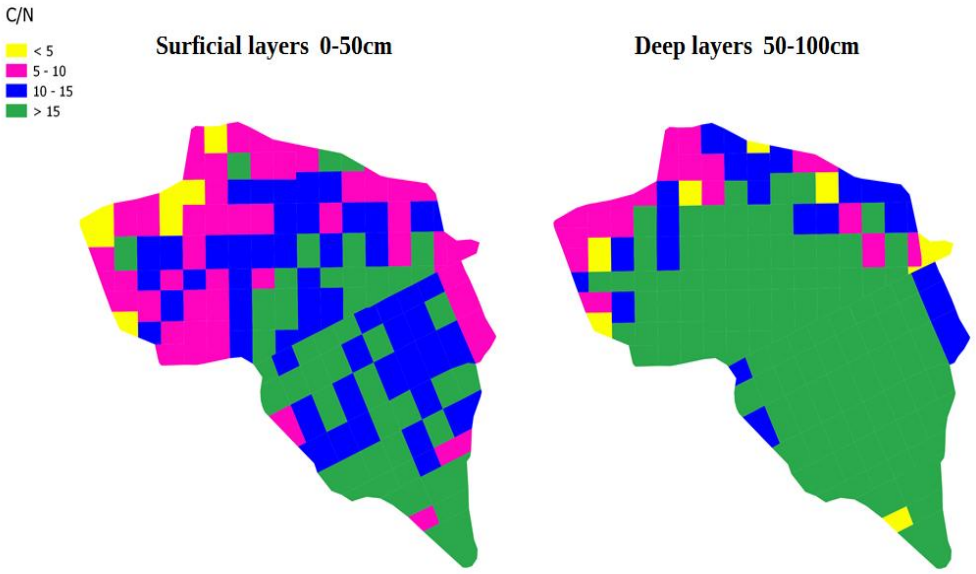
This focus on the area was intended to find criticism and potentiality of these lands, so that the future can be strategically planned with tangible data. General advices for a better management of reclaimed wetlands, as restricting the scale of industrial lands and increasing the proportion of land for ecological conservation, development ecological agriculture and construction of natural reserves, anyway must to carefully evaluated.

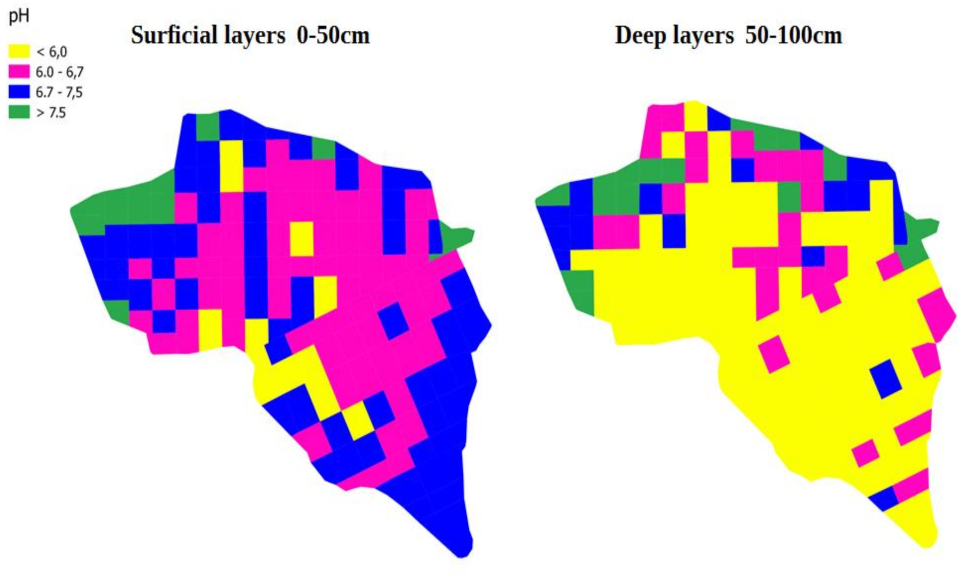
## Supplementary Material II

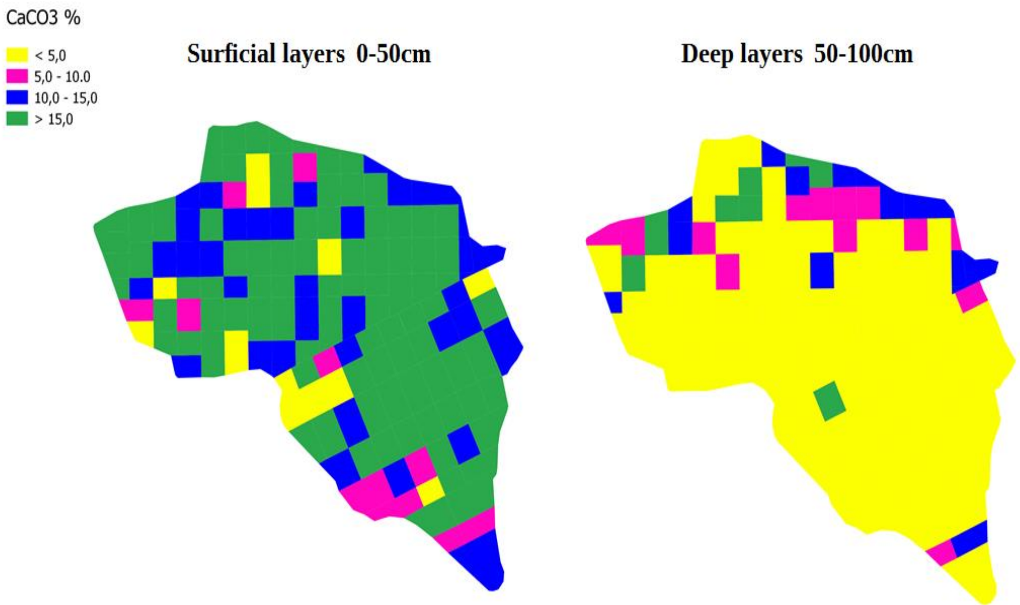
The followings maps are those presented in Boschi and Spallacci (1974). All the maps were reconstructed using original data and QGIS 2.16.3. Every box represents a sampling point. All the boxes were converted into polygons combined in a single vector layer, with the joined database. Colours for the discrete intervals of data representation are those used in the reference.

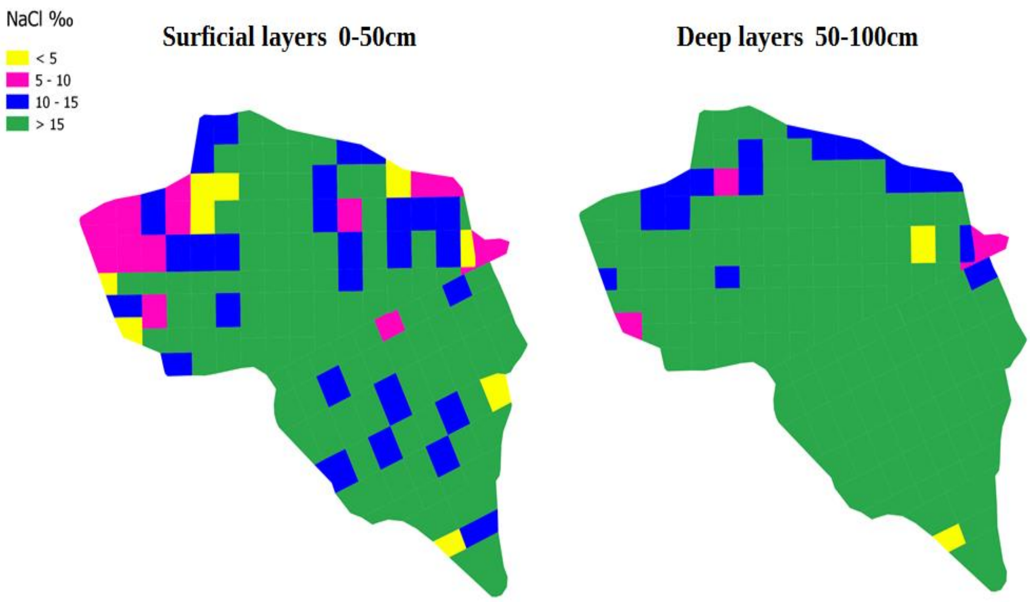


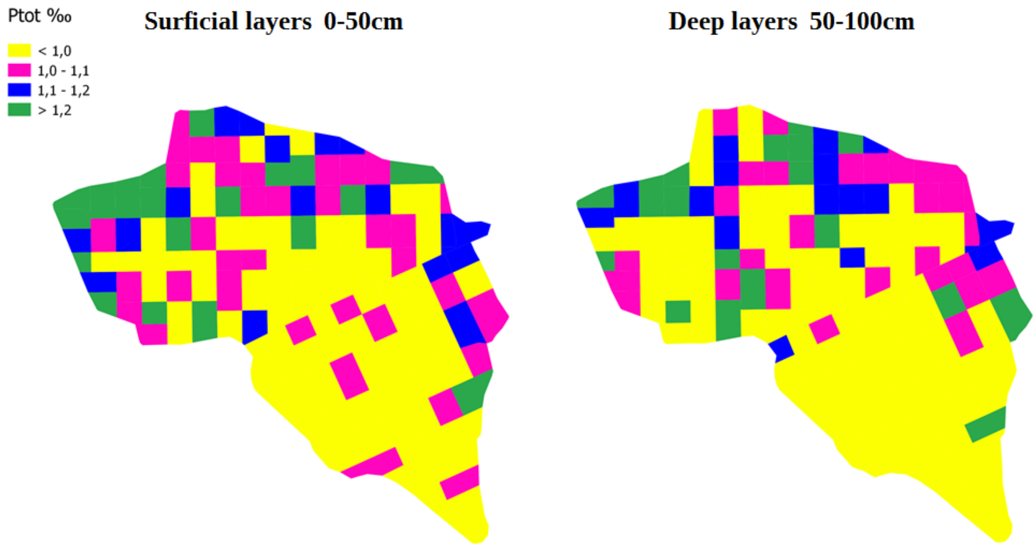



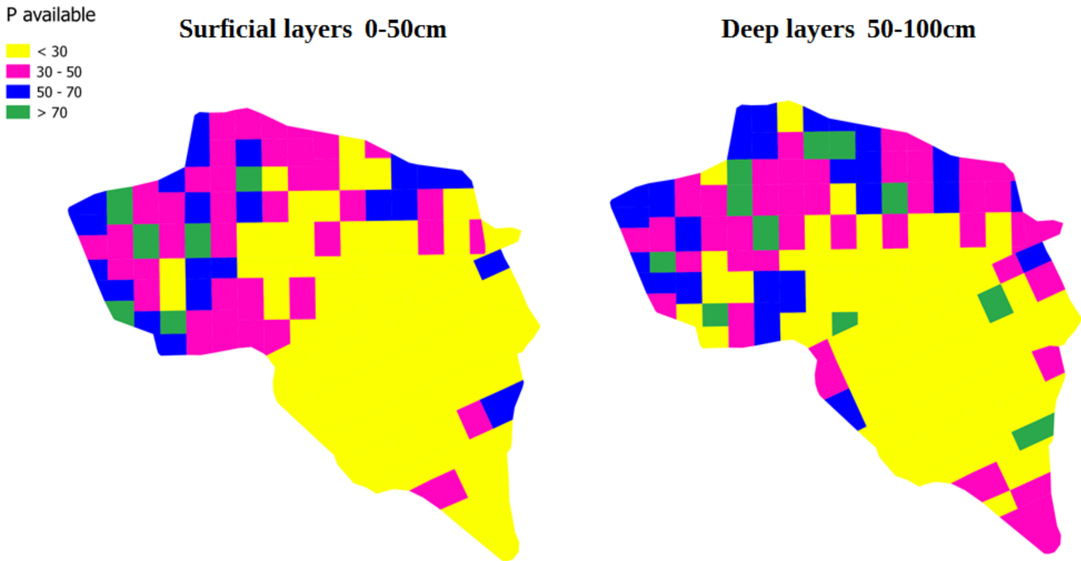

C/N
< 5
5 - 10
10 - 15
> 15
Surficial layers 0-50cm
Deep layers 50-100cm


pH
< 6,0
6.0 - 6,7
6.7 - 7,5
> 7.5
Surficial layers 0-50cm
Deep layers 50-100cm


CaCO3 %
< 5,0
5,0 - 10.0
10,0 - 15,0
> 15,0
Surficial layers 0-50cm
Deep layers 50-100cm


NaCl ‰
< 5
5 - 10
10 - 15
> 15
Surficial layers 0-50cm
Deep layers 50-100cm


Ptot ‰
< 1,0
1,0 - 1,1
1,1 - 1,2
> 1,2
Surficial layers 0-50cm
Deep layers 50-100cm


P available
< 30
30 - 50
50 - 70
> 70
Surficial layers 0-50cm
Deep layers 50-100cm

# Conclusion

Many problematics affect rural lands and probably one of the most underestimated is the essentiality of soil functions to maintain environmental sustainability. This study increased resolution of local soil maps and identified mistakes on soil classification as well as in the origin of their sediments. The investigated biochemical parameters helped to underlined weakness of the studied soils just when implemented with data of production per hectares. In fact, even if Emilia-Romagna's soils still seem to play a role in land capability and micronutrients distribution in industrial tomatoes plants, stunning were results on biological fertility that was subordinate to chemical fertilizers application. Strategies to improve soils fertility and resilience exist and are slowly improving, as well as the knowledge on soil functionality. Nevertheless, communities of agricultural areas must rethink their roles, as actively and positively contribute to ameliorate their position on sustainability, even more when exploitation occur on reclaimed wetlands. In fact, data confirming how could be bad decision to convert wetlands to farmlands exist, and this work is the umpteenth case-study to confirm it. It seemed that even soils under implanted wood in reclaimed wetlands did not reach their best, which could mean that their functionality is still on a diverse equilibrium, so that probably other management may fit better their "ecological profile". Actually, it was not the aim of this work to determine whether the lack of the application of sustainability strategies is due to cultural gaps in local communities or incapability of scientific community to be effective in this way or just bad policy. Hence, one of the next steps could be the understanding these structural problems also with perspectives that are different than business oriented in order to strengthen cooperative approaches that may increase awareness on lands sustainability, so that it would start to be seen as a real positive method to carry on.

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