



# Site investigation and field analysis

**SPIRE Deliverable 7.1.1.**



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## Table of Acronyms

Acronym	Description
B	Boron
Bp	Bioform
Ca	Calcium
CaCl <sub>2</sub>	Calcium chloride
CaSO <sub>4</sub>	Calcium sulphate
CEC	Cation exchange capacity
Cl	Chlorine
cmol	centimoles
Cp	Tolerance of mowing
CS	Contaminated site
Cu	Copper
DTPA	Diethylenetriaminepentaacetic acid
EC	Electrical conductivity
EDTA	Ethylenediaminetetraacetic acid
EPA	European Protection Agency
ESDAC	European Soil Data Centre
FAO	Organization of the United Nations
Fe	Iron
g	gram
GD (HG)	Government decisions
Gp	Resistance to grazing
H <sup>+</sup>	Hydrogen ion
ha	Hectare
HM	Heavy Metal
Hg	Mercury
Hp	Hemeroby
ICPA	National Institute of Pedology and Agrochemistry
ISO	International Organization for Standardization
K	Potassium
kg	Kilogram
m	Meter

m <sup>2</sup>	Square meter
MARD	Ministry of Agriculture and Rural Development - Romania
me	milli-equivalents
Mg	Magnesium
mg	Milligram
mg/Kg dw	Milligram per kilogram, dry weight
min	Minutes
mL	Millilitre
mm	Millimetre
Mn	Manganese
Mo	Molybdenum
Mp	Plants' resistance to mowing
N	Nitrogen
Na	Sodium
NEPA	National Environmental Protection Agency
NH <sub>2</sub>	Urea
Ni	Nickel
NIST	National Institute of Standards & Technology
NOCl	Nitrosyl chloride
Np	Plants' demand for soil's nitrogen
OBF	Other botanical families
OM	Organic matter
P	Phosphorus
PCS	Potentially contaminated site
pH	Soil reaction (potential of hydrogen)
Pp	Plants' resistance to grazing
µm	Micrometre
Rp	Plants' demand for soil's reaction
S	Sulphur
SOM	Soil organic matter
SOp	Sozological category
Sp	Plants' resistance to crushing
T	Temperature
UASVM CN	University of Agriculture Sciences and Veterinary Medicine Cluj-Napoca
UIA	Urban Innovative Actions

Up	Plants' demand for soil's moistures
UR	Urbanophile
VF	Feed value index
WHC	Water holding capacity
Zn	Zinc

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

# Executive abstract

SPIRE - Smart Post-Industrial Regenerative Ecosystem introduces an innovative perspective on the possibility to re-integrate the heavy metal-contaminated land in the city of Baia Mare, for the benefit of citizens. Aim of the project will be achieved through phytoremediation and the consolidation of the urban ecosystems, by building upon a vision of a long-term sustainable urban development. Vision of the project is to inspire action and environmental-conscious behavior for a better life.

This report is part of the first stage of SPIRE implementation framework, Activity 7.1 – Analysis and development of site management application. This material provides a general outlook on layout for the key concepts, methodologies and parameters considered in the evaluation of current state of soil and vegetation at the pilot sites selected for renaturing. Information presented is directed both towards citizens and scientists alike.

Soil is considered a non-renewable resource due to the long time required for its formation. Awareness about the link existing between soil health and human health has increased in last years. Today, the understanding of the interconnectedness existing between society-economy-environment is seen as key for addressing protection measures. The most important sources of pollution (especially with heavy metals) are former industrial activities. Their legacy are extensive areas with serious soil contamination, mainly with heavy metals. Given the negative health impact for human population, efforts to decontaminate and reduce these contaminants are essential for the present and future well-being of people. One of the best ways to reclaim polluted sites and improve their long-term quality, is revegetation. Soil quality is in direct connection with plant health and quality of the vegetation growing on a given land surface, and ultimately with the ecosystem stability. Thus, plant selection has to make in accordance with species potential, tolerance and results aimed at through phytoremediation. Vegetation assembly is a highly structured system and its dynamic is deeply dependent on many environmental variables.

This report presents the first results of the soil and vegetation assessment and serves as a base of knowledge for the decision-making and strategy of landscaping and renaturing the sites. As presented in this report, the evaluation of soil and vegetation parameters were performed following methodology and protocols with scientific validity.

SPIRE proposes the use of plant species that can perform several tasks: improve soil quality and decontaminate in time the sites, constitute raw material suitable for upcycling in order to build a sustainable value-chain, improve landscape and aesthetic value of the environment, provide other ecosystem services.

# TABLE OF CONTENTS

<b>Introduction .....</b>	<b>10</b>
<b>1.1. Introduction to the project.....</b>	<b>10</b>
1.1.1. Context and rationale.....	10
1.1.2. Goals and objectives. ....	11
<b>1.2. Methodological approach .....</b>	<b>11</b>
<b>1.3. Report structure and intended audience .....</b>	<b>11</b>
<b>2.1. Soil – general aspects .....</b>	<b>13</b>
2.1.1. Soil definition .....	13
2.1.2. Urban Soils .....	13
2.1.3. Soil pollution (contamination).....	14
2.1.4. Heavy metals soil contamination .....	15
2.1.5. Soil quality concept .....	16
2.1.6. Soil health concept .....	17
<b>2.2. Methodology for soil quality and HM pollution assessment of SPIRE pilot sites</b>	<b>17</b>
2.2.1. Soil Sampling Strategy .....	18
2.2.2. Selection of analytical parameters.....	20
2.2.3. Soil sample preparation .....	28
2.2.4. Microwave soil sample digestion .....	29
2.2.5. Heavy metals analysis by FAAS .....	31
2.2.6. Quality control and assurance.....	32
<b>2.3. Results for first assessment of soil indicators .....</b>	<b>33</b>
2.3.1. Soil pH .....	33
2.3.2. Soil humus content.....	33
2.3.3. Soil Pb concentration .....	34
2.3.4. Soil Cd concentration .....	35
2.3.5. Soil Cu concentration .....	35
2.3.6. Soil Zn concentration .....	36
<b>3.1. Vegetation-general aspects .....</b>	<b>37</b>
3.1.1. Legal framework.....	37
3.1.2. Methodology for identification and characterization of the main grassland (existing vegetation):	38
<b>3.2. Results regarding vegetation .....</b>	<b>46</b>
3.2.1. Pilot site 1. Romplumb .....	46
3.2.2. Pilot site 2. Ferneziu .....	48
3.2.3. Pilot site 3. Colonia Topitorilor.....	50



3.2.4.	Pilot site 4. Urbis .....	52
3.2.5.	Pilot site 5. Craica .....	53
<b>Conclusions .....</b>		<b>55</b>
<b>References .....</b>		<b>56</b>

# Introduction

## 1.1. Introduction to the project

### 1.1.1. Context and rationale

Baia Mare's industrial past in the mining and metallurgical sector left circa 627 hectares of land polluted by heavy metals (up to 5 times the acceptable value) within the metropolitan area, which are now disconnected from the urban framework and a danger to the inhabitants and the environment (Verga *et al.* 2020). SPIRE's challenge is to test an integrated, innovative strategy capable of:

- Recovering contaminated land and starting a long-term phytoremediation and land re-valorisation process;
- Co-creating new bio-based development models and novel solutions to pressing urban issues, like housing insulation or carbon emissions reduction;
- Finding alternatives to fossil fuel to foster sustainable energy transition;
- Supporting participation and a behavioural shift, leveraging on novel digital solutions to reward environmentally friendly actions.

**SPIRE – Smart Post-Industrial Regenerative Ecosystem Baia Mare** is an Urban Innovative Actions project financed under the Sustainable Land Use and Nature Based Solutions priority in the third UIA call, and it is being implemented between September 2019 and August 2022, with a one-year closure and knowledge transfer period after the end of the implementation period.

**The project's objective is to start a long-term redevelopment process through the participatory co-design of new adaptive and productive landscapes, integrated into a circular ecosystem of cascading material and energy value chains.**

To achieve this, SPIRE activates a critical mass of stakeholders and opens a Hub in the city center for co-design and mentoring activities. A GIS Dynamic Atlas and a Remediation Toolkit support co-design and implementation processes for **renaturing and phytoremediation of a total of 7.15 ha pilot sites**. An innovative iLEU local digital token system is under implementation, rewarding **civic environmental behaviour, involvement, and eco-entrepreneurship**.

Furthermore, the project develops a **bio-based circular ecosystem** in Baia Mare, using the biomass yields of the phytoremediation actions in two cascading value chains: 1) **to produce renewable energy** for a public building, and 2) **in carbon-neutral experimental materials with construction / industrial applications**, co-developed with young entrepreneurs who will be mentored in the SPIRE Hub. iLEU will incentivize further adoption of NBS at local level. Finally, Life Cycle Assessment will evaluate the SPIRE value chains, and a co-designed **Metropolitan 2050 strategy** will upscale the approach and open up the possibilities of urban regeneration, economies of scale, sustainable socio-economic and environmental transitions.

The project will be implemented between September 2019 and August 2023 (including closure and knowledge transfer), and is structured process-wise into three stages:

**The 1st stage** (WP4, WP5, and Activity 7.1) is dedicated to activation, development and construction of the support infrastructure of SPIRE:

- Activating local stakeholders (A4.1) and creating the SPIRE Hub (A4.2), where all participatory and mentoring initiatives will take place.

- Developing a GIS-based Dynamic Atlas (A5.1) for long-term monitoring and planning and the iLEU (A5.2): a local token-based value system aimed at rewarding sustainable behavior and eco-entrepreneurship.
- Surveying the latest applied research on in-situ phytoremediation and its integration in bio-based economies; on standards and KPIs (A4.3); and performing a multi-dimensional baseline analysis for BM (A7.1).

**The 2nd stage** (WP6) will be the core of SPIRE's strategy and will encompass all the activities instrumental to the development of a bio-based circular ecosystem in Baia Mare.

**The final stage** will implement a Life Cycle Assessment to evaluate the SPIRE value chains and will further co-develop the Masterplan 2050 for BM's Metropolitan Area: the long-term land re-use and bio-economy development strategy (Figure 1).

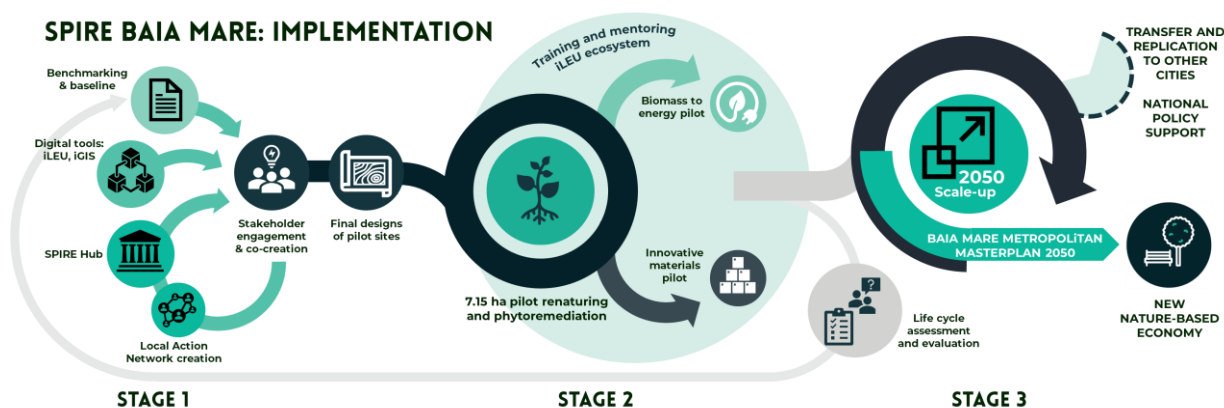


Figure 1 - The SPIRE implementation stages and workflow. Source: Leopa (2020)

### 1.1.2. Goals and objectives.

This report is part of the **Stage 1 – set-up of SPIRE implementation framework, Activity 7.1 – Analysis and development of site management application**. The report has the purpose to provide the initial picture of Baia Mare with respect to the following dimension: ecological & environmental; socio-cultural, health & well-being; land-use, built environment & strategic assets; services; economy & labor market.

## 1.2. Methodological approach

The purpose of D.7.1.1 is to provide the first assessment of the pilot sites before phytoremediation experiences.

## 1.3. Report structure and intended audience

This report is structured into three parts and are present report and methodology used for site investigation and field analysis.

The purpose of this deliverable was to investigate the natural conditions existing at point zero (the starting point of the project). Chapter 2 includes aspects related to the methodology and results found in the soil from the analyzed sites. Chapter 3 refers to the methodology to be used in mapping vegetation and presents the species found on the sites.

At present, the management of contaminated sites in Europe involves costs of around € 6 billion a year. It is reported that 40% of these sites are contaminated with persistent organic substances, such as aldrin, endrin, dieldrin, chlordan, mirex, anthracene, phenanthren, etc. (Crişan, 2020). They have low solubility, are difficult to degrade and accumulate in plant and animal organisms. These substances come from agriculture (pesticides) or various industries. There are numerous studies in recent years that have tested the possibility of using plants in phytoremediation.

Beyond supporting project implementation (see previous sub-chapter), the D.7.1.1 aims to provide European cities, policy-makers and planners with knowledge and guidance to assess the potential for replicating the SPIRE approach to phytoremediation and sustainable nature-based socio-economic regeneration. In this sense, apart from the SPIRE partnership, we address the following intended audience:

- **City, metropolitan and regional public authorities** aiming at developing brownfield regeneration strategies, operational plans or urban plans, within a wider urban, economic, social and environmental development policy;
- **Policy makers and urban planners** involved in urban regeneration, renaturing, climate change adaptation and heavy metal pollution mitigation policies;
- **Businesses, industries, polluted landowners and nature-based entrepreneurs** aiming at understanding the potential impact of SPIRE actions in generating economically viable business plans and new added-value products leveraging on short value chains;
- **Academia and the research community**, looking to use or benefit from the knowledge provided in this report pertaining to KPIs and existing standards for the SPIRE policy domains, and to increase the evidence base of the performance and fit of phytoremediation, social and digital solutions to HM-pollution mitigation;
- **Citizens of Baia Mare and NGOs** who wish to understand the process of data collection and performance assessment, and who might be interested in participating in the provision of data for the active monitoring of SPIRE KPI achievement.
- **The general public, beyond Baia Mare**, interested in finding out more about the instruments for monitoring, assessment and accountability of the NBS and SLU approach proposed by SPIRE.

## 2. Soil quality and heavy metals soil contamination assessment

### 2.1. Soil – general aspects

#### 2.1.1. Soil definition

Like many common words, the word soil has several meanings. In its traditional meaning, soil is the natural medium for the growth of plants. Soil has also been defined as a natural body consisting of layers (soil horizons) that are composed of weathered mineral materials, organic material, air and water (<http://www.fao.org/soils-portal/about/all-definitions/en/>).

According to the definition given by the Soil Science Society of America, soil represents - (i) the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants; (ii) the unconsolidated mineral or organic matter on the surface of the Earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time (Soil Survey Staff, 1999).

Soil is the end product of the combined influence of climate, topography, organisms (flora, fauna and human) on parent materials (original rocks and minerals) over time. As a result, soil differs from its parent material in texture, structure, consistency, colour, chemical, biological and physical characteristics.

Soil is a key component of World's natural capital. It contributes to basic human needs among other things, supporting food provision and water purification. But our soils are threatened and undergoing degradation.

The soil is the skin of the earth, a mantle full of scars, thousand-year-old wrinkles and more recent injuries caused both by man and nature itself (<https://www.iberdrola.com/environment/soil-pollution-causes-effects-solutions>).

#### 2.1.2. Urban Soils

'Urban soils' is a class of Anthropic soils, a term already used in several classification systems. Urban soils are soils extensively influenced by human activities, found mostly but not only in urban areas. They include: (1) soils that are composed of a mixture of materials differing from those in adjacent agricultural or forest areas, and that may present a surface layer greater than 50 cm, highly transformed by human activity through mixing, importing, and exporting material, and by contamination; (2) soils in parks and gardens that are closer to agricultural soils but offer different composition, use, and management than agricultural soils; and (3) soils that result from various construction activities in urban areas and that are often sealed (Morel *et al.*, 2005, Anderson, 2005).

According to this definition, urban soils are essentially under strong human influence in urban and suburban environments; they may exert a strong effect on human health, on plants and soil organisms, and on water infiltration. They are differentiated from other strongly influenced soils such as those found in quarries, mines, and mine tailings, and airfields away from cities. However, it is sometimes difficult to set a clear boundary between urban soils and agricultural soils.

In the urban areas, the soils are, most of the time, stripped, filled, mixed, compacted and supplemented with artificial materials (Sanchez-Hernandez, 2019). As opposed to agricultural soils, urban soils could have either lost their structures (i.e., soil aggregation) and/or accumulated pollutants because of the presence of large natural- and/or anthropogenic-sourced particles (El Khalil *et al.*, 2008; Nehls *et al.*, 2013).

Urban soil also differs from the agricultural one by the fact that the former is more strongly influenced by: (i) continuous and intense anthropogenic contaminating activities, (ii) contamination as the result of a higher loads of contaminants (Biasioli *et al.*, 2006) and (iii) the age of soil (Morel *et al.*, 2005).

From a chemical point of view, urban crop soils are characterized by heterogeneous values of pH and alkalinity due to carbonates (Morel *et al.*, 2005). The most common trace metals in the urban area are Cd, Cu, Ni, Pb and Zn (Dudka *et al.*, 1995).

Urbanization is a driver of unwanted environmental issues (Seto *et al.*, 2013). Urban greening strategies are being developed in major cities worldwide to support the transition towards sustainable urban planning (Anguluri & Narayanan, 2017; Liu & Jensen, 2018).

Recently, several studies have attempted to seek potential solutions that enable growing healthy vegetables. For example, the intervention in the physicochemical properties of the soil such as the pH has an immediate effect on tracing metal mobility (Kalkhajeh *et al.*, 2017, Tedoldi *et al.*, 2017).

Phytoremediation is a way to preserve or restore some of these services:

- a regulation service;
- a supply service owing to raw materials it generates for energy and/or metal recycling;
- a cultural service with its contribution to the greening of cities and contribution to urban landscapes.

### 2.1.3. Soil pollution (contamination)

Soil pollution or soil contamination is an issue that is strongly linked to our common past. Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease-causing agents, which have adverse effects on plant growth and animal health.

According to European Soil Data Centre, soil contamination is the occurrence of pollutants in soil above a certain level causing a deterioration or loss of one or more soil functions. Also, it can be considered as the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage (<https://esdac.jrc.ec.europa.eu/themes/soil-contamination>).

The European Soil Data Centre (ESDAC) provided the following definitions according to EEA (2011):

- **“Contaminated site” (CS)** refers to a well-defined area where the presence of soil contamination has been confirmed and this presents a potential risk to humans, water, ecosystems, or other receptors. Risk management measures (e.g., remediation) may be needed depending on the severity of the risk of adverse impacts to receptors under the current or planned use of the site.

- **“Potentially contaminated site” (PCS)** refers to sites where unacceptable soil contamination is suspected but not verified, and detailed investigations need to be carried out to verify whether there is unacceptable risk of adverse impacts on receptors.
- **“Management of contaminated sites” (MCS)** aims to access and, where necessary, reduce to an acceptable level the risk of adverse impacts on receptors (remediate). The progress in management of CS is traced in 4 management steps starting with preliminary study, continuing with preliminary investigation, followed by site investigation, and concluding with implementation of site remediation (reduction of risk).

Different contaminants have different sources but probably the most important sources are former industrial activities. Their legacy is areas with serious soil contamination, mainly with metals, tars and other associated substances. The range of different types of contaminants is vast, including not just metals but a range of organic molecules, pathogens, biologically active materials, radioactive substances and so on, and all these have different sources.

Regulations and standards have been increasingly successful over the past 30-40 years in preventing soil contamination. Meanwhile, many heavily contaminated sites have been brought to safer conditions, although many remain that have not been dealt with. A very wide range of technologies can be used to reduce the risk of soil contamination, either by removing the contaminant or by containing it. The critical issue is the level of residual risk we are prepared to accept in the context of the cost of remediation.

In effect, soils play an important role in maintaining the environmental quality as they can act as both source and sink for pollutants that can easily affect human health (De Kimpe & Morel, 2000). Humans can be affected by soil pollution through the inhalation of gases emitted from soils moving upward, or through the inhalation of matter that is disturbed and transported by the wind because of the various human activities on the ground (Environmental Pollution Centre).

Soil pollution may cause a variety of health problems, starting with headaches, nausea, fatigue, skin rash, eye irritation and potentially resulting in more serious conditions like neuromuscular blockage, kidney and liver damage and various forms of cancer (Environmental Pollution Centre). Soil acts as a natural sink for contaminants, by accumulating and sometimes concentrating contaminants which end up in soil from various sources.

Tiny amounts of contaminants accumulate in the soil and - depending on the environmental conditions (including soil types) and the degradability of the released contaminant - can reach high levels and pollute the soil. If the soil is contaminated, home-grown vegetables and fruits may become polluted too. This happens because most of the soil pollutants present in the soil are extracted by the plants along with water every time they feed (Environmental Pollution Centre).

Soil pollution is a global threat that is particularly serious in regions like Europe, Asia and North Africa, as indicated by the Food and Agricultural Organization of the United Nations (FAO). The FAO also affirms that both intense and even moderate degradation is already affecting one third of the world's soil. Moreover, recovery is so slow that it would take 1,000 years to create a 1-centimetre layer of arable soil.

#### **2.1.4. Heavy metals soil contamination**

Heavy Metals (HM's) make a significant contribution to environmental pollution as a result of human activities such as mining, smelting, power transmission, intensive agriculture (Nedelkoska & Doran, 2000) or heavy metal contamination affects the biosphere in many places worldwide (Meagher, 2000).



Industrial pursuits such as mining and manufacturing produce large amounts of heavy metal pollution worldwide (Anderson *et al.*, 2005; Sánchez, 2008; Wuana & Okieimen, 2011).

Heavy metal soil pollution has become a global environmental issue that has attracted considerable public attention, as heavy metal contamination is one of the main threats to soil-based ecosystem services, including food and feed production (CEC, 2006; Tóth *et al.*, 2016). Therefore, a reliable information on the concentration of heavy metals in the soil is essential.

At European level, heavy metal, together with mineral oils, is the most frequent contaminant in European soil. The study of van Liedekerke *et al.* (2014) had estimated that the number of potentially contaminated sites in Europe sum up to 2.5 Million, illustrating the extent of this challenge. Another study conducted in 2016 (Tóth *et al.*, 2016) identified a list of priority regions in Europe, where more detailed assessment is proposed. The Baia Mare area is among them (Fig. 2).

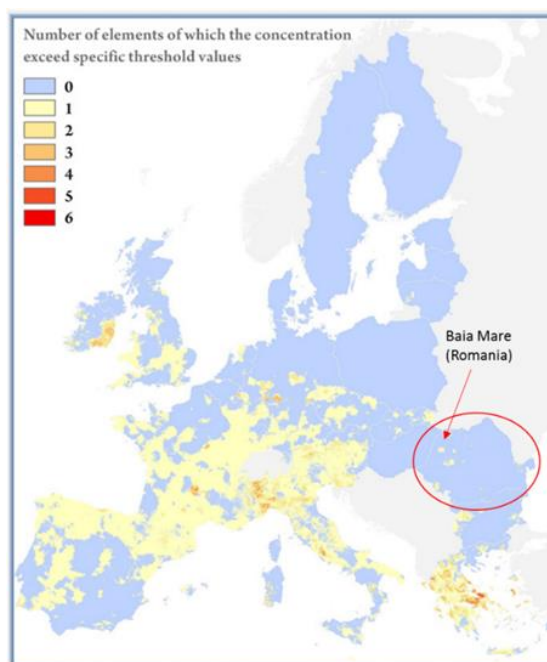


Figure 2 - Priority areas of detailed assessment of soil heavy metals in Europe. Source: after Tóth *et al.*, 2016

Recognizing the importance of this issue and the consequent need to stop further contamination and start cleaning up the EU polluted soils, the 7th Environment Action Program of the EU aimed to ensure that by 2020 "soil is adequately protected and remediation of contaminated sites is ongoing"(OJEU, 2013).

### 2.1.5. Soil quality concept

Soil quality is one of the main components of environmental quality, besides water and air quality and needs to be defined with respect to the desired function (Andrews *et al.*, 2002).

Soil quality is not limited to the degree of soil pollution, but is commonly defined much more broadly as "the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health"(Doran & Parkin, 1994; Doran & Parkin, 1996). This definition reflects the great complexity and site specificity of soil ecosystems as well as the many linkages between soil functioning and soil-based ecosystem services.



From the environmental perspective soil quality is defined as “the capacity of the soil to promote the growth of plants, protect watersheds by regulating the infiltration and partitioning of precipitation, and prevent water and air pollution by buffering potential pollutants such as agricultural chemicals, organic wastes, and industrial chemicals” (Sims *et al.*, 1997).

Soil quality varies and soils respond differently, depending on the management inputs. Elements of the soil quality include physical, chemical and biological properties. Soil quality has both inherent and dynamic characteristics.

### **2.1.6. Soil health concept**

The term “soil health” originates in the observation that soil quality influences the health of animals and humans via the quality of crops (Warkentin, 1995). Soil health has thus also been illustrated via the analogy to the health of an organism or a community (Doran & Parkin, 1994; Larson & Pierce, 1991). Likewise, linkages to plant health can be established, as in the case of disease-suppressive soils (Almario *et al.*, 2014).

Soil health has been defined as "the continued capacity of the soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health" (<http://www.fao.org/soils-portal/soil-survey/soil-properties/en/>).

## **2.2. Methodology for soil quality and HM pollution assessment of SPIRE pilot sites**

The design of the site investigation aimed to determine the soil quality and the presence and extent of heavy metals contamination on the SPIRE pilot sites.

In the context of land evaluation, soil quality assessment focuses on the matching of the specific soil requirements of the land use versus the properties of the soil. Most of soil assessments have been made for agricultural land uses and cropping systems, but the same principles could be applied for other applications, i.e. heavy metals pollution.

Monitoring of the soil quality to get the accurate status and distribution of the environmental contaminants is therefore not only essential but the quality of the monitoring data also becomes the basis of the objective concerning the further use of the area studied. Also, since the processing and analysis of soil samples in the laboratories are already developed the chances of errors are relatively very small compared to errors in collecting such samples, the sampling therefore becomes the most important component in soil investigation studies specially those involving contaminated sites/areas (IAEA, 2004).

The soil sampling techniques/methods developed in the past mainly cover soil sampling for the purpose of soil characterization in general and in fact these methods/tools got developed when the soil contamination due to release of manmade sources was not so predominant. Also, the soil within its own matrix itself is so anisotropic that it is not easy to formulate a general method which can meet the requirements of soil sampling at different locations even in the absence of soil contamination from anthropogenic sources.

The monitoring of soil for environmental contaminants is even more difficult not only because of the complex soil matrices but also the differences in soil types from site to site and a rather uncertain fate of environmental pollutants in the soil makes the situation more complicated (IAEA, 2004).

### 2.2.1. Soil Sampling Strategy

The "sampling strategy" can be defined as the approach used to select the units of the target subject to controls. Comparability and interpretation of results are mainly based on the sampling strategy, but as well on other parameters such as the methods of analysis, analysis of the matrices, sample preparation, calculating results methods etc.

The methods and procedures for obtaining soil samples vary according to the purpose of the sampling. The results of even very carefully conducted soil analyses can only be as good as the soil samples themselves. Thus, the efficiency of a soil testing depends on the care and skill with which soil samples are collected. Non-representative samples constitute the largest single source of error in soil quality monitoring and assessment. The most important phase of soil analysis takes place not in the laboratory but in the field where the soil is sampled.

Soils vary from place to place. In view of this, efforts should be made to take the samples in such a way that they are fully representative of the field. Only 1–10 g of soil is used for each chemical determination and this sample needs to represent as accurately as possible the entire surface 0–22 cm of soil (FAO, 2008).

Generally speaking, soil sampling strategies can be grouped into three main categories: random, systematic and stratified sampling methods.

The random sampling strategy is the simplest of the three, where soil samples are collected randomly and stochastically independently across the site of interest. It can be used as a quick sampling program of a pilot study. A major disadvantage of this sampling strategy is that soil samples may not represent the whole study site. Therefore, this sampling strategy is usually employed in relatively homogenous sites and applicable to investigations where the major objective is to determine whether heavy metal concentrations of the soils are elevated above background and/or legislative standards (Scholz *et al.*, 1994; Petersen & Calvin, 1996; EPA, 2002; Wong & Li, 2003).

In the case of relatively heterogeneous sites are required stratified and systematic sampling strategies, as they are able to produce a more detailed and accurate description of a given site with respect to the spatial and vertical distribution of HM metals in the soil.

In a stratified sampling program, the population is broken into a number of subgroups, and a simple random sample is taken from each subgroup. This sampling strategy allows a detailed study on each of the subgroups and increases the precision and accuracy of the estimate over the entire population (Petersen & Calvin, 1996, Wong & Li, 2003).

In a systematic sampling, soil samples are collected from points at regular and even intervals. The site is divided into rectangular or triangular grids and each grid points are given numbers. This method of soil sampling ensures complete site coverage and a homogenous distribution of samples, hence minimizing bias in the estimation of mean concentration of the pollutant. A square grid is the most preferred type of systematic sampling pattern (Saha *et al.*, 2017).

The systematic sampling strategy is often employed in the geochemical mapping of heavy metals, since it enables detailed characterization of the spatial distribution of heavy metals in a large region (Appleton & Ridgeway, 1993; Xuejing & Cheng, 2001).

Other factors that should also be considered during soil sampling include sampling density, sampling depth and the use of composite soil samples. In an ideal situation, the larger the number of soil samples collected, the better the sample population can reflect the conditions of the site. However, in reality,

sampling density is often a compromise between representativeness of the site and the availability of resources.

Sampling depth is determined based upon the purpose of the investigation and/or the specific requirements of a regulatory guideline. Also, in cases where heavy metal contamination of subsurface soils is suspected or groundwater contamination is a concern, sampling of soil profiles or subsurface soils may be necessary (Wong & Li, 2003). The two common approaches are metric (depth-related) sampling and soil-horizon-related sampling. In general, the metric sampling approach is used for the purposes of screening analysis of potentially contaminated land. In more detailed environmental assessments, a horizon-related sampling approach is recommended (Paetz & Cröbmann, 1994).

The use of composite soil samples offers the advantage of increased accuracy/representativeness through the use of large numbers of sampling units per sample. A composite soil sample is formed by combining equal portions of individual sub-samples. It is based on the fundamental assumption that analysis of the composite sample yields a valid estimate of the mean, which is obtained by averaging the results of analysis from each of the sampling units contributing to the composite (Tan, 1996).

Ultimately, a suitable sampling strategy should maximize the representativeness of the study area with a minimal number of soil samples and resources to be utilized, while meeting the requirements of the investigation.

In the case of the 5 pilot sites of the SPIRE project it was considered that the soil samples will be taken following a regular grid pattern (which may be a regular square grid or an off-set square grid, known as a herringbone pattern) in order to provide a representation of the extent and nature of contamination at the site. The patterns are presented in Fig. 3.

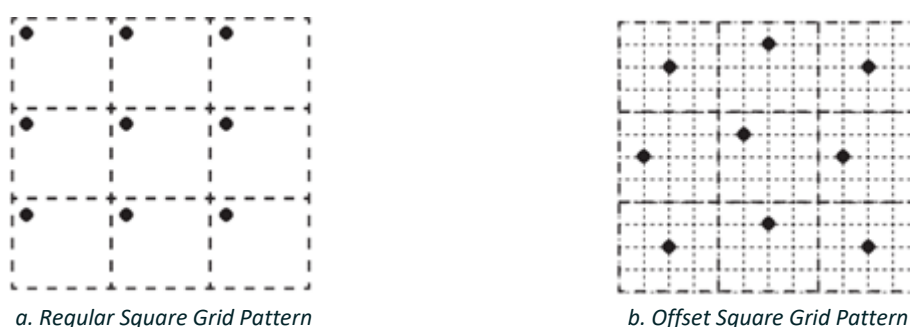


Figure 3 - Sampling Design Patterns

Following the results obtained at the first background evaluation, extra sampling points can be considered, located at or near potential sources of contamination (ex. hot spot).

Regarding the number of samples required for the first background evaluation, it was established on the basis of literature data (DEFRA, 1994; Carter & Gregorich, 2007; [https://www.epd.gov.hk/epd/sites/default/files/epd/gn\\_pdf/GN2014P244-2011c-e.pdf](https://www.epd.gov.hk/epd/sites/default/files/epd/gn_pdf/GN2014P244-2011c-e.pdf)) (Table 1 and Table 2). For more heavily contaminated site (or sites on which 100 m grid has revealed the need for more testing) a 50 m grid is appropriate. Closer grids would be appropriate for small sites (Kelly, 1980). Waterhouse (1980) recommends the following grid sizes related to site size: 10 m for 0.5 ha; 20 m for 5 ha and 30 m for 16 ha.

Table 1 - Minimum Number of Grid Soil Sampling Points for Investigation of Contaminated Land. Source: [https://www.epd.gov.hk/epd/sites/default/files/epd/gn\\_pdf/GN2014P244-2011c-e.pdf](https://www.epd.gov.hk/epd/sites/default/files/epd/gn_pdf/GN2014P244-2011c-e.pdf)

AREA OF SITE (m <sup>2</sup> )	SQUARE GRID SIZE (m)	MINIMUM NUMBER OF SAMPLING POINTS
-----------------------------------	-------------------------	--------------------------------------

100	6	3
500	13	3
1000	13	6
2000	13	12
4000	17	14
5000	17	17
8000	17	28
10000	19	29
30000	31	32

Table 2 - Minimum Number of Grid Soil Sampling Points for Investigation of Contaminated Land according Romanian legislation. Source: Order no. 184/1997 on the approval of environmental balance procedure

AREA OF SITE (m <sup>2</sup> )	MINIMUM NUMBER OF SAMPLING POINTS
1000	4
1000 ÷ 5000	8
5000 ÷ 10000	15

In order to determine the vertical spread of contamination, soil samples shall be taken at various vertical depths at different locations on the site. Three soil samples or more should be taken at each sampling point to determine vertical distribution of contaminants.

### 2.2.2. Selection of analytical parameters

Selection of specific soil quality indicators is an essential issue for evaluating the success of a phytoremediation strategy of HMs polluted land.

These indicators reflect the structure and function of ecological processes on these lands. Temporal changes in the status of these indicators give an indication of the sustainability of the adopted strategy.

Numerous studies, investigations, and observations indicated that the principle soil parameters governing the binding of heavy metals and hence their bioavailability include pH, soil texture, cation exchange capacity (CEC), organic matter, oxides and hydroxides, mainly Fe, Mn, and Al, activity of microorganisms, occurrence and form of cations, content of macro and micronutrients, oxidation-reduction potential, sorption capacity, bioavailability for plants and animals, and resistance of the soil (Alamgir, 2016).

A summary of soil quality indicators in the view of different authors is presented in Table 3.

Table 3 - Summary of Soil Quality Indicators Used to Assess Soil Quality. Source: after Mukhopadhyay et al., 2019

SOIL QUALITY INDICATORS	REFERENCE
Aggregation, electrical conductivity, infiltration, organic matter, pH, topsoil depth, suspected pollutants, soil respiration	Arshad & Martin, 2002
Biological descriptors of soil health, biodiversity, or functional processes	Dickinson <i>et al.</i> , 2005
Soil bulk density, water infiltration, water holding capacity, total organic carbon and nitrogen, electrical conductivity, pH, plant available nutrients, and measures of microbial biomass and activity	Doran & Parkin, 1996
Soil aggregate stability, infiltration, and bulk density	Bengtsson, 1998; Swift <i>et al.</i> ,

	2004
Extractable soil nutrients, pH, NPK and base cations, Ca, Mg, and K	Doran & Parkin, 1996; Drinkwater <i>et al.</i> , 1996
Base saturation, coarse fragments, water holding capacity, total porosity, and electrical conductivity	Rodrigue & Burger, 2004
Organic matter content and accumulation of heavy metals	MAFF, 2000
Soil texture, organic matter, pH, nutrient status, bulk density, electrical conductivity, and rooting depth	Larson & Pierce, 1996
Soil organic matter (SOM)	Gregorich <i>et al.</i> , 1994; Carter, 2002
Soil microbial biomass, soil organic matter, textural characteristics	Ruzek <i>et al.</i> , 2003
Soil organic carbon, electrical conductivity, available soil water, microaggregates, dehydrogenase activity	Rajan <i>et al.</i> , 2010
Vegetation type and litter quality, soil microbial activity	Šourková <i>et al.</i> , 2002; Knoepp <i>et al.</i> , 2000
Soil enzyme activities	Bandick & Dick, 1999; Vance & Entry, 2000
Dehydrogenase activity	Skujins, 1973; Sinha <i>et al.</i> , 2009
Soil microbial biomass	Carter <i>et al.</i> , 1999
Soil MBC, mycorrhizal association, and soil respiration	Chodak & Niklińska, 2010; Brookes, 1995
Microbial biomass C and N; soil respiration, potentially mineralizable N	Doran & Parkin, 1994
Soil microbial biomass carbon (MBC), soil organic carbon (SOC), microbial quotient (MBC/SOC)	Insam & Domsch, 1988; Anderson & Domsch, 1989; Sinha <i>et al.</i> , 2009
Bulk density, water infiltration, aggregate size, organic carbon, total nitrogen	Shukla <i>et al.</i> , 2004
Organic carbon, CO <sub>2</sub> flux, dehydrogenase, coarse fraction	Mukhopadhyay <i>et al.</i> , 2013
Organic carbon, CO <sub>2</sub> flux, dehydrogenase, coarse fraction, moisture, base saturation	Mukhopadhyay <i>et al.</i> , 2014

In the case of the 5 pilot sites of the SPIRE project have been selected the soil indicators presented below.

#### 2.2.2.1. Soil structure

Soil structure describes the physical configuration of the soil and is defined as the arrangement of the soil particles, by the way individual particles of sand, silt, and clay are assembled. With regard to structure, soil particles refer not only to sand, silt and clay but also to the aggregate or structural elements that have been formed by the aggregation of smaller mechanical fractions. Therefore, the word “particle” refers to any unit that is part of the make-up of the soil, whether a primary unit (sand, silt or clay fraction) or a secondary (aggregate) particle.

Soil structure is most usefully described in terms of grade (degree of aggregation), class (average size) and type of aggregates (form). In some soils, different kinds of aggregates may be found together and they are then described separately.

By definition, type of structure describes the form or shape of individual aggregates. Generally, soil technicians recognize seven types of soil structure, but here only four types are used. They are rated from 1 to 4 as follows:

Granular and crumb structures are individual particles of sand, silt and clay grouped together in small, nearly spherical grains. Water circulates very easily through such soils. They are commonly found in the A-horizon of the soil profile (Fig. 4a).

Blocky and subangular blocky structures are soil particles that cling together in nearly square or angular blocks having more or less sharp edges. Relatively large blocks indicate that the soil resists penetration and movement of water. They are commonly found in the B-horizon where clay has accumulated (Fig. 4b).

Prismatic and columnar structures are soil particles which have formed into vertical columns or pillars separated by miniature, but definite, vertical cracks. Water circulates with greater difficulty and drainage is poor. They are commonly found in the B-horizon where clay has accumulated (Fig. 4c).

Platy structure is made up of soil particles aggregated in thin plates or sheets piled horizontally on one another. Plates often overlap, greatly impairing water circulation. It is commonly found in forest soils, in part of the A- horizon, and in claypan soils (Fig. 4d).

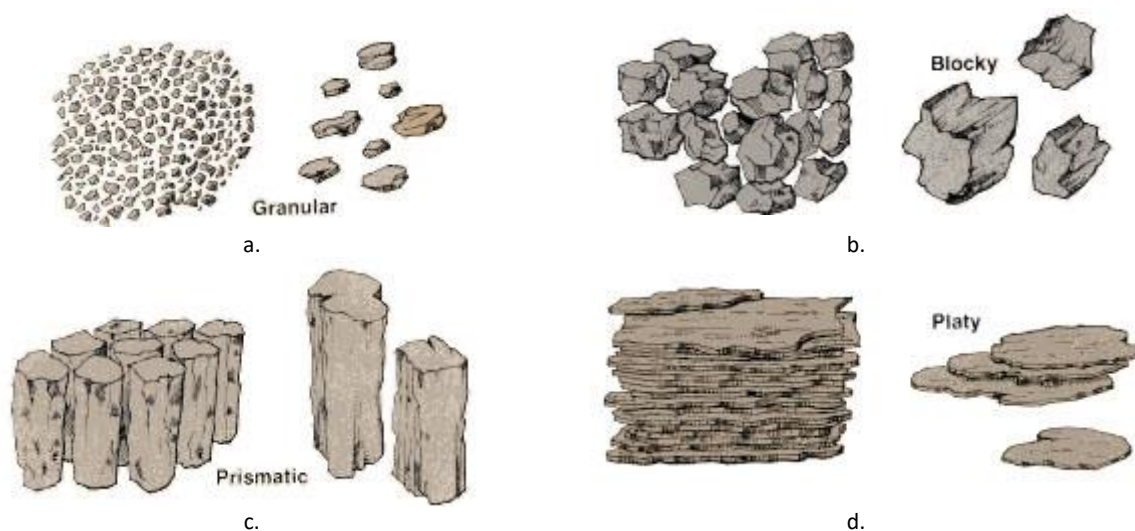


Figure 4 - Types of soil structure. Source: <http://www.fao.org/>

The size, shape and character of the soil structure varies (e.g. cube-like, prism-like or platter-like). On the basis of size, the soil structure is classified as:

- very coarse: > 10 mm;
- coarse: 5–10 mm;
- medium: 2–5 mm;
- fine: 1–2 mm;
- very fine: < 1 mm.

Depending on the stability of the aggregate and the ease of separation, the structure is characterized as:

- poorly developed;
- weakly developed;
- moderately developed;
- well developed;



- highly developed.

The soil structure or aggregate consists of an intermediate grouping of a number of primary particles into a secondary unit. The important factors that facilitate the aggregation of soil particles are:

- clay particles and types of clay minerals;
- cations such as Ca;
- organic matter (OM);
- colloidal matter such as oxides of Fe and Al;
- plant roots;
- soil microbes and their types (fungi being most effective).

Soil structure influences the extent of pore space in the soil, water movement, water holding capacity (WHC), aeration, conduction of heat, root movement and nutrient availability, plant root growth and resistance to erosion. The better and more stable soil aggregates are considered a desirable soil property with regard to plant growth. Water has the strongest effect on soil structure due to its solution and precipitation of minerals and its effect on plant growth.

Therefore, the determination of soil structure is an important exercise in a soil fertility evaluation programmed. An aggregate analysis aims to measure the percentage of water-stable secondary particles in the soil and the extent to which the finer mechanical separates are aggregated into coarser fractions.

#### **2.2.2.2. Soil texture and clay mineralogy**

Both soil texture and mineral types play an important role in mobility of metals in soil. The mineral components of soil, sand, silt and clay, determine a soil's texture. Soil texture (or particle size distribution) is a stable soil characteristic that influences the physical and chemical properties of the soil. The sizes of the soil particles have a direct relationship with the surface area of the particles. Soil particles remain aggregated owing to various types of binding forces and factors. These include the content of organic matter (OM), other colloidal substances present in the soil, oxides of Fe and Al, and the hydration of clay particles. To estimate the content of various sizes of soil particles, the soil sample has to be brought into a dispersed state by removing the various types of binding forces.

In the dispersed soil samples, the soil particles settle down at a differential settling rate according to their size. In the estimation of soil texture, particles of less than 2 mm in diameter are determined separately and characterized as: coarse sand (2.0–0.2 mm); fine sand (0.2–0.02 mm); silt (0.02–0.002 mm); and clay (< 0.002 mm).

Particles less than 0.001 mm size possess colloidal properties and are known as soil colloids. The soil colloids are the most active portion of the soil and largely determine the physical and chemical properties of a soil.

Clay fraction, which is mainly composed of clay minerals, has a high sorption capacity and a strong ability to bind metallic elements due to their large specific surface area, chemical and mechanical stability, layered structure and high cation exchange capacity (CEC).

Generally, soils having higher amounts of clay and humus also have high buffering capacity, the sorption capacity of soils which despite the increase in concentrations of contaminants do not cause adverse biological effects. Compared to clay soils, sandy soils have lower sorption capacity and larger pore size so they weakly absorb heavy metals, which lead to their movement to groundwater and surface water. Clay minerals may contain negligible amounts of trace elements as structural components, but their sorption capacities to trace elements play the most important role.

There are four major types of clay minerals. These include the layer silicates, iron and aluminum oxides, amorphous and allophanes, and humus. Layer silicate clays, iron and aluminum oxide clays, allophane and associated amorphous clays are inorganic colloids while humus is an organic colloid. Inorganic colloids usually make up the bulk of soil colloids (Alamgir, 2016).

Soil texture affects, also, the soil behavior, in particular its retention capacity for nutrients and water.

The particle size distribution is estimated separation of the mineral part of the soil into various size fractions and determination of the proportion of these fractions. The analysis includes all soil material, i.e. including gravel and coarser material. Of paramount importance in this analysis is the pretreatment of the sample aimed at complete dispersion of the primary particles. Therefore, generally, cementing materials (usually of secondary origin) such as organic matter, salts, iron oxides and carbonates such as calcium carbonate are removed. After shaking with a dispersing agent, sand (63  $\mu\text{m}$ -2 mm) is separated from clay and silt with a 63  $\mu\text{m}$  sieve (wet sieving). The clay (< 2  $\mu\text{m}$ ) and silt (2-63  $\mu\text{m}$ ) fractions are determined by the pipette method (sedimentation). (ISO 11277:2020 - Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation).

### **2.2.2.3. Cation exchange capacity and Base Saturation**

Cation exchange capacity (CEC) is a dominant factor in HM retention. Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions (<http://www.soilquality.org.au/factsheets/cation-exchange-capacity>). It can be expressed in terms of milli-equivalents per 100 g of soil (me/100 g) or in centimoles of positive charge per kilogram of soil (cmol/kg), which is numerically equal to me/100 g.

CEC gives an insight into the fertility and nutrient retention capacity of soil. Certain soil minerals, such as clay, particularly in combination with organic matter, possess a number of electrically charged sites, which can attract and hold oppositely charged ions. The negatively charged sites make up the CEC, the ability to hold  $\text{H}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$  and  $\text{NH}_4^+$  etc., and the positively charged sites, which hold  $\text{OH}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$  etc., make up the anion exchange capacity. Ions held at these sites can be exchanged with others of similar charge. CEC is an important index of nutrient status because exchangeable cations are the most important source of immediately available plant nutrients.

It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants (Hazleton & Murphy, 2016).

The CEC of soils depends on soil types, amounts, and types of different colloids present and on the CEC of the colloids. Fine-textured (clay) soils tend to have higher cation exchange capacity than sandy soils. CEC for clay soils usually exceeds 30 cmolc/kg while the value ranges from 0 to 5 for sandy soils. 2:1 type clays have higher CEC than 1:1 clay. The CEC values of clay vary in the following sequence: montmorillonite, imogolite >vermiculite >illite, chlorite >halloysite >kaolinite. Humus has very high CECs compared to the inorganic clays, especially kaolinite and Fe, Al oxides.

The capacity of the soils for adsorbing HM is correlated with their CEC (Fontes *et al.*, 2000; Harter & Naidu, 2001). The greater the CEC values, the more exchange sites on soil minerals will be available for metal retention. Clay minerals, such as montmorillonite and vermiculite, have a high cation exchange capacity and have a high total capacity toward some heavy metals (Malandrino *et al.*, 2006).

Competing ions can have a marked effect on ion sorption by soils. In solution, metal cations such as Cu, Zn, Cd, and Pb compete with more abundant soil cations such as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  for both nonspecific and specific exchange sites. Chen (2012) found that the presence of Pb did significantly reduce the



adsorption maximum of Cd on soils (Alamgir, 2016). Mutual interactions between clay minerals, metal oxides, and organic matter can greatly alter the sorptive properties of these soil constituents for heavy metals because such interactions usually involve cation exchange sites (Cruz-Guzmán *et al.*, 2003).

CEC helps characterize the soil type under consideration. For example, because organic matter in the soil is a major source of negative electrostatic sites there is a strong correlation between CEC values, and the amount of organic matter present in the soil.

Base saturation (BS) is another important parameter that influences plant growth in polluted soils (Rodrigue & Burger, 2004). BS and CEC depend on the rock type/parent material of the soil (Czapowskyj, 1978; Pedersen *et al.*, 1978).

The method used for CEC and BS determination was based on the standard ISO 11260:2018 - Soil quality — Determination of effective cation exchange capacity and base saturation level using barium chloride solution.

#### **2.2.2.4. Soil moisture**

Water is present in most naturally occurring soils and has a profound effect in soil behavior. The soil moisture content is a value that determines the amount of water in a certain known amount of soil; it can be expressed as a percentage, water by the weight or volume of soil.

Soil moisture content is a variable parameter that depends on a number of factors (sampling time, sampling depth, stone content, amount of soil organic carbon and soil texture and thickness). Water content has an important role for soil chemistry. Not all the water, held in soil, is available to plants. Much of water remains in the soil as a thin film. Soil water dissolves salts and makes up the soil solution, which is important as medium for supply of nutrients to growing plants.

A knowledge of the moisture content is used as a guide to the classification. It is also used as a subsidiary to almost all other field and laboratory tests of soil.

The gravimetric method of moisture estimation is most widely used where the soil sample is placed in an oven at 105°C and dried to a constant weight. The difference in weight is considered to be the water present in the soil sample (ISO 11465:1993 Soil quality — Determination of dry matter and water content on a mass basis — Gravimetric method).

#### **2.2.2.5. Soil pH**

Soil pH is an important indicator for the phytoremediation strategies on HM polluted soils, as pH affects nutrient availability and changes the mobility of toxic trace elements.

Generally speaking, soil pH value has the greatest effect of any single factor on the solubility or retention of metals in soils (Ghosh & Singh, 2005; Alloway, 2012; cited by Alamgir, 2016). The main mechanisms by which soil pH influences the sorption of heavy metals are represented by:

- changes in surface charge (Naidu *et al.*, 1997);
- competition for adsorption sites (Benjamin & Leckie, 1981);
- hydrolysis of metal species in solution (McBride, 1989);
- dissolution of metal complexing anions.

The soil pH is the negative logarithm of the active hydrogen ion ( $H^+$ ) concentration in the soil solution. It is the measure of soil solidity, acidity or neutrality. It is a simple but very important estimation for soils as soil pH has a considerable influence on the availability of nutrients to crops. Studies in different environments (agricultural, urban and transition land-use zones) demonstrate that in the acid soils,

heavy metals are more mobile than in the alkaline one, and the alkaline environment better sustains metals (Kazlauskaitė-Jadzevičė *et al.*, 2014).

The solubility of HM decreases with increasing pH and vice versa, therefore accumulation of heavy metals is often observed in the alkaline environment. On other hand - contamination of soil with HM can stimulate rising of soil pH level. It also affects microbial population in soils. Most nutrient elements are available in the pH range of 5.5–6.5. In various chemical estimations, pH regulation is critical. Based on soil pH values, soil reactions are distinguished as per Table 4 and Table 5.

Table 4 - Classification of soil pH ranges. Source: FAO, 2008.

pH RANGE	SOIL REACTION RATING
< 4.6	Extremely acidic
4.6–5.5	Strongly acidic
5.6–6.0	Moderately acidic
6.1–6.5	Slightly acidic
6.6–7.3	Neutral
7.4–7.8	Slightly alkaline
7.9–8.4	Moderately alkaline
>8.5	Strongly alkaline

Table 5 - Classification of soil pH ranges. Source: The United States Department of Agriculture Natural Resources Conservation Service

pH RANGE	SOIL REACTION RATING
< 3.5	Ultra acidic
3.5–4.4	Extremely acidic
4.5–5.0	Very strongly acidic
5.1–5.5	Strongly acidic
5.6–6.0	Moderately acidic
6.1–6.5	Slightly acidic
6.6–7.3	Neutral
7.4–7.8	Slightly alkaline
7.9–8.4	Moderately alkaline
8.5–9.0	Strongly alkaline
> 9.0	Very strongly alkaline

Acid soils need to be limed before they can be put to normal agricultural production. Alkali soils need to be treated with gypsum in order to remove the excessive content of Na.

Soil pH is one of the most common and important measurements in standard soil analyses. Many soil chemical and biological reactions are controlled by the pH of the soil solution in equilibrium with the soil particle surfaces.

Soil pH is measured in an aqueous matrix such as water or a dilute salt solution. Soil pH measured in water is the pH closest to the pH of soil solution in the field (this is true for soils with low electrical conductivity and for soils that are not fertilized), but is dependent on the degree of dilution (the soil to solution ratio)(ISO 10390:2005 Soil quality — Determination of pH). Measuring soil pH in a matrix of 0.01 M CaCl<sub>2</sub>, as opposed to water, has certain advantages, but the addition of the salt does lower the pH by about 0.5 pH units compared to soil pH in water (Carter & Gregorich, 2007). In soil correlation

work, the use of pH in  $\text{CaCl}_2$  is preferred because the measurement will be less dependent on the recent fertilizer history (Gavriloaie, 2012).

#### 2.2.2.6. Soil electrical conductivity

Electrical conductivity is a measure of the ionic transport in a solution between the anode and cathode. This means, EC is normally considered to be a measurement of the dissolved salts in a solution. Similar to a metallic conductor, they obey Ohm's law.

As EC depends on the number of ions in the solution, it is important to know the soil/water ratio used. The EC of a soil is conventionally based on the measurement of the EC in the soil solution extract from a saturated soil paste, as it has been found that the ratio of the soil solution in saturated soil paste is about 2–3 times higher than that at field capacity.

Table 6 - General interpretation of EC values. Source: FAO, 2008

SOIL	EC (ms/cm)	TOTAL SALT CONTENT (%)	CROP REACTION
Salt free	0-2	<0.15	Salinity effect negligible, except for more sensitive crops
Slightly saline	4-8	0.15-0.35	Yield of many crops restricted
Moderately saline	8-15	0.35-0.65	Only tolerant crops yield satisfactorily
Highly saline	>15	>0.65	Only very tolerant crops yield satisfactorily

#### 2.2.2.7. Organic matter content

In the context of critical loads of HM in soils, a particular issue is the potential for the retention of atmospherically derived metal inputs in the surface humic layer of soils. This aspect has important implications for metal mobility down the soil profile and for the bioavailability of metals to surface dwelling organisms (Rieuwerts *et al.*, 1998). Whilst the organic matter content of soils is often small compared to that of clay, the organic fraction has a significant influence on metal binding (Zimdahl & Skogerboe, 1977).

In addition to decomposing plant material, other organic components, such as soil fauna and microbiota (dead and alive) may also be important sinks for HM.

Organic matter accumulates at the soil surface, mainly as a result of decomposing plant material. Soil organic matter is comprised of humic substances (humus), and non-humic substances. The humus, comprised of humic and fulvic acids and humins, is the fraction of soil organic matter which has been extensively decomposed and is resistant to further alteration (Foth, 1978).

The mechanisms involved in the retention of HMs by organic matter appear to include both complexation and adsorption.

There are various methods for estimating OM in soil. Loss of weight on ignition can be used as a direct measure of the OM contained in the soil. It can also be expressed as the content of organic C in the soil. It is generally assumed that, on average, OM contains about 58 percent organic C.

The wet combustion analysis of soils by chromic acid digestion has been accepted as a standard method for determining total C, as it gives acceptable results.

The organic matter content of a soil may be estimated by multiplying the organic carbon concentration by a constant factor based on the percentage of Carbon (C) in organic matter. Published organic C to total organic matter conversion factors for surface soils vary from 1.724 to 2.0.

Soil organic matter content can be used as an index of N availability (potential of a soil to supply N to plants) because the N content in SOM is relatively constant.

The salt–acid (weight–volume) ratio should not be less than 1:1 at the end of digestion. Commonly used catalysts to accelerate the digestion process are  $\text{CuSO}_4$  and mercury (Hg).

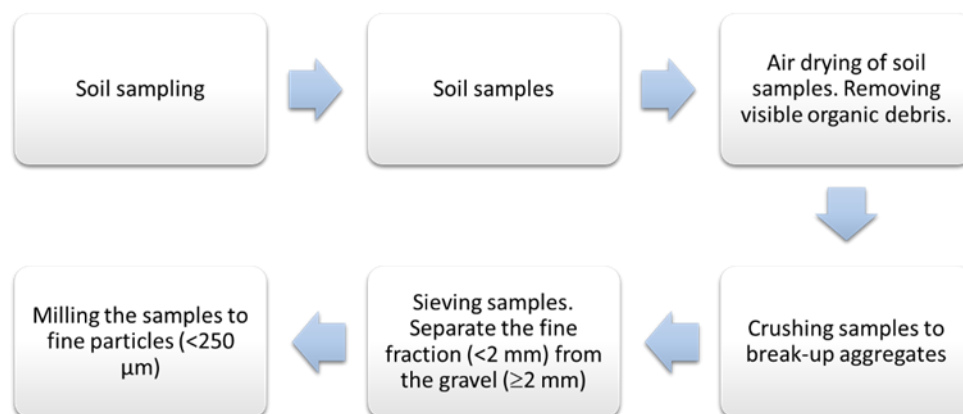
Potassium sulphate is added to raise the boiling point of the acid so that loss of acid by volatilization is prevented.

### 2.2.3. Soil sample preparation

Soil sample preparation is an absolutely critical step and tends to be overlooked in a review of methods, but if the preparation is not carefully done, then no amount of sophisticated instrumentation will improve the result (Agazzi & Pirola, 2000).

From the analytical methods perspective, the sampled soil presents some issues in terms of homogenization and pre-treatment of the soil sample, which can significantly impact the precision of final analytical result. In literature there are guideline documents and standards operating procedures detailing different sample preparations applicable for the determination of heavy metals content. To facilitate the soil HM analysis, drying, grinding and sieving of the soil samples are required.

Sample preparation steps include air-drying, crushing, sieving, milling and sub-sampling cores or composites as illustrated in Figure 5.



*Figure 5 - Steps involved in preparing soil samples for HM laboratory analysis*

Prior to analytical determination, the collected soil samples were air-dried to remove moisture, for one week or until constant mass has been achieved. Each soil sample was dried separately. Once air-drying was complete any visible organic debris in the soil (leaves, stalks and roots) were removed.

After drying, aggregates within the soil were crushed and broken up in a porcelain mortar with a pestle. To minimize spillage during manual crushing soil sample was placed into a sturdy plastic bag.

The next step involved the sieving of each soil sample in order to separate the <2 mm fraction from any gravel, rubble or coarse debris (≥2 mm). A non-metallic sieve was used to avoid contamination. The sieve was gently shaken to allow the soil to pass through. The ≥2 mm fraction that does not pass through the sieve was collected and set aside. If soil aggregates were present in the ≥2 mm fraction after sieving, the crushing and sieving steps were repeated.

The <2.0 mm fraction of each soil sample was mixed thoroughly to produce a homogenous sample and was manually milled to fine particles (<250  $\mu\text{m}$ ) in a mortar with a pestle to increase homogeneity.

#### 2.2.4. Microwave soil sample digestion

In order to analyze HM concentrations of soils by atomic absorption spectrometry, decomposition of the soil samples and the dissolution of heavy metals in solution are required by using strong acid digestion or fusion agents. This sample preparation step is very important during atomic absorption analysis and sometimes contributes the main error in the result obtained. The successfully chosen method of decomposition makes it possible not only to transfer the element determined in solution but also to simplify its isolation from the accompanying elements. The decomposition of samples is a labor-intensive operation, the effectiveness and duration of which depend on the method chosen (Safarova *et al.*, 2011).

For the decomposition of the soil samples we have chosen the microwave digestion in sealed containers. This is a more versatile method compared to traditional methods for the following reasons:

- a shorter acid digestion time;
- a supposed better recovery of volatile elements and compounds;
- lower contamination levels;
- lower reagent and sample usage;
- more controlled and reproducible results;
- a better working environment and enhanced operator safety.

Furthermore, the closed vessel microwave digestion technology has a unique advantage over other closed vessel technologies. Microwaves only heat the liquid phase, while vapor's do not absorb microwave energy. The temperature of the vapors phase is therefore lower than the temperature of the liquid phase and vapors condensation on cool vessel walls takes place. As a result, the actual vapors pressure is lower than the predicted vapors pressure. This sort of sustained dynamic, thermal non-equilibrium is a key advantage of microwave technology, as very high temperatures and in turn short digestion times can be reached at relatively low pressures (Agazzi & Pirola, 2000).

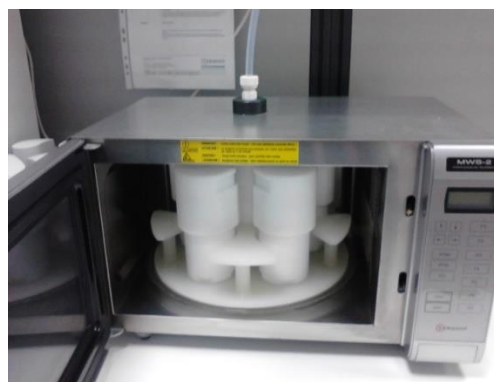
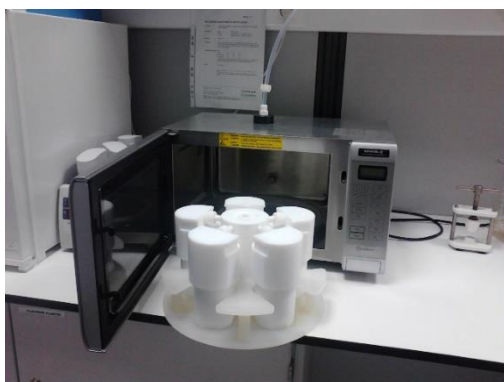


Figure 6 - Micro-wave assisted digestion device

A microwave device, BERGHOF speed wave MWS-2 (Berghof Products + Instruments GmbH Germany) microwave oven was employed for sample digestion (Fig. 6).

The followed procedure is the procedure described in the Application Report MWS-2 Microwave Pressure Digestion - Environment V.4.0 - Extraction of soil with aqua regia using a Berghof microwave digestion system (Fig. 7).

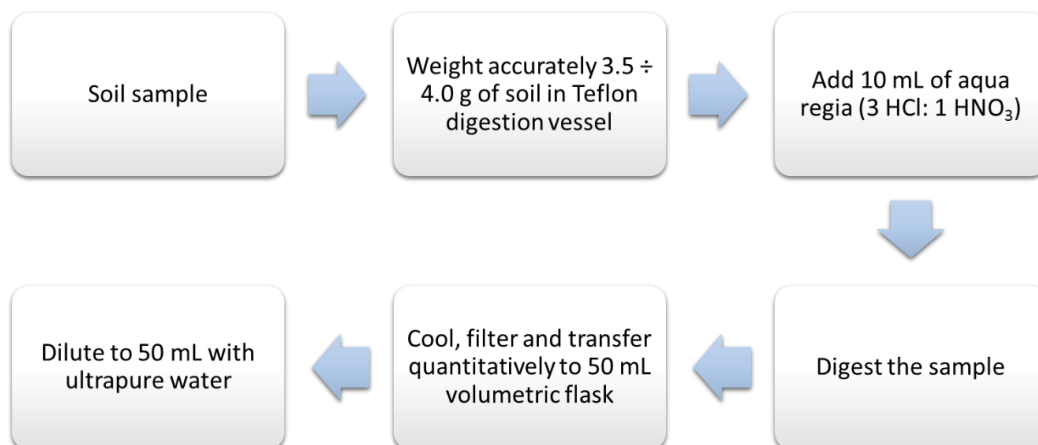


Figure 7 - Steps involved in microwave wet digestion of soil samples with aqua regia for HM laboratory analysis

About 3.5 ÷ 4.0 g of soil sample was accurately weighed in duplicate into the digestion vessel using an electronic balance (Shimadzu AX120, Shimadzu Corp, Japan) with a precision of 1 µg (Fig. 8). The amount of organic material should not exceed 250 mg.



Figure 8 - Weighing the soil sample in the Teflon digestion vessel

10 mL of aqua regia, 2.5 mL of HNO<sub>3</sub> (65% concentration, Merck extra pure) and 7.5 mL HCl (37% concentration, Merck p.a.), was carefully added to each digestion vessel.

The mixture of hydrochloric and nitric acid at the ratio of 3:1 (aqua regia) is one of the most aggressive solvents. The acting component of this mixture is nitrosyl chloride (NOCl). Aqua regia oxidizes most materials more effectively than hydrochloric or nitric acid separately.

The obtained mixture (soil and aqua regia) was swirled gently to mix the sample properly. The vessel is allowed to react for approximately 10 minutes prior to sealing. Then the vessels were closed and placed inside the rotor of the microwave digestion system (Berghof MWS-2)(Fig. 6), sealed, tightened using a torque wrench and finally submitted to a microwave dissolution program given in Table 7. Aqua regia mixture was used as blank solution.

Table 7 - The program used for digestion of soil samples

PARAMETER	STEP 1	STEP 2
T°[C]	180	100
Power [%]	99	99



Time [min]	25	10
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After cooling, the digests were filtered through a 0.45 mm filter and quantitatively transferred to polyethylene volumetric flask, diluted to 50 mL with ultrapure water with a specific resistance of 18.2 MΩ/cm obtained from a Direct Q3UV Smart (Millipore, USA).

### 2.2.5. Heavy metals analysis by FAAS

The measurements of Cd, Cu, Pb and Zn concentrations in the digested samples were performed in an air acetylene flame using the Analyst 800 Atomic Absorption Spectrophotometer (Perkin Elmer, USA)(Fig. 9) equipped with the WinLab32 for AA (Version 6.5) software, which features all the tools to analyze samples, report and archive data and ensure regulatory compliance. Lamps with a hollow cathode from Perkin Elmer were used as the light sources. The signal of nonselective absorption was corrected with the use of a deuterium lamp of a continuous spectrum.



Figure 9 - The Analyst 800 Atomic Absorption Spectrophotometer (Perkin Elmer, USA)

Five-point calibration curves (four standards and one blank) were constructed for all the metal ions and the calibration curve correlation coefficient was ensured to be better than 0.999 before the start of the sample analysis. Calibrating standard solutions of Cd, Cu, Pb and Zn were fresh prepared daily by accurate dilution of the respective stock standard solutions (1000 mg/L, Merck, Germany).

All reagents used were of analytical grade (Merck, Germany). Ultrapure water with a specific resistance of 18.2 MΩ/cm obtained from a Direct Q3UV Smart (Millipore) was used to prepare the standard solutions. The laboratory wares were cleaned by soaking with 10% volume/volume HNO<sub>3</sub> for at least 24 hours and rinsed abundantly in deionized water before use.

The operation conditions were those recommended for each metal in the instrument's method (Table 8).

Table 8 - Instrumental parameters for heavy metal analysis by FAAS

STANDARD CONDITIONS	ELEMENT			
	Cd	Cu	Pb	Zn
Wavelength, λ [nm]	228.8	324.7	283.3	213.9
Slit width [nm]	0.5	0.5	0.5	0.7

<b>HCL* current [mA]</b>	4	4	5	4
<b>Background correction</b>	Deuterium	Deuterium	Deuterium	Deuterium
<b>Flame</b>	C <sub>2</sub> H <sub>2</sub> /air	C <sub>2</sub> H <sub>2</sub> /air	C <sub>2</sub> H <sub>2</sub> /air	C <sub>2</sub> H <sub>2</sub> /air
<b>Fuel flow [N l/h]</b>	50	50	65	50
<b>Calibration</b>	Linear with calculated intercept	Linear with calculated intercept	Linear with calculated intercept	Linear with calculated intercept
<b>Correlation Coefficient</b>	0.9997	0.9998	0.9991	0.9992
<b>Read time [sec.]</b>	5	5	5	5
<b>Measurement</b>	peak area	peak area	peak area	peak area

\*HCL - Hollow-Cathode Lamp

Final concentrations of the HMs in the soil samples were calculated using the following formula:

$$HM \text{ Concentration [mg/kg]} = \frac{Concentration [mg/L] \times V}{W}$$

where: V = final volume [50 mL] of solution, and W = initial weight [g] of soil sample measured.

The sensitivity of FAAS method was estimated as the limit of detection (LOD) and the limit of quantification (LOQ). LOD and LOQ were calculated based on the standard deviation of the response and the slope, using the following equations (Thomsen *et al.*, 2003; Chan, 2008; Sun & Li, 2011).

$$LOD = \frac{3 \times \sigma}{S} ; \quad LOQ = \frac{10 \times \sigma}{S}$$

where, “σ” is the standard deviation of 10 replicate measurements of the blank signal and “S” is the slope of calibration curve.

Table 9 - LOD and LOQ of the FAAS method

PARAMETER	ELEMENT			
	Cd	Zn	Pb	Cu
<b>Linear working range [mg/L]</b>	0 – 1	0 – 1	0 – 1	0 – 3
<b>LOD [mg/L]</b>	0.012	0.013	0.083	0.036
<b>LOQ [mg/L]</b>	0.039	0.042	0.276	0.119

### 2.2.6. Quality control and assurance

Quality control is defined as a system of procedures and practices which result in an increase in precision and a decrease in bias. The use of duplicate analysis, spiked samples, standard reference materials, and QC check samples are all mechanisms used to demonstrate the control of quality (Klesta & Bartz, 1996).

In general, to detect contamination and evaluate the reproducibility and effectiveness of the analytical procedures, procedural blanks, duplicates and certified standard reference materials, such as those offered by the National Institute of Standards & Technology (NIST), should be included in the analytical program (Wong & Li, 2003).

During sampling and laboratory analysis of heavy metal contaminated soils in SPIRE project, care has been taken to prevent contamination of the samples and to ensure the reliability and quality of analytical results. First of all, the use of metal tools was avoided whenever possible. Soil samples were



collected using stainless steel tools and stored in polyethylene bags. All glass- and plastic-ware were soaked in weak inorganic acid, e.g. 10% (v/v) nitric acid, and rinsed thoroughly with distilled and deionized water before use, to ensure that there is no contamination of the laboratory accessories. For quality control purpose, blanks and triplicates samples ( $n = 3$ ) were analyzed during the procedure. The variation coefficient was under 5%.

## 2.3. Results for first assessment of soil indicators

### 2.3.1. Soil pH

Table 10 - The soil reaction in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH (cm)	pH	SOIL REACTION RATING
"ROMPLUMB"	N47°41'19.5'' E23°37'41.6''	< 20	6.86	Neutral
		> 20	7.22	Neutral
"FERNEZIU 1"	N47°40'34.5'' E23°37'23.2''	< 20	6.73	Neutral
		> 20	6.60	Neutral
"COLONIA TOPITORILOR"	N47°40'02.6'' E23°36'21.4''	< 20	7.55	Slightly alkaline
		> 20	7.29	Neutral
"URBIS – LOCAL POLICE STATION"	N47°39'49.3'' E23°36'24.5''	< 20	7.51	Slightly alkaline
		> 20	7.74	Slightly alkaline
"CRAICA 1"	N47°38'18.5'' E23°34'6.6''	< 20	<b>6.06</b>	Moderately acid
		> 20	<b>5.95</b>	Moderately acid
"CRAICA 2"	N47°38'18.6'' E23°34'12.1''	< 20	<b>4.35</b>	Extremely acid
		> 20	<b>4.19</b>	Extremely acid

The soil pH in the SPIRE pilot sites of Baia Mare basically ranged from extremely acid (4.19-4.35)(Craica 2) to slightly alkaline (7.51-7.74)(Urbis – Local Police station)(Table 10). The soil reaction can be corrected by adding amendments.

Soil pH is one of the most important factors that control HM uptake. In fact, solubility and bioavailability of heavy metals increased with a decrease in the soil pH, resulting in an increased metal uptake by the plants. The behaviour of heavy metals (translocation in plants and biological absorption coefficient) is different in acidic and alkaline soils. Heavy metals are more soluble or available in acid soils than in neutral or slightly alkaline soils. Extremely and strongly acid soils (pH 4.0-5.0) can have high concentrations of heavy metals which may be toxic to the growth of some plants.

The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Bacteria that decompose soil organic matter are hindered in strong acid soils. This prevents organic matter from breaking down, resulting in an accumulation of organic matter and the tie up of nutrients, particularly nitrogen, that are held in the organic matter.

Increased heavy metal content negatively affects soil microbial population, which may have direct negative effect on soil fertility. Environmental pressure resulting from the contamination may reduce the biodiversity of microorganisms and disturb the ecological balance.

### 2.3.2. Soil humus content

Table 11 – Soil Humus content (%) in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH (cm)	HUMUS CONTENT (%)	DESCRIPTIVE TERM
“ROMPLUMB”	N47°41’19.5’’ E23°37’41.6’’	< 20	<b>2.12</b>	low
“FERNEZIU 1”	N47°40’34.5’’ E23°37’23.2’’	< 20	5.29	high
“COLONIA TOPITORILOR”	N47°40’02.6’’ E23°36’21.4’’	< 20	3.42	normal
“URBIS – LOCAL POLICE STATION”	N47°39’49.3’’ E23°36’24.5’’	< 20	4.41	medium
“CRAICA 1”	N47°38’18.5’’ E23°34’6.6’’	< 20	5.45	high
“CRAICA 2”	N47°38’18.6’’ E23°34’12.1’’	< 20	4.51	high

Humus is the soil basic specific constituent, resulting from the biocenosis action during soil formation process.

It is an important ecological determinant of soil, playing physical, chemical and trophic functions, contributing to the soil structure formation, water absorption, cation adsorption and exchange, and supplying nutrients as a result of organic matter mineralization (Dumitru *et al.*, 2011).

Humus is an important soil indicator because:

- significantly affects the bulk density of soil and contributes to its retention of moisture and nutrients.
- has many nutrients that improve the health of soil, nitrogen being the most important.
- helps the soil retain moisture by increasing microporosity.
- encourages the formation of good soil structure.
- the process that converts soil organic matter into humus feeds the population of microorganisms and other creatures in the soil, and thus maintains high and healthy levels of soil life.

The soil humus content (%) in the SPIRE pilot sites of Baia Mare basically ranged from low (2.12)(Pilot site Romplumb) to high (4.51-5.45)(Pilot site Craica 1 and Craica 2 – Pilot site Ferneziu 1)(Table 11).

Soil pH increases the solubility of soil organic matter by increasing the dissociation of acid functional groups and reduces the bonds between the organic constituents and clays (Neina, 2019). Thus, the content of dissolved organic matter increases with soil pH and consequently mineralizable C and N.

### 2.3.3. Soil Pb concentration

Lead (Pb) in soil, registered levels that ranged from 43.69 mg/kg dw (Pilot Site Craica 1 < 20 cm) and 417.97 mg/Kg dw (Pilot Site URBIS – Local Police Station > 20 cm). It can be seen that the lead levels in soil exceeded the normal value (20 mg/kg dw). The alert threshold for sensitive soil (50 mg/kg dw) was exceeded in all SPIRE pilot sites except for the pilot site Craica 1. The alert threshold for less sensitive soil (250 mg/kg dw) was exceeded in Pilot site Ferneziu 1 > 20 cm and Pilot site URBIS – Local Police Station (Table 12).

Table 12 - Soil Pb concentration in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH	Pb	REFERENCE VALUES (mg/kg dw) (Order 756/97)
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		(cm)	(mg/kg dw)	Normal value	Alert threshold		Intervention threshold	
					sensitive	less sensitive	sensitive	less sensitive
"ROMPLUMB"	N47°41'19.5'' E23°37'41.6''	< 20	117.32	20	50	250	100	1000
		> 20	172.39					
"FERNEZIU 1"	N47°40'34.5'' E23°37'23.2''	< 20	119.77					
		> 20	288.05					
"COLONIA TOPITORILOR"	N47°40'02.6'' E23°36'21.4''	< 20	114.92					
		> 20	123.81					
"URBIS – LOCAL POLICE STATION"	N47°39'49.3'' E23°36'24.5''	< 20	342.98					
		> 20	417.97					
"CRAICA 1"	N47°38'18.5'' E23°34'6.6''	< 20	43.69					
		> 20	46.36					
"CRAICA 2"	N47°38'18.6'' E23°34'12.1''	< 20	50.59					
		> 20	52.42					

### 2.3.4. Soil Cd concentration

Table 13 - Soil Cd concentration in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH (cm)	Cd (mg/kg dw)	REFERENCE VALUES (mg/kg dw) (Order 756/97)				
				Normal value	Alert threshold		Intervention threshold	
					sensitive	less sensitive	sensitive	less sensitive
"ROMPLUMB"	N47°41'19.5'' E23°37'41.6''	< 20	0.24	1	3	5	5	10
		> 20	0.27					
"FERNEZIU 1"	N47°40'34.5'' E23°37'23.2''	< 20	0.33					
		> 20	1.22					
"COLONIA TOPITORILOR"	N47°40'02.6'' E23°36'21.4''	< 20	0.99					
		> 20	1.17					
"URBIS – LOCAL POLICE STATION"	N47°39'49.3'' E23°36'24.5''	< 20	0.46					
		> 20	0.51					
"CRAICA 1"	N47°38'18.5'' E23°34'6.6''	< 20	0.80					
		> 20	1.25					
"CRAICA 2"	N47°38'18.6'' E23°34'12.1''	< 20	1.10					
		> 20	0.43					

Cadmium (Cd) in soil registered levels that ranged from 0.24 mg/kg dw (Pilot Site "ROMPLUMB" < 20 cm) and 1.25 mg/kg dw (Pilot Site Craica 1 > 20 cm). Compared to the threshold value it can be seen that the levels of cadmium in soil, have not exceeded the threshold value.

### 2.3.5. Soil Cu concentration

Table 14 - Soil Cu concentration in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH	Cu	REFERENCE VALUES (mg/kg dw) (Order 756/97)				
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		(cm)	(mg/kg dw)	Normal value	Alert threshold		Intervention threshold	
					sensitive	less sensitive	sensitive	less sensitive
"ROMPLUMB"	N47°41'19.5'' E23°37'41.6''	< 20	21.13	20	100	250	200	500
		> 20	27.00					
"FERNEZIU 1"	N47°40'34.5'' E23°37'23.2''	< 20	25.45					
		> 20	38.82					
"COLONIA TOPITORILOR"	N47°40'02.6'' E23°36'21.4''	< 20	32.27					
		> 20	64.44					
"URBIS – LOCAL POLICE STATION"	N47°39'49.3'' E23°36'24.5''	< 20	22.45					
		> 20	24.06					
"CRAICA 1"	N47°38'18.5'' E23°34'6.6''	< 20	86.33					
		> 20	128.78					
"CRAICA 2"	N47°38'18.6'' E23°34'12.1''	< 20	124.31					
		> 20	128.96					

Copper (Cu) in soil registered levels that ranged from 21.13 mg/kg dw (Pilot Site "ROMPLUMB" < 20 cm) and 128.96 mg/kg dw (Pilot Site Craica 2 > 20 cm). It can be seen that the levels identified in soil exceeded in all sampling points the normal value (20 mg/kg). The alert threshold for sensitive soil (100 mg/kg) was exceeded only in Pilot site Craica 1 and Pilot site Craica 2.

### 2.3.6. Soil Zn concentration

Table 15 - Soil Zn concentration in SPIRE pilot sites

PILOT SITE	GPS COORD.	DEPTH (cm)	Zn (mg/kg dw)	REFERENCE VALUES (mg/kg dw) (Order 756/97)				
				Normal value	Alert threshold		Intervention threshold	
					sensitive	less sensitive	sensitive	less sensitive
"ROMPLUMB"	N47°41'19.5'' E23°37'41.6''	< 20	84.57	100	300	700	600	1500
		> 20	113.88					
"FERNEZIU 1"	N47°40'34.5'' E23°37'23.2''	< 20	105.20					
		> 20	152.67					
"COLONIA TOPITORILOR"	N47°40'02.6'' E23°36'21.4''	< 20	125.69					
		> 20	160.57					
"URBIS – LOCAL POLICE STATION"	N47°39'49.3'' E23°36'24.5''	< 20	88.43					
		> 20	115.68					
"CRAICA 1"	N47°38'18.5'' E23°34'6.6''	< 20	270.09					
		> 20	385.22					
"CRAICA 2"	N47°38'18.6'' E23°34'12.1''	< 20	349.86					
		> 20	62.85					

Zinc (Zn) levels ranged between 62.85 mg/kg (Pilot Site Craica 2 > 20 cm) and 385.22 mg/kg dw (Pilot Site Craica 1 > 20 cm). It can be seen that the levels identified in soil exceeded in most points (red values) the normal value (100 mg/kg dw).

## 3. Vegetation contamination assessment



Fig. 7.8. Location of SPIRE pilot sites

### 3.1. Vegetation-general aspects

#### 3.1.1. Legal framework

The contaminated land regulation is defined at the national level by the Romanian Government (Ministry of the Environment). The general framework is established by the Law No. 138 of 27 April 2004 defining the outline of the national soil protection and management of polluted soils.

The law No. 68 of June 28, 2007 determines the principles of legal and financial responsibilities applicable to damage to the environment (including soil pollution). These two laws are supplemented by two ministerial decisions, more technical, one on how to assess soil contamination (1403/2007 - 2007) and the other on the legal framework for polluted sites and soils rehabilitation (1403/2007). Romanian regulations concerning contaminated sites appeared in 2007 by two government decisions: GD (HG) 1408/2007 on procedures for investigating and assessing soil and subsoil - GD (HG) 1403/2007 on the restoration of the soil, subsoil and terrestrial ecosystems have been affected.

Globally, in recent years, energy and climate policies have focused on materials that can be a source of renewable energy (Buhr *et al.*, 2014). In the European Union, biomass has already become the most important source of renewable energy and accounts for around two thirds of all energy sources used. According to several forecasts, by 2020, an area of 30 million hectares of agricultural land will be used for the production of plant crops that will be used for bioenergy production. By 2030, it is very likely that this area will increase by 15% to 35 million hectares (Thr  n, 2009).

The complexity of the study of grassland phytocenoses is given by the multitude of species that coexist according to natural rules and between which certain relationships are established. The participation of each species with a greater or lesser number of individuals in a phytocenosis is regulated by seasonal conditions (P  curar & Rotar, 2014). Both ecological and agronomic conditions make their mark on the



structure of the phytocenosis and influence each of them in a specific way. At the same time, the floristic structure can have indicative value for the intensity of ecological and agronomic factors. Even if in conservation and biological studies, most of the times, agronomic factors are either ignored or treated superficially and unprofessionally, they are the ones who contributed, sometimes even decisively, to the creation of semi-natural meadows and their maintenance. We must not forget the fact that most of the Romanian meadows are semi-natural and without human intervention they will be reforested, as is the case of quite large areas in successive stages (Păcurar & Rotar, 2014). In this project, several agronomic factors were treated, which were taken from German literature and adapted to the conditions of our country. The forage value of the species was classified in such a way as to facilitate the task of decision makers and to provide information at a glance at the spectrum. Regarding the data collection, two other vegetation study scales are proposed in the volume, because the Braun-Blanquet scale has a too high degree of approximation and which causes gross errors in establishing the agronomic value and not only. For the statistical processing and interpretation of phytocenosis data, an introduction is made in this field, which is very complex and requires special computer programs (Păcurar & Rotar, 2014). The evaluation of the anthropogenic influence on the meadow systems is not missing here, a particularly important indicator. Therefore, the study of grassland phytocenoses is plurivalent and requires an intense interdisciplinary collaboration with implications from quite diverse fields (Păcurar & Rotar, 2014).

### **3.1.2. Methodology for identification and characterization of the main grassland (existing vegetation):**

**The geobotanical or phytosociological method** is used both in the research carried out on the itinerary on large areas of grassland, and in the stationary works on smaller areas. The basis of this method is the phytocenological surveys (reliefs) which represent the floristic and seasonal description of the sample surfaces. The sampled data will be written in a special phytocenological file, in which will be entered both seasonal characterization data and vegetation appreciation, as follows:

- the current number of the survey, the name of the pasture body and of the locality (county, commune) within its radius;
- the surface of the survey;
- coordinates;
- the picture;
- altitude;
- exhibition;
- slope (degrees or percentages);
- the relief;
- characterization of the resort (type of soil, pseudogleization, erosion, salinization, etc.);
- general vegetation cover in percentages;
- the height and tier of the vegetation;
- observations on vegetation dynamics;
- green mass production and expected improvement measures;
- a soil sample will be collected and the genetic type will be described.
- *Poaceae*;
- *Fabaceae*;
- *Cyperaceae* and *Juncaceae*;
- species from other botanical families;

- mosses and lichens;
- goals etc.

Abundance-dominance is estimated using the Braun-Blanquet scale, as follows (Cristea *et al.*, 2004):

- r - one or several individuals;
- + - few individuals, with low coverage;
- 1 - quite abundant individuals, but with the degree of coverage below 1/20 of the sample area;
- 2 - very abundant individuals or at least 1/20 of the sample area;
- 3 - the coverage oscillates between ¼ and ½ of the surface, regardless of the number of individuals;
- 4 - coverage from ½ to ¾ of the sample area, regardless of the number of individuals;
- 5 - over coverage of the sample area, regardless of the number of individuals.

This system was modified and improved by Tüxen and Ellenberg (1937, cited by Cristea *et al.*, 2004) through a numerical transformation and a clear establishment of the appreciation intervals and the central value of abundance-dominance, however taking into account more much coverage (Trempe 2005; Sărățean 2011). A schematic representation is particularly useful in estimating abundance-dominance in the field (Figure 7.9).

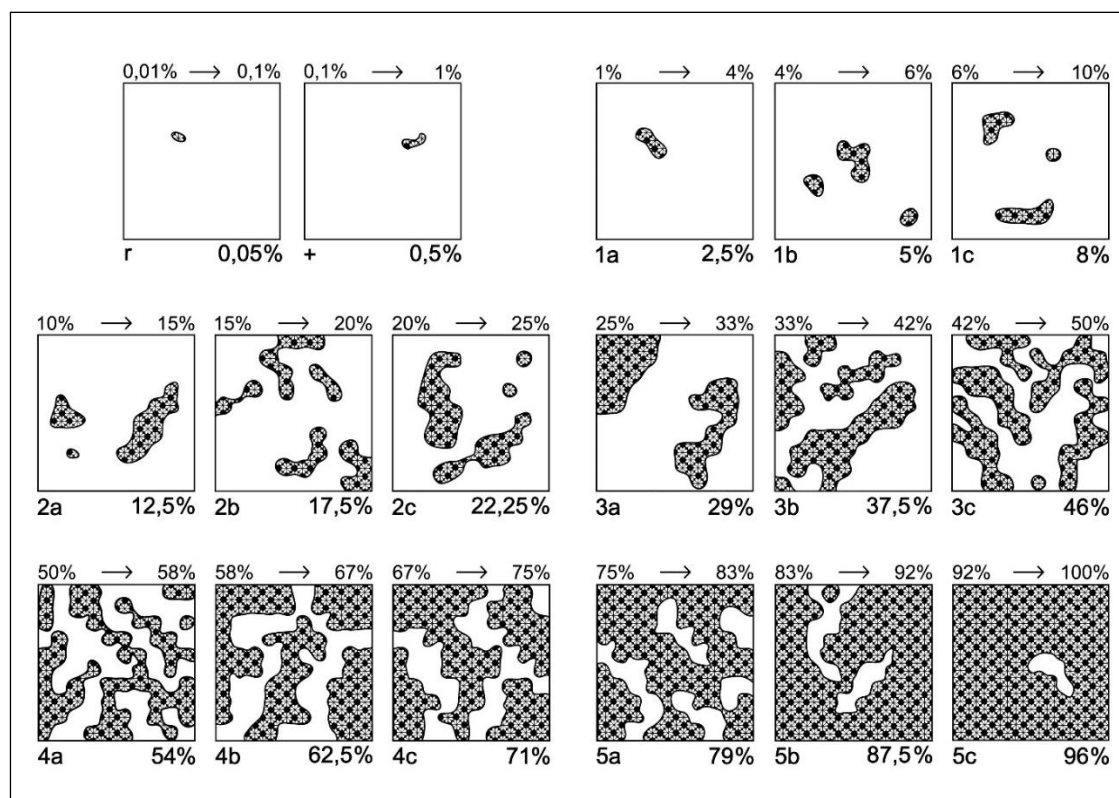


Fig. 7.9. Scheme for assessing abundance-dominance according to the Braun-Blanquet method, using three sub-notes

Table 7.41

The floristic composition was interpreted using an improved Braun-Blanquet scale with subdivisions (Păcurar & Rotar, 2014).

Note	Coverage range (%)	Central value of the class (%)	Sub-note	Sub-ranges (%)	Adjusted central values of the sub-range (%)
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<b>5</b>	75 – 100	87,5	5c	92 – 100	<b>96</b>
			5b	83 – 92	<b>87,5</b>
			5a	75 – 83	<b>79</b>
<b>4</b>	50 – 75	62,5	4c	67 – 75	<b>71</b>
			4b	58 – 67	<b>62,5</b>
			4a	50 – 58	<b>54</b>
<b>3</b>	25 – 50	37,5	3c	42 – 50	<b>46</b>
			3b	33 – 42	<b>37,5</b>
			3a	25 – 33	<b>29</b>
<b>2</b>	10 – 25	17,5	2c	20 – 25	<b>22,25</b>
			2b	15 – 20	<b>17,5</b>
			2a	10 – 15	<b>12,5</b>
<b>1</b>	1 – 10	5	1c	6 – 10	<b>8</b>
			1b	4 – 6	<b>5</b>
			1a	1 – 4	<b>2,5</b>
<b>+</b>	0,1 – 1	0,5	-	-	<b>0,5</b>
<b>r</b>	<b>0,01 – 0,1</b>	<b>0,05</b>	-	-	<b>0,05</b>

Sward fodder value was calculated based on species quality score on a scale from 1 (poor) to 9 (excellent), after Dierschke and Briemle (2002), as modified by Păcurar and Rotar (2014). Sward fodder value was performed on a scale from 1 (poor sward, quality dominated by toxic species) to 9 (excellent) after Păcurar and Rotar (2014). Data regarding the share of economic groups (Poaceae, Cyperaceae-Juncaceae, Fabaceae and other botanical families- OBF), species number will be process by analysis of variance. Plant resistance against interference mechanical, such as mowing, grazing and crushed materialized by value indicator (from 1-9) after Dierschke and Briemle (2002), and the names of appropriate species depending on the category disturbance were taken after Păcurar and Rotar (2014).

Table 7.42

*Plants' demand for soil's temperature*

(by ELLENBERG et al., 1992, modified by Păcurar & Rotar, 2014)

<b>Temperature index (T)</b>			
<b>Value</b>	<b>Prevalence</b>	<b>Observations</b>	<b>Name</b>
<b>1</b>	Species spread on very cold areas.	Species spread in arctic and alpine areas.	<b>cryophilic (hekistotherm)</b>
<b>2</b>	Species between 1 and 3	Species with transitional characters between value 1 and value 3.	<b>cryophilic (hekistotherm)</b>
<b>3</b>	Species spread in cool areas	Species spread in subalpine and mountainous areas.	<b>microtherme</b>
<b>4</b>	Species between 3 and 5	Species with transitional characters between value 3 and value 5.	<b>microtherm</b>
<b>5</b>	Species spread in temperate areas	Species spread in hilly and sub-mountainous areas.	<b>mesotherm</b>
<b>6</b>	Species between 5 and 7	Species with transitional characters between value 5 and value 7.	<b>mesotherm</b>
<b>7</b>	Species spread particularly in warm areas	Species spread in plains.	<b>thermophilous</b>
<b>8</b>	Species between 7 and 9	Species with transitional characters between value 7 and value 9.	<b>thermophilous</b>



9	Species spread in warm areas	Species spread in the Mediterranean and the hottest areas in Central Europe.	<b>megatherm</b>
x	<b>Indifferent species</b>	<b>Species with a wide range of tolerance for temperature called thermo-indifferent.</b>	<b>eurytherm</b>

Table 7.43

Plants' demand for soil's moistures

(by Ellenberg et al., 1992, modified by Păcurar & Rotar, 2014)

<b>The moisture index (Up)</b>			
<b>Value</b>	<b>Prevalence</b>	<b>Observations</b>	<b>Name</b>
<b>1</b>	Species spread on dry to dry-moist soils	Dry soils – the water is hardly available, close to the level of wither coefficient. Dry-moist soils – the water is hardly available and it represents 5-10% of the RAH	<b>xerophiles</b>
<b>2</b>	Species between 1 and 3	Species with transitional characters between value 1 and value 3.	<b>xerophiles</b>
<b>3</b>	Species spread on dry-moist to moist soils	Moist soils – the water is hardly available, approximately 20 % from RAH.	<b>mesoxerophiles</b>
<b>4</b>	Species between 3 and 5	Species with transitional characters between value 3 and value 5.	<b>e mesoxerophiles</b>
<b>5</b>	Species spread on moist to moist-damp soils	Moist-damp soils –water is medium available, approximately 50 % of the RAH.	<b>mesophytes</b>
<b>6</b>	Species between 5 and 7	Species with transitional characters between value 5 and value 7.	<b>mesophytes</b>
<b>7</b>	Species spread on moist-damp to damp-humid	Damp soils – the water is easy available, approximately 75 % of the RAH.	<b>mesohygrophylic</b>
<b>8</b>	Species between 7 and 9	Species with transitional characters between value 7 and value 9.	<b>mesohygrophilic</b>
<b>9</b>	Species spread on damp-humid to humid-wet soils	Damp-humid soils - the water is easy available at field capacity level.	<b>hydrophytes</b>
<b>x</b>	<b>Indifferent species</b>	<b>Species with a wide range of tolerance for the humidity regime which often is alternating.</b>	<b>euryecious</b>

Table 7.44

Plants' demand for soil's reaction

(by Ellenberg et al., 1992, modified by Păcurar & Rotar, 2014)

<b>The soil pH index (Rp)</b>			
<b>Value</b>	<b>Prevalence</b>	<b>Observations</b>	<b>Name</b>
<b>1</b>	Species spread on	pH below 4	<b>strongly acidophilous</b>

	extremely acid soils		(extremely)
<b>2</b>	Species spread on very strongly acid soils	pH between 4 – 4.5	<b>strongly acidophilous</b>
<b>3</b>	Species spread on strongly acid soils	pH between 4.5 – 5	<b>moderate acidophilous</b>
<b>4</b>	Species spread on acid soils	PH between 5 – 5.5.	<b>moderate acidophilous</b>
<b>5</b>	Species spread on moderate acid soils	pH between 5.5 – 6	<b>lightly acidophilous</b>
<b>6</b>	Species spread on lightly acid soils	pH between 6 – 6.8	<b>lightly acidophilous</b>
<b>7</b>	Species spread on neutral soils	pH between 6.8 – 7.2	<b>neutrophilous</b>
<b>8</b>	Species spread on lightly alkaline soils	pH between 7.2 – 8.4	<b>alkaliphile (lightly)</b>
<b>9</b>	Species spread on alkaline soils	pH over 8.4	<b>alkaliphile</b>
<b>x</b>	<b>Indifferent species</b>	<b>Species with a wide range of tolerance for soil's pH.</b>	<b>euryacidophilous</b>

Table 7.45

Plants' demand for soil's nitrogen

(by Ellenberg et al., 1992, modified by Păcurar & Rotar, 2014)

<b>The nitrogen index (Np)</b>			
<b>Value</b>	<b>Prevalence</b>	<b>Observations</b>	<b>Name</b>
<b>1</b>	Species spread on very poorly supplied soils	The nitrogen content is below 50 mg/100g of soil.	<b>nitrophobic</b>
<b>2</b>	Species between 1 and 3	Species with transitional characters between value 1 and value 3.	<b>nitrophobic</b>
<b>3</b>	Species spread on poorly supplied soils	The nitrogen content is comprised between 50 and 100 mg/100 g of soil.	<b>moderate nitrophilous</b>
<b>4</b>	Species between 3 and 5	Species with transitional characters between value 3 and value 5.	<b>moderate nitrophilous</b>
<b>5</b>	Species spread on moderate supplied soils	The nitrogen content is comprised between 100 and 150 mg /100 g of soil.	<b>medium nitrophilous</b>
<b>6</b>	Species between 5 and 7	Species with transitional characters between value 5 and value 7.	<b>medium nitrophilous</b>
<b>7</b>	Species spread on well supplied (rich) soils	The nitrogen content is comprised between 150 and 200 mg/100 g of soil.	<b>nitrophilous</b>
<b>8</b>	Species between 7 and 9	Species with transitional characters between value 7 and value 9.	<b>nitrophilous</b>
<b>9</b>	Species spread on over fertilized soils	The nitrogen content is over 200 mg/100 g of soil.	<b>extremely nitrophilous</b>
<b>X</b>	<b>Indifferent species</b>	<b>Species with a wide range of tolerance for soil's nitrogen supply.</b>	<b>eurytnitrophilous</b>

Table 7.46

*Plants' resistance to mowing (Mp)*

(by Dierschke & Briemle, 2002, modified by Păcurar & Rotar, 2014)

Value	Observations	Stand	No. of cuts	Harness	Name
1	Plants that cannot undergo mowing	Old fallow land, hay meadows exploited late, forests limits, dense herbs	0	The resulted material after mowing cannot be used as fodder	<b>sensitive (extremely)</b>
2	Plants between 1 and 3		1		<b>sensitive</b>
3	Plants sensitive to mowing (undergo only the autumn cut)		1		<b>medium sensitive (tolerante)</b>
4	Plants between 3 and 5	Meadows exploited extensively to medium intensive	1-2	The material resulted can be used as fodder	<b>medium sensitive (tolerante)</b>
5	Plants that medium undergo mowing (the first cut must not be taken before the 1 <sup>st</sup> of July)		2		<b>medium resistant</b>
6	Plants between 5 and 7 (the first cut must not be taken before the middle of July)		2-3		<b>medium resistant</b>
7	Plants that undergo well mowing	Intensive meadows and turf	3-4	The resulted material can be used as fodder	<b>resistant</b>
8	Plants between 7 and 9		4-6		<b>resistant</b>
9	<b>Plants very resilient to mowing (they have a great competitiveness capacity only when several cuts are made and are often stepped on)</b>		>6		<b>extremely resistant</b>

Table 7.47

*Plants' resistance to grazing (Gp)*

(by Dierschke & Briemle, 2002, modified by Păcurar & Rotar, 2014)

Value	Observations	Grazing cycles	Grazing intensity, effect upon species composition	The grazing type	Name
1	Plants that do not stand grazing	0 to 1 or once at two years	Species composition unsuitable for grazing or suitable for an extensive grazing.	Grazing with sheep at well-established moments or a rational grazing could be performed, but in a short period of time	<b>sensitive (extremely)</b>
2	Plants between 1 and 3	0 to 1 or once at two years	Species composition medium suitable for grazing	-	<b>sensitive</b>
3	Plants sensitive to grazing	1	Species composition suitable for grazing	-	<b>medium sensitive (tolerant)</b>

<b>4</b>	Plants between 3 and 5	1-2	During grazing the plants are partially consumed	Extensive pastures	<b>medium sensitive (tolerant)</b>
<b>5</b>	Plants medium resistant to grazing	2	During grazing the plants are partially consumed	Extensive pastures	<b>medium resistant</b>
<b>6</b>	Plants between 3 and 5	2-3	During grazing the entire plant is consumed	Pastures with dosed system	<b>medium resistant</b>
<b>7</b>	Plants resistant to grazing	3	During grazing the useful parts of the plants are frequently and more often consumed	Pastures with dosed system	<b>resistant</b>
<b>8</b>	Plants between 3 and 5	3-4	During grazing the useful parts of the plants are frequently and more often consumed	Intensive pastures	<b>resistant</b>
<b>9</b>	<b>Plants extremely resistant to grazing</b>	<b>&gt;4</b>	<b>During grazing the useful parts of the plants are frequently and more often consumed</b>	<b>Intensive pastures and pastures with portion</b>	<b>extremely resistant</b>

Table 7.48

*Plants' resistance to crushed (Sp)*

*(by Dierschke & Briemle, 2002, modified by Păcurar & Rotar, 2014)*

<b>Value</b>	<b>Observations</b>	<b>Grassland type</b>	<b>Trampling frequency</b>	<b>Name</b>
<b>1</b>	Plants that do not stand stepping	Hay meadows with tall species, forests limits, fallow land, irregularly used pastures, afforested pastures	Stepping does not take place or happens only irregularly. It can stand 1-2 stepping (grazing or passing through with agricultural machines) during the vegetation season.	<b>sensitive (extremely)</b>
<b>2</b>	Plants between 1 and 3			<b>sensitive</b>
<b>3</b>	Plants sensitive to stepping; tall grasses and medium height species of OBF			<b>medium sensitive (tolerant)</b>
<b>4</b>	Plants between 3 and 5	Pastures used in free system, pastures in rational system, intensive hay meadows, combined (mixed) grasslands and paths.	Plants frequently stepped during the vegetation by animals or cars	<b>medium sensitive (tolerant)</b>
<b>5</b>	Plants medium resistant to trample: grasses of medium height and plants which develop aerial stolons and species with rosettes, as well as species that can stand ramed soils			<b>medium resistant</b>

6	Plants between 5 and 7			medium resistant
7	Plants resistant to trample: short grasses, short OBF and aerial stolons plants	Pastures in dosed system or grazing by the portion or herbs which grow on roads, un-asphalted or unpaved parkings, golf areas, space between pave rocks	Plants continuously stepped during the vegetation period, every day or every hour, by animals or agricultural or road machines	resistant
8	Plants between 7 and 9			resistant
9	<b>Plants extremely resistant to stepping, only by trampling they become competitive, plants of small height or with rosettes</b>			<b>extremely resistant</b>

Table 7.49

*Agronomic categories and fodder value (after Briemle, 1996, modified and adapted to Romanian conditions)*

Feed value index		
The value index	Characteristics	The name of the agronomic category
1	Toxic plants for animals (and humans)	<b>Non-fodder species (toxic species)</b>
2	Plants without fodder value which in one way or another depreciates the quality of the animal product	<b>Species without fodder value (species harmful to animal products)</b>
3	Plants with a low forage value that in one way or another depreciates the quality of the plant carpet. This includes semi-parasitic and parasitic species.	<b>Low-forage species (species harmful to grassland vegetation)</b>
4	Plants with low fodder value not consumed by animals or consumed to a lesser extent	<b>Low forage species (unconsumed or ballast species)</b>
5	Plants with an average fodder value	<b>Average forage species</b>
6	Species with transition characters between 5 and 7	<b>Medium feed species</b>
7	Plants with high fodder value	<b>Good forage species</b>
8	Species with transition characters between 7 and 9	<b>Good forage species</b>
9	Plants with excellent fodder value	<b>Excellent forage species</b>
x	<b>Plants of unknown forage value</b>	<b>Species of unknown forage value</b>

Agro-biological table of grassland species (after Ellenberg, 1992; Boşcaiu *et al.*, 1994; Dierschke & Briemle, 2002; Klotz & Kühn, 2002; Sanda *et al.*, 2004; Dihoru & Negrean, 2009 [www.floraweb.de](http://www.floraweb.de) modified):

- Bp - bioform
- H - hemicryptophyte
- HT - shrub plants
- HR - rosette plants
- HRs - semi-rosette plants
- HS - stoloniferous plants
- HA - hanging plants

The bioforms below will be subdivided exactly as in H

- Hy - hydrophyte
- G - geophyte
- T - therophyte
- Ch - herbaceous camephyte
- ChL - woody camelids
- Ph - phanerophyte
- Phn - nanophanerophyte
- PhM - megaphanerophyte

SO - the sociological index

- 1 = endangered species
- 2 = vulnerable species
- 3 = rare species
- 4 = endangered species in Europe
- n = non-threatened species

H - hemerobia index

- 1 = ahemerobe
- 2 = oligohemerobe
- 3 = mesohemerobe
- 4 = beta-euhemerobe
- 5 = alpha-euhemerobe
- 6 = polyhemerobic
- 7 = metahemerobe

UR - urbanophilia index

- 1 = urbanophobic
- 2 = moderately urbanophobic
- 3 = urbanoneutral
- 4 = moderately urbanophile
- 5 = urbanophile

## 3.2. Results regarding vegetation

### 3.2.1. Pilot site 1. Romplumb

Gps Coordinate: (N - 47°41'19.5", E - 23°37'41.6")

Surface area: 1.25 ha

Location: near Romplumb, in the Ferneziu district.

Access: To reach this location we have to go on "Barajului Str." which is the continuation of "8 Martie Str." On the left-hand side, we pass the property of the old Romplumb Company. Site location is just a few meters further on the right-hand side.

Contamination: historical pollution from the major polluter in the area: Romplumb.

**Vegetation:** There were planted hundreds of trees a few years ago. Now, there are only a few trees alive because they haven't been watered properly. The field was polluted by the Romplumb Company but it hasn't been covered by a slag (clinker) layer. This field is situated right before the woodworking company (GATER) so the "Gater area" is very close to this field.

Table 7.50

Floristic composition of the grassland and specific requirement on ecological, agronomic and anthropogenic (Bp - BioForm, T - temperature, Up - humidity, Rp - soil reaction, Np - nutrition, Cp - tolerance of mowing, Pp - tolerance of grazing, Sp - tolerance of crushed, VF- fodder value, Hp - hemeroby, UR - urbanophile, SOp - sozological category)

Ecological indexes					Agronomical indexes				Anthropogenic indexes			Stand conditions
Bp	T	Up	Rp	Np	Cp	Pp	Sp	VF	SOp	Hp	UR	SPECIES
HT	x	x	x	4	6	5	5	6	n	2-4	3	<i>Agrostis capillaris</i>
TT	6	x	5	3	6	4	5	4	n	4-6	3	<i>Bromus squarosus</i>
HT	x	5	x	6	8	4	6	9	n	3-4	3	<i>Dactylis glomerata</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Elymus elongatus</i>
HT	x	5	x	x	9	8	8	8	n	3-5	3	<i>Poa pratensis</i>
-	-	-	-	-	-	-	-	-	-	-	-	POACEAE
-	-	-	-	-	-	-	-	-	-	-	-	CYPERACEAE-JUNCACEAE
HS	5	4	8	x	7	4	6	8	n	3-5	3	<i>Medicago lupulina</i>
HT	7	3	8	x	6	2	2	8	n	3-4	1	<i>Onobrychis viciifolia</i>
H	7	4	6	3	4	4	4	6	n	2-3	1	<i>Trifolium medium</i>
HT	x	x	x	6	7	4	4	8	n	3-4	2	<i>Trifolium pratense</i>
ChR <sub>s</sub>	x	x	x	6	8	8	8	8	n	3-5	3	<i>Trifolium repens</i>
TA	5	x	x	6	6	1	1	7	n	3-5	2	<i>Vicia angustifolia</i>
-	-	-	-	-	-	-	-	-	-	-	-	FABACEAE
ChR <sub>s</sub>	x	4	x	5	7	4	5	6	n	2-4	3	<i>Achillea millefolium</i>
TT	5	3	x	8	3	7	3	2	n	3-5	3	<i>Carduus acanthoides</i>
H	x	4	7	3	-	-	-	4	n	2-3	1	<i>Clinopodium vulgare</i>
HRs	6	4	8	5	4	5	5	5	n	3-5	3	<i>Cichorium intybus</i>
HRs	5	5	6	5	6	2	2	4	n	3-4	3	<i>Crepis biennis</i>
HRs	6	4	x	4	6	3	4	5	n	3-5	3	<i>Daucus carota</i>
H	6	6	8	7	5	7	3	2	n	4-6	3	<i>Dipsacus fullonum</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Erodium hoefftianum</i>
H	7	3	8	4	2	4	3	2	n	2-4	2	<i>Eryngium campestre</i>
HT	5	4	7	3	5	4	4	5	n	2-3	2	<i>Galium verum</i>
HRs	6	6	x	5	4	3	3	4	n	2-3	1	<i>Inula britannica</i>
HR	x	5	x	5	7	7	7	5	n	3-4	3	<i>Leontodon autumnalis</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Papaver rhoeas</i>
HRs	x	4	8	4	5	4	2	4	n	2-5	2	<i>Picris hieracioides</i>
HRs	-	8	7	6	3	2	2	4	n	2-3	1	<i>Pseudolysimachion longifolium</i>
HR	x	5	x	6	8	7	7	7	n	3-5	3	<i>Taraxacum officinale</i>



TT	7	5	7	6	2	-	8	2	n	5-6	-	<i>Xanthium strumarium</i>
												<i>Reynoutria japonica</i>
												<i>Robinia pseudoacacia</i>
												<i>Myschanthus gygantheus</i>
												<i>Pinus silvestris</i>
												<i>Populus tremula</i>
-	-	-	-	-	-	-	-	-	-	-	-	OBf
												Number of species



Fig. 7.10. Pilot site 1 - Romplumb

### 3.2.2. Pilot site 2. Ferneziu

Gps Coordinate: (N - 47°40'34.5" , E - 23°37'23.2")

Surface area: 0.8 ha

Location: near the school fence, in the Ferneziu district.

Access: To reach this location we have to go on "Barajului Str." and then to turn right on "ARENEI Str." These 2 fields are situated on both sides of the school. To step on these fields, we have to cross over the old railways.



*Fig. 7.11. Pilot site 2 - Ferneziu 1*

**Pollution:** being located lower (some hundreds meters away from Romplumb) and affected by the airflow which is going down towards the city, the pollution is a little bit lower than at Romplumb area but higher than at Gater area.

**Vegetation:** The field is just right, very even, covered by small spontaneously grown vegetation.

Table 7.51

Floristic composition of the grassland and specific requirement on ecological, agronomic and anthropogenic (Bp - BioForm, T - temperature, Up - humidity, Rp - soil reaction, Np - nutrition, Cp - tolerance of mowing, Pp- tolerance of grazing, Sp - tolerance of crushed, VF- fodder value, Hp - hemeroby, UR - urbanophile, SOp - sozological category)

Ecological indexes					Agronomical indexes				Anthropogenic indexes			Stand conditions
Bp	T	Up	Rp	Np	Cp	Pp	Sp	VF	SOp	Hp	UR	SPECIES
HT	x	x	x	4	6	5	5	6	n	2-4	3	<i>Agrostis capillaris</i>
TT	6	x	5	3	6	4	5	4	n	4-6	3	<i>Bromus squarrosus</i>
HT	x	5	x	6	8	4	6	9	n	3-4	3	<i>Dactylis glomerata</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Elymus elongatus</i>
HT	x	5	x	x	9	8	8	8	n	3-5	3	<i>Poa pratensis</i>
-	-	-	-	-	-	-	-	-	-	-	-	POACEAE
-	-	-	-	-	-	-	-	-	-	-	-	CYPERACEAE- JUNCACEAE
HS	5	4	8	x	7	4	6	8	n	3-5	3	<i>Medicago lupulina</i>
ChRs	x	x	x	6	8	8	8	8	n	3-5	3	<i>Trifolium repens</i>
-	-	-	-	-	-	-	-	-	-	-	-	FABACEAE
ChRs	x	4	x	5	7	4	5	6	n	2-4	3	<i>Achillea millefolium</i>
GRs	x	6	x	x	5	7	6	1	n	3-6	3	<i>Equisetum arvense</i>
HRs	x	5	x	8	7	3	3	5	n	3-6	3	<i>Anthriscus sylvestris</i>
HRs	5	x	x	7	7	7	3	4	n	3-4	3	<i>Rumex obtusifolius</i>
HRs	x	5	x	6	4	8	2	5	n	3-5	3	<i>Urtica dioica</i>
HT	5	x	x	6	4	2	2	4	n	2-3	1	<i>Viola canina</i>
												<i>Reynoutria japonica</i>
												<i>Robinia pseudoacacia</i>
												<i>Myschanthus gygantheus</i>
-	-	-	-	-	-	-	-	-	-	-	-	OBF
												Number of species

### 3.2.3. Pilot site 3. Colonia Topitorilor

Gps Coordinate: (N - 47°40'02.6" , E - 23°36'21.4")

Surface area: 1.5 ha

Location: in full neighborhood (Ferneziiu).

Access: To reach this location we have to go on "8 Martie Str." and then take a left onto "Colonia Topitorilor Str." The field is on the left hand side.

Vegetation: The field is even, covered by small and medium spontaneously grown vegetation.

Table 7.52

Floristic composition of the grassland and specific requirement on ecological, agronomic and anthropogenic (Bp - BioForm, T - temperature, Up - humidity, Rp - soil reaction, Np - nutrition, Cp - tolerance of mowing, Pp- tolerance of grazing, Sp - tolerance of crushed, VF- fodder value, Hp - hemeroby, UR - urbanophile, SOp - sozological category)

Ecological indexes					Agronomical indexes				Anthropogenic indexes			Stand conditions
Bp	T	Up	Rp	Np	Cp	Pp	Sp	VF	SOp	Hp	UR	SPECIES
HT	x	x	x	4	6	5	5	6	n	2-4	3	<i>Agrostis capillaris</i>
TT	6	x	5	3	6	4	5	4	n	4-6	3	<i>Bromus squarrosus</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Elymus elongatus</i>
HT	5	7	7	4	7	6	7	7	n	3	1	<i>Festuca arundinaceae</i>
-	-	-	-	-	-	-	-	-	-	-	-	POACEAE
-	-	-	-	-	-	-	-	-	-	-	-	CYPERACEAE- JUNCACEAE
HT	x	4	7	4	6	4	4	7	n	2-4	3	<i>Lotus corniculatus</i>
HS	5	4	8	x	7	4	6	8	n	3-5	3	<i>Medicago lupulina</i>
H	7	4	6	3	4	4	4	6	n	2-3	1	<i>Trifolium medium</i>
HT	x	x	x	6	7	4	4	8	n	3-4	2	<i>Trifolium pratense</i>
TA	5	x	x	6	6	1	1	7	n	3-5	2	<i>Vicia angustifolia</i>
-	-	-	-	-	-	-	-	-	-	-	-	FABACEAE
ChRs	x	4	x	5	7	4	5	6	n	2-4	3	<i>Achillea millefolium</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Anthemis cotula</i>
TT	5	3	x	8	3	7	3	2	n	3-5	3	<i>Carduus acanthoides</i>
HRs	5	5	6	5	6	2	2	4	n	3-4	3	<i>Crepis biennis</i>
HRs	6	4	x	4	6	3	4	5	n	3-5	3	<i>Daucus carota</i>
H	6	6	8	7	5	7	3	2	n	4-6	3	<i>Dipsacus fullonum</i>
												<i>Echium vulgare</i>
H	7	3	8	4	2	4	3	2	n	2-4	2	<i>Eryngium campestre</i>
GRs	x	6	x	x	5	7	6	1	n	3-6	3	<i>Equisetum arvense</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Papaver rhoeas</i>
H	4	7	5	5	6	4	5	4	n	3-4	2	<i>Polygonum bistorta</i>
HR	x	5	x	5	7	7	7	5	n	3-4	3	<i>Leontodon autumnalis</i>
HR	x	4	8	3	4	8	8	5	n	2-4	2	<i>Plantago media</i>
HS	x	x	4	x	9	8	8	4	n	3-4	2	<i>Prunella vulgaris</i>
HRs	5	x	x	7	7	7	3	4	n	3-4	3	<i>Rumex obtusifolius</i>
HS	x	4	4	x	4	5	5	1	n	2-4	2	<i>Stelaria graminea</i>
HR	x	5	x	6	8	7	7	7	n	3-5	3	<i>Taraxacum officinale</i>
												<i>Reynoutria japonica</i>
												<i>Robinia pseudoacacia</i>
												<i>Mysanthus gygantheus</i>
												<i>Crataegus monogyna</i>
-	-	-	-	-	-	-	-	-	-	-	-	OBF
Number of species												



Pollution: being located lower from Romplumb and in the airflow which is going down towards the city, the pollution is a little bit lower than at Ferneziu Upper as considered lead. But this area was also under the influence from Cuprom, so it is polluted with copper and zinc.



Fig. 7.12. Pilot site 3 - Colonia Topitorilor

### 3.2.4. Pilot site 4. Urbis

Gps Coordinate: (N - 47°39'49.3", E - 23°36'24.5")

Surface area: 0.75 ha

Location: near Local Police Station.

Access: To reach this location we have to go on "8 Martie Str". On the right, immediately after the Local Police Station, we see the property of the URBIS ("The Public Transport Company") where they do some car technical inspections. There is a possibility to create the access to our site from the Urbis property because our field is separated by them through a fence of concrete slabs but there is also a gate behind the local police allowing the entrance at the start of the area.

Vegetation: The terrain is fairly even, except that portion close to the river-bank where the inclination is visible. It is covered by small and medium spontaneously grown vegetation on almost all the surface. Towards the river-bank you can see bigger trees and taller vegetation.

Table 7.53

Floristic composition of the grassland and specific requirement on ecological, agronomic and anthropogenic (Bp - BioForm, T - temperature, Up - humidity, Rp - soil reaction, Np - nutrition, Cp - tolerance of mowing, Pp - tolerance of grazing, Sp - tolerance of crushed, VF- fodder value, Hp - hemeroby, UR - urbanophile, SOp - sozological category)

Ecological indexes					Agronomical indexes				Anthropogenic indexes			Stand conditions
Bp	T	U p	R p	N p	Cp	Pp	Sp	VF	SOp	Hp	UR	SPECIES
ChR s	x	x	x	6	8	8	8	8	n	3-5	3	<i>Trifolium repens</i>
												<i>Reynoutria japonica</i>
												<i>Robinia pseudoacacia</i>
												<i>Myschanthus gygantheus</i>

-	-	-	-	-	-	-	-	-	-	-	-	OBF
												Number of species

Pollution: similar as Topitorilor area (combined air pollution from the 2 major polluters in the area: Romplumb and Cuprom).



Fig. 7.13. Pilot site 4 - Urbis

### 3.2.5. Pilot site 5. Craica

- contaminated with copper and zinc

PLOT 1 : Gps Coordinate: (N - 47°38'18.5" , E - 23°34'06.6")

PLOT 2 : Gps Coordinate: (N - 47°38'18.6" , E - 23°34'12.1")

Surface area: 3 ha

Location: in the largest neighborhood of the city, Alecsandri.

Access: To reach this location we have to go on "Bulevardul Unirii" Str., towards "Italsofa" (a big sofas manufacturer). After we exit the city, right after the roundabout (the intersection with Granicerilor Str.) we can see the train railways. The access to our terrain is right before the railways, making a left turn. This land is the demarcation line between the residential area and the industrial area and was polluted from Cuprom.

Vegetation: The field is more than 90% very even, with a small inclination to the "Craica River". The spontaneously grown vegetation has small dimensions but there are a few bigger trees, also. Closer to the river banks we have medium size dry vegetation.

Table 7.54

Floristic composition of the grassland and specific requirement on ecological, agronomic and anthropogenic (Bp - BioForm, T - temperature, Up - humidity, Rp - soil reaction, Np - nutrition, Cp - tolerance of mowing, Pp - tolerance of grazing, Sp - tolerance of crushed, VF - fodder value, Hp - hemeroby, UR - urbanophile, SOp - sozological category)

Ecological indexes					Agronomical indexes				Anthropogenic indexes			Stand conditions
Bp	T	U	R	N	Cp	Pp	Sp	VF	SOp	Hp	UR	SPECIES

		p	p	p								
HT	x	x	x	4	6	5	5	6	n	2-4	3	<i>Agrostis capillaris</i>
												<i>Arrhenatherum elatius</i>
TT	6	x	5	3	6	4	5	4	n	4-6	3	<i>Bromus squarrosus</i>
-	-	-	-	-	-	-	-	-	-	-	-	<i>Elymus elongatus</i>
HT	x	6	x	6	6	4	6	9	n	2-4	2	<i>Festuca pratensis</i>
HT	x	5	x	x	9	8	8	8	n	3 - 5	3	<i>Poa pratensis</i>
-	-	-	-	-	-	-	-	-	-	-	-	POACEAE
HT	5	7	4	4	4	7	6	3	n	2-4	2	<i>Juncus effusus</i>
-	-	-	-	-	-	-	-	-	-	-	-	CYPERACEAE- JUNCACEAE
HT	x	x	x	6	7	4	4	8	n	3-4	2	<i>Trifolium pratense</i>
ChR s	x	x	x	6	8	8	8	8	n	3-5	3	<i>Trifolium repens</i>
TA	5	x	x	6	6	1	1	7	n	3-5	2	<i>Vicia angustifolia</i>
-	-	-	-	-	-	-	-	-	-	-	-	FABACEAE
ChR s	x	4	x	5	7	4	5	6	n	2-4	3	<i>Achillea millefolium</i>
HT	x	5	x	5	8	4	4	4	n	3-5	3	<i>Cerastium holsteoides</i>
TT	5	3	x	8	3	7	3	2	n	3-5	3	<i>Carduus acanthoides</i>
HRs	5	5	6	5	6	2	2	4	n	3-4	3	<i>Crepis biennis</i>
HRs	6	4	x	4	6	3	4	5	n	3-5	3	<i>Daucus carota</i>
H	7	3	8	4	2	4	3	2	n	2-4	2	<i>Eryngium campestre</i>
HR	x	5	x	5	7	7	7	5	n	3-4	3	<i>Leontodon autumnalis</i>
HR	x	4	8	3	4	8	8	5	n	2-4	2	<i>Plantago media</i>
HS	x	4	4	x	4	5	5	1	n	2-4	2	<i>Stelaria graminea</i>
HR	x	5	x	6	8	7	7	7	n	3-5	3	<i>Taraxacum officinale</i>
H	6	4	8	6	3	2	3	1	n	3 - 4	2	<i>Verbascum phlomoides</i>
												<i>Reynoutria japonica</i>
												<i>Robinia pseudoacacia</i>
												<i>Myschanthus gygantheus</i>
												<i>Crataegus monogyna</i>
GRs	5	10	7	5	3	3	2	3	n	2-4	2	<i>Phragmites australis</i>
												<i>Typha latifolia</i>
-	-	-	-	-	-	-	-	-	-	-	-	OBF
Number of species												





Fig. 7.14. Pilot site 5 - Craica

## Conclusions

Given the level of pollution with heavy metals such as: Cu, Pb, Cd and Zn, phytoremediation is necessary.

The choice of species will be made according to the interest of those who manage the surfaces, namely:

**Energy species (*Salix spp.*).** It could be promoted and extended the use of plants that were researched and were proved to have bioremediation capacity; however, their utilization and integration in landscaping, the aspects regarding maintenance and requirements impose the assistance with a speciality data base for the company interested in extending its assortment.

**Decorative species (*Iris pseudocorus*).** Several ornamental plants exhibit capacity to depollute the environment, fact attested by the results of scientific research on the topic.

**Wood selections** that extract variable amounts of heavy metals but also fix the soil through the depth of the root system: *willow*, *poplar*, etc.

**Species whose area proves to be adapted to local pedoclimatic conditions – *Miscanthus spp.*** and which can be used, concomitantly with the capitalization of the lands there is the possibility of diminishing in time the Content in heavy metal.

Diversification and promotion of the assortment of species with phytoremediation capacity and reduction of pollution from the urban external environment and the import of those with real chances of cultivation in the urban climate of Romania in order to be traded.

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