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PHYSICAL AND CHEMICAL CHARACTERIZATION AND FLORISTIC PECULIARITIES OF A SOIL AFFECTED BY ANTHROPIC ACTIVITIES

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Abstract

In last years, a significant decline in soil quality has occurred due to contamination caused by anthropic activities. These lead to adverse changes in soil physical, chemical and biological attributes and drastically reduce soil fertility. There currently are no generally accepted criteria to evaluate changes in soil quality. This lack impedes the design and evaluation of meaningful soil management programs. This paper examines the principal physical, chemical and biological characteristics that can serve as indicators of a change in soil quality under particular anthropic pollution. The proposed indicators include bulk density/penetration resistance, pH, soil organic matter, nutrient availability, heavy metal concentration and floristic peculiarities in terms of number of species, subspecies and varieties, the presence of different families of vascular plants and categories of life forms. We also discuss the justification for selecting these key attributes and critical concentrations for changes in soil quality. All these data represent inputs for a diagnostic analysis of a polluted area.

Key words: soil quality, pollution, physical and chemical characteristics, floristic elements

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1. Introduction

Soil is a natural resource, a basic medium for plant growing and a part of matter and energy circulation in terrestrial ecological systems (Alloway, 2013; Chen et al., 2015; Dedeke et al., 2016; Sobolev and Begonia, 2008; Zhang et al., 2018). Being a largely non-renewable component of ecosystem, soil is very sensitive to industrial pollutants (Tzovolou and Tsakiroglou, 2018). As a component of ecosystem soil might be considered as filter, buffer and transformational component (Palavan-Unsal et al., 2011). Due to the strong internal connectedness in the ecosystem, soil could be a source for pollutants to migrate to atmosphere, water bodies, and organisms (Caeiro et al., 2005; Gay and Korre, 2006; Serafimovski et al., 2018; Silva et al., 2014).

Cause to continuous industrialization and urbanization, the content of soil pollutants has increased rapidly (Liu et al., 2018). Thus, a significant decline in soil quality has occurred through adverse changes in its physical, chemical and biological attributes. Soil monitoring and remediation is therefore a very important component in ecosystems managing (Tănase et al., 2014).

The area of study has a length of 385 m and a width of 202 m and is affected by some anthropic activities such as the proximity of transport infrastructure, accidentally waste disposal and more important by industrial activities. The area is located in the proximity of a thermal power plant operating since 1986 and covering 1.387.574 square meters of land. The power plant converts the chemical energy of solid fuels into thermal and electrical energy by

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exploiting two 420 t/h steam boilers. Also, intensive but unauthorized grazing was reported in the area.

There currently are no generally accepted criteria to evaluate the soil quality. This lack impedes the design and evaluation of meaningful soil bioremediation programs (Arshad and Coen, 1992).

This paper examines some physical and chemical attributes that can serve as indicators of soil quality. Proposed indicators include soil depth to a root restricting layer, bulk density/penetration resistance, soil organic matter, nutrient availability/retention capacity, pH, heavy metal concentration and floristic peculiarities in terms of number of species, subspecies and varieties, the presence of different families of vascular plants, categories of life forms, floristic elements, ecological preferences and economic value of species. We also discuss the justification for selecting these key attributes, critical concentrations for changes in soil quality. All these data represent inputs for a diagnostic analysis of the polluted area in order to design an ecological restoration plan.

2. Material and methods

2.1. The study area

The selected study area is located in Holboca village (47°09'02.6" N - 27°42'51.5" E), at approximately 10 km outside Iasi district, Romania (Fig. 1).

The inventory at the operation site covers the inputs and outputs for the generation of steam energy in the entire life of the boiler. The data of inputs, i.e. boiler, water, electricity and wood chips are obtained from the textile manufacturer in Thailand and calculated from boiler efficiency. The transportation of wood chips and boiler to the operation plant are also included. The installation and maintenance of the boiler are excluded because the detailed data of these steps are not available and their burdens are insignificant compared to the total burden of whole life time of the boiler (Beccali et al., 2012). The emissions from biomass combustion are calculated using emission factors reported by IPCC (2006) and EEA (2013).

Emission of CO_2 from the combustion process is excluded according to a carbon neutral rule. The functional unit of 1 MJ of steam energy is used at the operation stage. The input and output for 1 MJ of steam energy production, shown in Table 2, are calculated based on the total energy produced, the input used and the output released through the entire life of the boiler. While the energy of 43,441,110 MJ is produced through the entire life of the new boilers, the energy of 24,815,700 and 28,960,740 MJ is produced through the entire life of the recycled boilers, having the efficiency 60 and 70%, respectively. Since the recycled boiler generates less steam energy in its entire life, the amount of boiler needed is larger per unit of steam.

The inventories for the production of raw materials, water and waste management are obtained from the database in SimaPro 7.3.3 software, such as the database of Ecoinvent 2.0, ELCD 2.0. For example, “steel hot rolled coil” in ELCD 2.0 database is used for the steel plate, grade ss400 applied in the boiler construction.

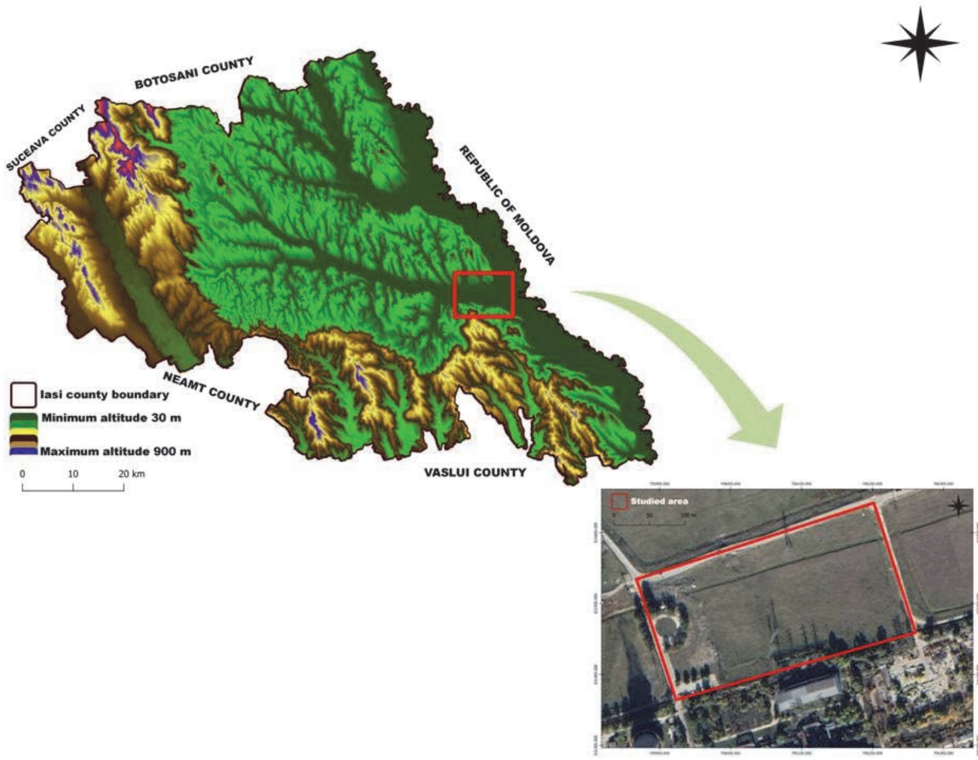

Fig. 1. Location of study area

2.2. Sampling, processing and analysis

The sampling points were set taking into account the pollution sources and were chosen at different distances from the thermal power plant, in all directions of wind. The study focused on 15 sampling points and the samples were collected within an 80 m grid (Fig. 2). The raster method was used as a research tool for soil sampling. A raster contains data points equally spaced from each other (Goodchild, 1992) and is commonly used in digital soil mapping (McBratney and Minasny, 2003). All the maps in this work were realized using ArcGis 10.2.1 (Geographic Information System).

Soil samples were collected in 2018 on March 30, and for each sampling point two samples were taken: one surface sample (after eliminating the vegetation) - 0 cm and one depth sample - 25 cm. For all physical and chemical tests soil samples were pre-treated according SR ISO 11464 (1998) standard. The samples have undergone certain steps of cleaning, drying, grinding, sieving and homogenization and were subsequently stored at 20°C, in a room free of dampness, solar radiation and airflow.

Soil pH was measured according to SR ISO 10390 (2015) and volumetric density determinations were followed the SR ISO 39231 (2008) standard. For soil humus determinations the Walkley-Black (Tiurin) method was used (Abraham, 2013) and soil organic carbon was calculated based on the percentage average carbon content in humus (Lăcătuşu et al., 2011).

To evaluate the concentration of heavy metals such Cd, Cu, Fe, Pb and Zn, the soil samples were digested by a mixture of HNO_3 (65 %, analytical grade, Merck), HCl (35% analytical grade, Merck) and deionized water (4/12/5) (v/v/v) at 150ºC for 7 hours. Samples and blank digestions were performed in triplicate. After digestion, solutions were filtered, using cellulose acetate membranes (Sartorius Stedim, porosity 0.45 mm), and metal concentrations were measured using a GBS Avanta atomic absorption spectrometer, following SR ISO 11047:1999 method.

2.3. Vascular flora analysis

The vascular flora of the area was studied during the optimal vegetation period in 2018, from March to November, using the line transect method (Buckland et al., 2007). The voucher collected served as a study material and subsequently determined in laboratory conditions. In order to organise the information and to establish the floral elements bio-forms the comparative-morphological methods were used (Ciocârlan, 2000; Ellenberg, 1974; Sanda et al., 1983; Sârbu et al., 2001). Regarding the systematic classification of taxa, the phylogenetic system implemented by Pop and collaborators (1983) was adopted.

3. Results and discussions

3.1. *Study area characterization*

The climate area is continental, with a mean annual temperature of 9ºC. The multi-annual average cold season temperature is around -1ºC and during the warm season the average is approximately 21ºC. The average temperature during the vegetation season is 14-15° C. Multiannual average rainfall is around 500-550 mm per year. The most frequent winds blow in the north-west and south-east directions, generally winds of low intensity, with an average annual speed of 6 m/s.

Fig. 2. Distribution of the sampling points in the study area

3.2. Characterization of soil: physical and chemical attributes

The type of soil identified in area is Solonthes, on recent fluvial and fluvial-lake deposits. This type of soil is part of the Salsodisols class (SAL), the Solonite (SN) type having a loamy texture, and a strong to very strong casting. These types of soils are formed under the influence of salts such as $NaHCO_3$, Na_2CO_3, Na_2SiO_3 and $MgCO_3$, but also neutral salts (Na_2SO_4, NaCl) and they are conditioned by the groundwater and poor drainage conditions. Specific to this type of soil is halophilous vegetation and the presence of the nitric horizon, often associated with a humus-rich surface horizon and underlying salinized horizons.

The color of the soil is from brown to black and the structure is large, prismatic or even massive. The dominant physical characteristics of this type of soil are the weak structure stability, waterproofing under wet conditions and the strengthening of the matric dry horizon. For chemical characterization the proposed indicators include pH, bulk density/penetration resistance, total soil organic matter, nutrient availability/retention capacity, and heavy metal concentration.

Soil pH is one of the main soil properties to maintain an active concentration of hydrogen ions in soil solutions. It is determined by the nature of soil, by biological and chemical processes occurring in soil such decomposition (Bååth et al., 1980), mineralization (Aciego Pietri and Brokes, 2008) and respiration (Högberg et al., 2007). Likewise, metal availability and speciation, physiological and ecological pH thresholds and tolerance ranges, availability of nutrients and metal toxicity/availability are influenced by pH (Nielsen et al., 2017; Sauve et al., 2000).

In the study area the pH values decreased with depth increasing. In most of the sampling points the pH are over 8 describing an alkalinized soil (Fig. 3 and Fig. 4). In the charts, each column corresponds to the sampling points identified in Fig. 2. The bulk density values are closely correlated with penetration resistance or degree of soil compaction. These values can oscillate frequently between 1-2 g/cm³, being smaller in humus-rich and well-structured soils.

For all soil samples the bulk density values were between 0.954 and 1.104 g/cm^3 for higher horizons and between 0.966 and 1.140 g/cm^3 for depth ones (Fig. 5 and Fig. 6). Lower densities were recorded in higher horizons where the compression is lower. The concentration of heavy metal ions was assessed in surface samples in P3, P8 and P13 sampling point at different distances from the thermal power plant (Table 1). The results reported represent the average values of triplicate determinations (Table 2). The normal content of cadmium in soils is 1 mg/kg, the alert limit for sensitive uses is 3 mg/kg, and the intervention one is 5 mg/kg (Order 756, 1997). For P13 and P8 sampling point (located at the nearest distance from slag and ash storage yard and from the flue gas stack) the cadmium concentration average values are 1 mg/kg or exceed the normal concentration.

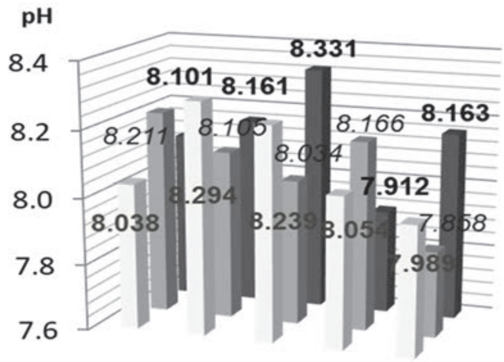

Fig. 3. pH values - Surface samples (0 cm)

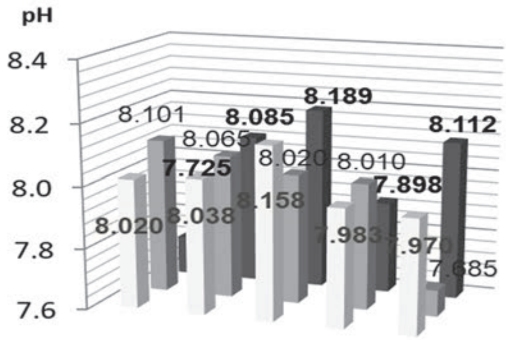

Fig. 4. pH values – Depth samples (25 cm)

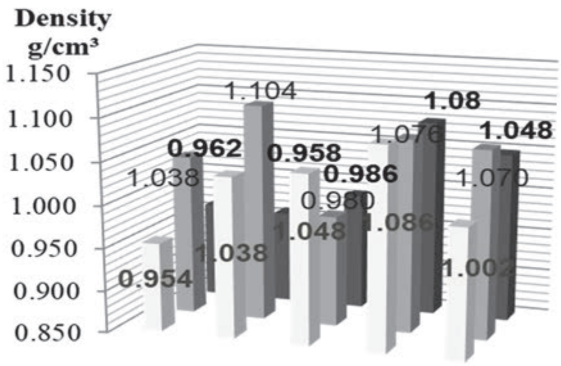

Fig. 5. Volumetric density (g/cm³) –
Surface samples (0 cm)

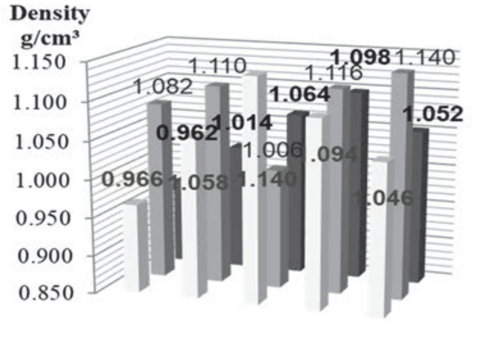

Fig. 6. Volumetric density (g/cm³) - Depth samples (25cm)

Table 1. Location of soil sampling points

Soil sample	*Location of soil sampling points*
P3	360m from the flue gas stack and 760 m from the slag and ash disposal
P8	280m from the flue gas stack and 680 m from the slag and ash disposal
P13	200m from the flue gas stack and 600 m from the slag and ash disposal

Table 2. Concentration of heavy metals in soil samples (mg/kg dry substance)

Sample	*Cadmium ions concentration (mg/kg)*	*Copper ions concentration (mg/kg)*	*Iron ions concentration (mg/kg)*	*Lead ions concentration (mg/kg)*	*Zinc ions concentration (mg/kg)*
P3	0.75	38.875	24834	68	83.75
P8	1	42.75	31904	89.25	92.125
P13	1.125	37.125	25582	94.61	81.75

Copper has an average content in soils of 20 mg/kg, an alert limit for sensitive uses of 100 mg/kg and an intervention limit of 200 mg/kg. Therefore, on all sampling points there were excesses of the average value. The highest concentration for copper recorded was 42.75 mg/kg.

The concentrations of lead ions in soil have an average of 20 mg/kg, an alert limit of 50 mg/g and an intervention limit of 100 mg/kg. The content of lead ions has decreased with the distance to the flue gas stack. However, the concentrations exceed the limit alert being very close to the intervention limit. High concentration of potentially mobile Pb(II) and Cu(II) in soil run the risk of their downward migration and possible contamination of groundwater (Tănase, 2014). Iron concentration for all soil samples was appeared to be higher than Fe(III) critical level.

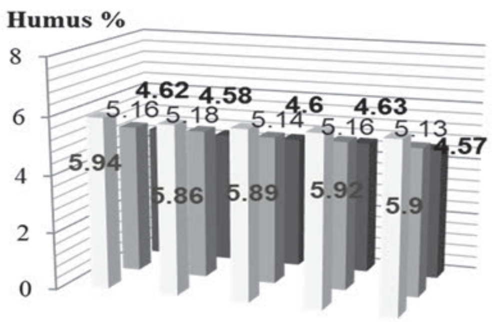

Fig. 7. Soil humus content

Humus and soil organic carbon content are excellent indicators for evaluating ecosystem's functioning efficiency. The soils, which have under 2% humus content, are the arable land. The water erosion has in this case a major negative impact where the first shifting material is the organic matter. On the arable land the values of humus % do not show considerable fluctuation contrary the grassland. On the grassland the humus content shows high heterogenity, having higher humus content values as a result of the smaller disturbance and the persistence of the vegetal ground cover (Fehér et al., 2016). The soil organic carbon and humus content in the study area fits into the limits of high and medium textured soils, with values of SOC % in the range 2.596 - 3.56 and humus % between 4.57 – 5.94 (Fig.7 and Fig. 8).

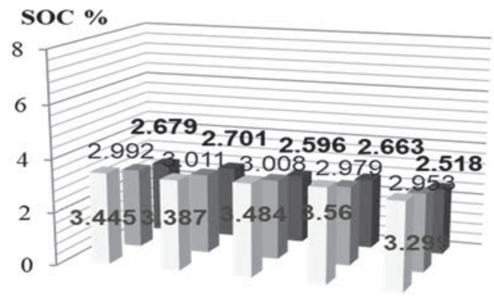

Fig. 8. Soil organic carbon content

3.3. Vascular flora assessment

The list of the vascular flora identified in studied area contains 123 taxa, who belong to 78 genres and 28 botanical families. The largest share belongs to the families: Compositae (18 species), Poaceae (14 species), Fabaceae (9 species), Lamiaceae (6 species), Rosaceae (5 species), Brassicaceae, Cyperaceae (4 species). These 7 families comprise 60 species, totalizing for 65.21% of all species reported. The other 21 families identified in our study area are represented by 1-3 plant species (Table 3). The spatial distribution of botanical families in the study area are highlighted in Fig. 9. The largest majority of the plants are distributed as far away as possible from the anthropic activities.

Life forms analysis

The analysis of bioforms reveal the high share of the hemicryptophytes (H) (44 species), which represents 47.82% of the total (Table 4). The next category is represented by the terophytes (T) 14.13%. The relatively high percentage of annual or biennial therophytes reflects a high degree of anthropization of vegetation in the area. Hemitherophytes (Ht) represent 13.04% of the total number of species in the area. The significant percentage of hemiterophites could be explained by the milder winters in this area.

Geophytes (G) have also an important representation. These mainly gather the prevernal and vernal species and less aestival species, all of these having different resistance and propagation underground organs, as an adaptation of short vegetation periods or to maintain optimal ecological conditions for a limited period of time (hibernal season). Very low percentage have the hydrohelophytes (HH) represented by only one species (1.08%). In order to assess the anthropic influence the flora altitudinal index (Pop and Drăgulescu, 1983) was calculated and additional information about the climate, the vegetation layers, and the intensity of the anthropic pressure were obtained. This index can be calculated by Eq. (1):

$$K = T / H \times 100 \qquad (1)$$

where: K – is flora altitudinal index, T – therophytes percentage, H – hemicryptophytes number.

For the studied area the K index is 70,83%. The value is included in 51-90% range highlighting a significant anthropic impact in the area.

Table 3. Numeric distribution of vascular flora in study area

Magnoliophyta/Magnoliatae						
No. crt.	***Family***	***Genus***	***Species***	***Subspecies***	***Variety***	**Total**
1.	**Apiaceae lindl.**	2	2	-	-	2
2.	**Boraginaceae juss.**	3	3	-	-	3
3.	**Brassicaceae burnett**	4	4	1	-	5
4.	**Caryophyllaceae juss.**	1	1		-	1
5.	**Chenopodiaceae vent.**	1	1	1	1	3
6.	**Compositae giseke**	15	18	7	-	25
7.	**Convolvulaceae juss.**	1	1	-	-	1
8.	**Dipsacaceae juss.**	1	1	-	-	1
9.	**Euphorbiaceae juss.**	1	1	-	-	1
10.	**Fabaceae lindl.**	7	9	4	1	14
11.	**Geraniaceae juss.**	1	1	-	-	1
12.	**Lamiaceae lindl.**	5	6	2	-	8
13.	**Lythraceae j. St.-hil.**	1	1	-	-	1
14.	**Malvaceae juss.**	1	1	1	-	2
15.	**Plantaginaceae juss.**	3	3	1	-	4
16.	**Polygonaceae juss.**	3	3	-	-	3
17.	**Ranunculaceae juss.**	2	3	2	-	5
18.	**Rosaceae**	3	5	2	-	7
19	**Scrophulariaceae juss.**	1	1	-	-	1
20.	**Rubiaceae juss.**	1	2	-	-	2
21.	**Ulmaceae mirb.**	1	1	-	-	1
22.	**Urticaceae juss.**	1	1	1	-	2
23.	**Verbenaceae**	1	1	-	-	1
Total	**23**	**60**	**70**	**22**	**2**	**94**
Magnoliophyta/Liliatae						
No. crt.	***Family***	***Genus***	***Species***	***Subspecies***	***Variety***	**Total**
1.	**Alismaceae vent.**	1	1	-	-	1
2.	**Cyperaceae juss.**	3	4	1	-	5
3.	**Juncaceae**	1	1	-	-	1
4.	**Poaceae barnhart**	12	14	6	1	21
5.	**Typhaceae juss.**	1	1	-	-	1
Total	**5**	**18**	**21**	**7**	**1**	**29**

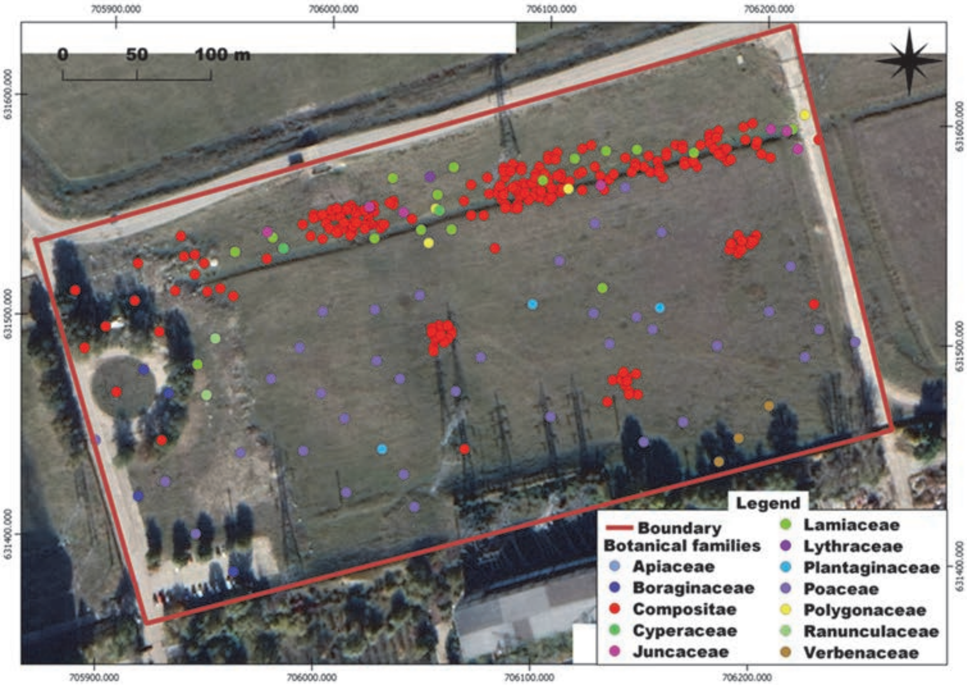

Fig. 9. Spatial distribution of botanical families in study area

Table 4. Statistical analysis of the life forms

Life form		*No. of. species*	*% per categories*	*% from total*
H.	Hemicryptophytes	44	91.66	47.82
	Hemicryptophytes (Geophytes)	3	6.25	3.26
	Hemicryptophytes (Hydrohelophytes)	1	2.08	1.08
	Total H	48	100	52.16
HH.	Hydrohelophytes	1	100	1.08
Ht.	Hemitherophytes	12	80	13.04
	Hemiterophites – Hemicryptophytes	3	20	3.26
	Total Ht	15	100	16.30
G.	Geophytes	2	33.33	2.17
	Geophytes (Hydrohelophytes)	3	50	3.26
	(Geophytes) Hemicryptophytes	1	16.66	1.08
	Total G	6	100	6.51
Ph.	Phanerophytes	3	100	3.26
T.	Therophytes	13	68.42	14.13
	Therophytes - TH.	1	5.26	1.08
	Therophytes – Hemitherophytes	5	26.31	5.43
	Total T	19	100	20.64

4. Conclusions

A soil affected by anthropic activities was chose for a diagnostic analysis and the following effects were observed:

The climate area is continental, with a mean annual temperature of 9ºC. The type of soil identified in area is Solonthes, on recent fluvial and fluvial-lake deposits.

The high pH values, in most of the cases over 8, describe an alkalinized soil; pH values decreased with depth increasing. Volumetric density values are a little higher on the depth samples than the surface ones but still in normal limits. The soil organic carbon and humus contents set out the soil fits into the limits of high and medium textured soils. Concerning the heavy metal ions concentration, the soil exceeded the average for cadmium and copper.

For lead, the concentrations exceeded the limit alert, being very close to the intervention limit and the iron content was higher than the critical level.

The vegetation is composed of halophilous plants; the spatial distribution of botanical families is dominated by *Compositae, Fabaceae, Lamiaceae* and *Rosaceae*. Regarding the statistical analysis of the life forms, the study area belongs to the hemicryptophytes (H) with (44 species), which has the highest dominance and generally characterizes a high degree of anthropization.

All data conclude in the studied area an ecological restoration plan have to be design and implemented in order to mitigate the anthropic effects on ecosystem.

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