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Preliminary assessment of the vulnerabilities in urban ecosystems as a result of climate change effects. Case studies.

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Abstract
The current context of the increasing manifestation of climate change in the form of extreme weather phenomena prioritizes efforts to find solutions as quickly as possible to ensure adaptation to these new conditions and to achieve climate resilience. The phenomena are problematic, they usually cause much material damage, and therefore knowing the particularities of each urban or peri-urban environment where they occur can ensure the finding of viable and sustainable solutions in the long term. The current knowledge of the phenomena related to pollution and the variation of some climatic parameters, such as temperature and humidity, can bring valuable information for understanding the phenomena that appear against the background of the manifestation of climatic changes in urban environments and those adjacent to them. The analysis presented in this article refers to three cities in Romania, analyzed as case studies, for understanding climatic vulnerabilities in parallel with a quantification of the quality of environmental factors, in an integrated air, water, and soil approach. In these areas, the manifestation of natural factors, together with the anthropic footprint, particularly more evident in the urban environment, offers the possibility of an objective, quantifiable evaluation of the studied areas. The proposed comparisons will allow highlighting the vulnerabilities together with the zonal variability that is the basis of the influencing factors, as well as the way in which the quality of the monitored parameters will evolve in space and time.

Keywords: *climate changes, adaptation, urban environment*

INTRODUCTION
Urban agglomerations viewed from the perspective of climate change present an increased thermal stress, the urban heat island effect. Another manifestation of meteorological phenomena attributed to climate change are those of risk, such as disturbances related to precipitation that are either absent for long periods of time and determine a deficient water regime for the soil, or as large amounts in very short periods of time causing floods [1]. In the urban environment, large amounts of precipitation only to a small extent infiltrate rates into the unsaturated zone, most of it drains under the effect of gravity. Where the slopes have higher values, major risk phenomena also occur as a rule, because floods can form that lead to important damages. The facilities of the urban infrastructure for collecting, storing and directing rainwater are either deficient, due to a reduced dimensions in relation to the amounts of rainwater that fall in short periods of time, or are missing in many situations [2]. A beneficial approach to urban areas would be that of green spaces. They help reduce flooding during periods of intense rainfall by facilitating faster infiltration of water into the soil, mitigating the surface runoff of rainwater, reducing air pollution and moderating thermal stress.

The implementation in the urban environment of solutions such as green roofs and walls of the buildings are solutions based on reducing the scale of the solutions offered by nature. Here we can mention: the development of national networks of natural parks and urban forests; the creation of "green-blue" corridors in large cities that are crossed by watercourses, the construction of urban and rural wetlands as a solution for the biological purification of wastewater, the maintenance of natural habitats and biodiversity, adaptation to heat wave episodes [3].

A particularly important aspect is the assessment of vulnerabilities, a key aspect of identifying the potential impact of climate change today, in order to be able to plan future developments in a sustainable environment [4].

Specialists' estimates lead to a possible increase in precipitation in Europe, with a direct consequence in terms of soil erosion, but at the same time the effects of thermal heating overlap, which would lead to a better vegetative cover in these conditions [5,6]. Well highlighted is the role of protected areas, such as those in the Natura 2000 network, which play a major role in protecting biodiversity [7÷10]. However, in the conditions of global temperature increases of over 4^0C, the estimate regarding the loss of terrestrial species from these protected areas, would exceed 60% [11÷15]. Among the long-term strategies are mentioned the rehabilitation of abandoned agricultural lands for the conservation of biodiversity. Rehabilitation strategies of specific sectors (such as peat bog) can also be taken into account, but the most important are actions to support species resistant to climate change, the functional diversity of habitats, going as far as assisting of some species migration and increasing capacity to adaptation [16]. The restoration and creation of ecosystems represent adaptation measures that build climate resilience and ensure to a large extent the synergies necessary for climate adaptation and mitigation in other sectors [17]. In addition, the growth of wetlands in the urban environment, tree planting can works as part of a functional flood management [18]. A well-developed green infrastructure in the urban environment can successfully mitigate floods and thermal stress [19]. Improving thermal comfort is one of the important objectives aimed at the urban environment, respective for adaptive planning for climate resilience, but green spaces are reduced by covering land for urban development, which produces an impermeability of soils, and an additional contribution comes from the manifestation of drought [20]. The cooling effect due to green spaces in the urban environment is determined and influenced by the heterogeneity at landscape level and positively by the composition, size and structure of green spaces [21].The presence of natural landscapes around cities can make a major contribution to the cooling effect inside the urban environment, to which can be added local meteorological factors, respectively atmospheric air circulation [22].

To investigate the vulnerability of urban ecosystems, soil, air, and water quality were monitored in three municipalities in Romania (Tulcea, Galati, and Ploiesti). A sensor system was implemented in each location to monitor air temperature, pressure, humidity, soil temperature, and humidity, the measured data were automatically transmitted to a dedicated cloud platform and periodically reported.

MATERIALS AND METHODS

Studied area

The research performed was related with the documentation and preliminary development of the experimental field in order to assess the relevant environmental aspects in three urban areas. The climatic relevance was followed in relation to the specifics of the studied areas, the approach was focused on the air-soil-water environmental factors. The location of the cities involved in the climate study are Ploiesti, Galati and Tulcea and can be seen in figure 1.

Tulcea is the seat of the 4th largest county in the country, it is located in the South-East Development Region of Romania, in the northern extremity of Dobrogea, on the right bank of the Danube. The city has the shape of amphitheater, is surrounded by hills and open to the north towards the Danube Delta.

Galati is the seat of the county of Galaţi. It belongs to the Southeast Development Region, being one of the region's economic development engines. The municipality of Galați is located in the

eastern part of Romania, in the southern extremity of the Moldavian plateau. Located on the left bank of the Danube, it occupies an area of 243.6 km^2, at the confluence of the rivers Siret (to the west) and Prut (to the east), near Lake Brateș. Galati is a first-rank municipality, a city of national importance, located on major transport axes, an important regional pole in the South-Eastern area of Romania.
Ploiesti is the seat municipality of Prahova County, located in Muntenia. Compared to Bucharest, the country's capital, it is only 60 km in the North direction. The surface is approximately 60 km².
It is surrounded by the communes: Blejoi (to the North), Targusoru Vechi (to the West), Barcanesti, Brazi (to the South) and Bucov (to the East), which form the extra-urban area of Ploiesti.

Fig. 1. Location of the urban areas from study

Data collection
In the following paragrafs are presented selected sampling points related to the soil investigation in all municipalities.
Sampling was carried out with proper equipment, the Edelman type pedological kit. Precise location of the sampling points has been achieved with a GPS receiver, Montana 610 model from Garmin, Labelling and preservation of the samples was carried out properly, and the time of transport of the samples from sampling point to the laboratory was reduced to a minimum.
The map and the samples location from Tulcea City are shown in figure 2 and GPS coordinates are presented in table 1.

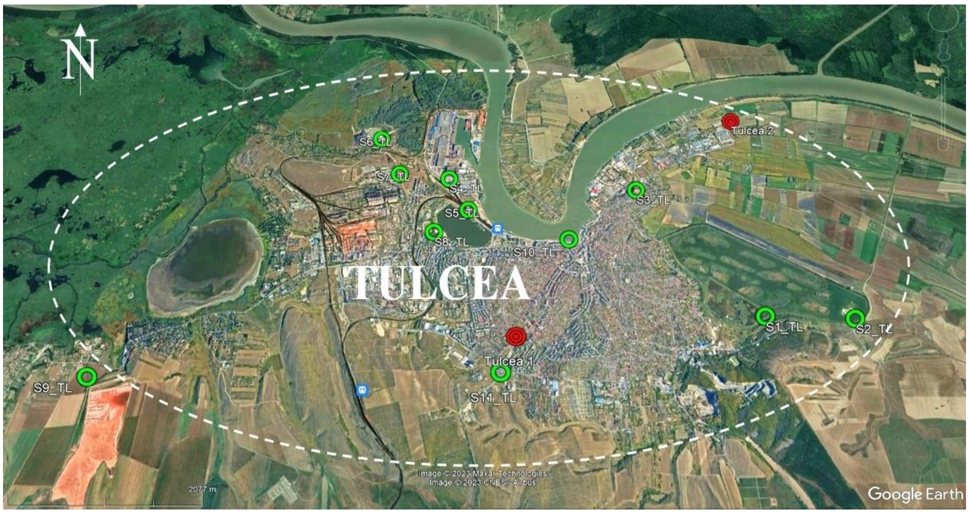

Fig. 2. Soil sampling points in Tulcea Municipality [earth.google.com]

Table 1. Soil sampling points in Tulcea Municipality and GPS coordinates

Soil sample ID	Description of the sampling location	GPS coordinates (WGS'84) GPS Garmin – Montana 610 model	
		Latitude	Longitude
S1_TL	Groundwater well area, Bogza Hill	45°10'5.43"N	28°49'51.91"E
S2_TL	Recreation area Zagan	45°10'2.89"N	28°50'40.92"E
S3_TL	Park area around the Independence Monument	45°11'8.93"N	28°48'53.09"E
S4_TL	Green area located near the shipyard in Tulcea	45°11'19.02"N	28°47'0.77"E
S5_TL	Green area near Ciuperca lake	45°11'2.36"N	28°47'11.55"E
S6_TL	Area near the slag dump - access from Bizamului street	45°11'42.38"N	28°46'19.20"E
S7_TL	Area located in the vicinity of the area with an industrial profile - access from str. Bizamului (residential area) - str. Taberei	45°11'21.93"N	28°46'30.79"E
S8_TL	„Oraselul Copiilor" Park	45°10'51.70"N	28°46'50.79"E
S9_TL	Vicinity of the Vimetco red sludge deposit	45° 9'51.94"N	28°43'45.33"E
S10_TL	Park - the central area of the city - Isaccea street	45°10'45.63"N	28°48'9.41"E
S11_TL	Area of the intersection between Babadag Street and Viticulturii Street	45° 9'46.12"N	28°47'24.77"E

Samples map from Galati city are shown in figure 3 and GPS coordinates in table 2.

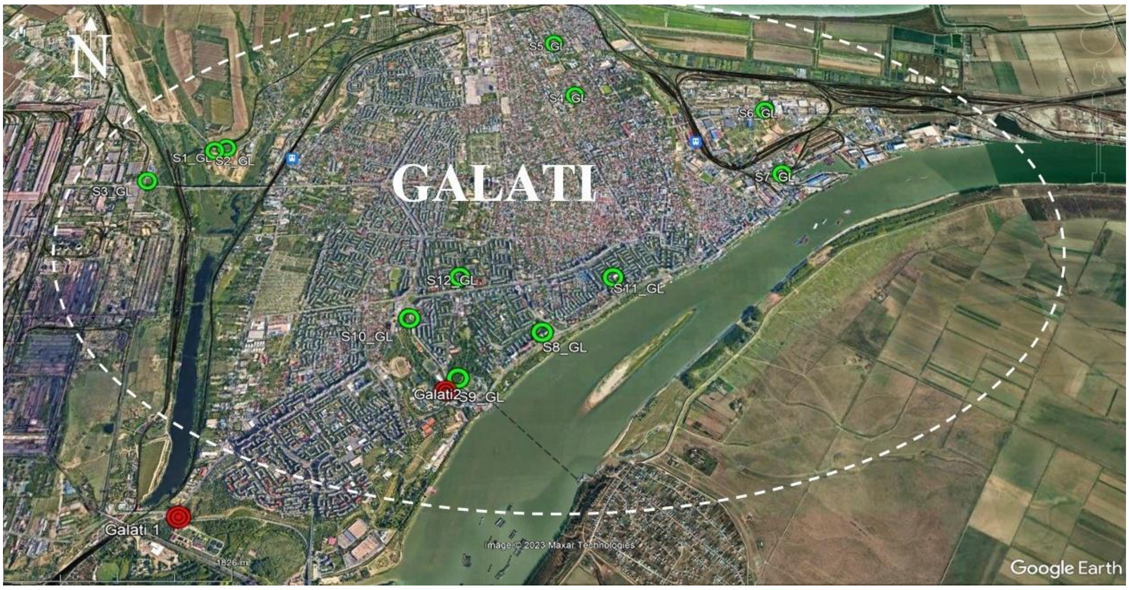

Fig. 3. Soil sampling points in Galati Municipality [earth.google.com]

Table 2. Soil sampling points in Galati Municipality and GPS coordinates

Soil sample ID	Description of the sampling location	GPS coordinates (WGS'84) GPS Garmin – Montana 610 model	
		Latitude	Longitude
S1_GL	Potentially contaminated site on Calea Smardan	45°26'41.29"N	27°59'57.01"E
S2_GL		45°26'40.21"N	27°59'51.62"E
S3_GL	Area near Libery Galati, in the area of the main entrance	45°26'26.88"N	27°59'23.56"E
S4_GL	Rizer Park	45°27'1.11"N	28° 2'43.43"E
S5_GL	Residential area on Radu Negru street	45°27'27.46"N	28° 2'34.50"E
S6_GL	Industrial area on Calea Prutului street	45°26'52.02"N	28° 4'15.24"E
S7_GL	Galati shipyard area	45°26'22.61"N	28° 4'17.31"E
S8_GL	Danube embankment area, the area with intense road traffic	45°25'22.09"N	28° 2'23.22"E
S9_GL	Natural Sciences Museum Complex	45°25'7.23"N	28° 1'48.22"E
S10_GL	Closca Park	45°25'28.71"N	28° 1'27.35"E
S11_GL	Area inside Mazepa District 1, Rosiri street	45°25'41.87"N	28° 2'54.78"E
S12_GL	Proximity of the County Directorate of the Galati National Archives, 2 Constructorilor street	45°25'43.47"N	28° 1'48.45"E

Samples map from Ploiesti city are shown in figure 4 and GPS coordinates in table 3.

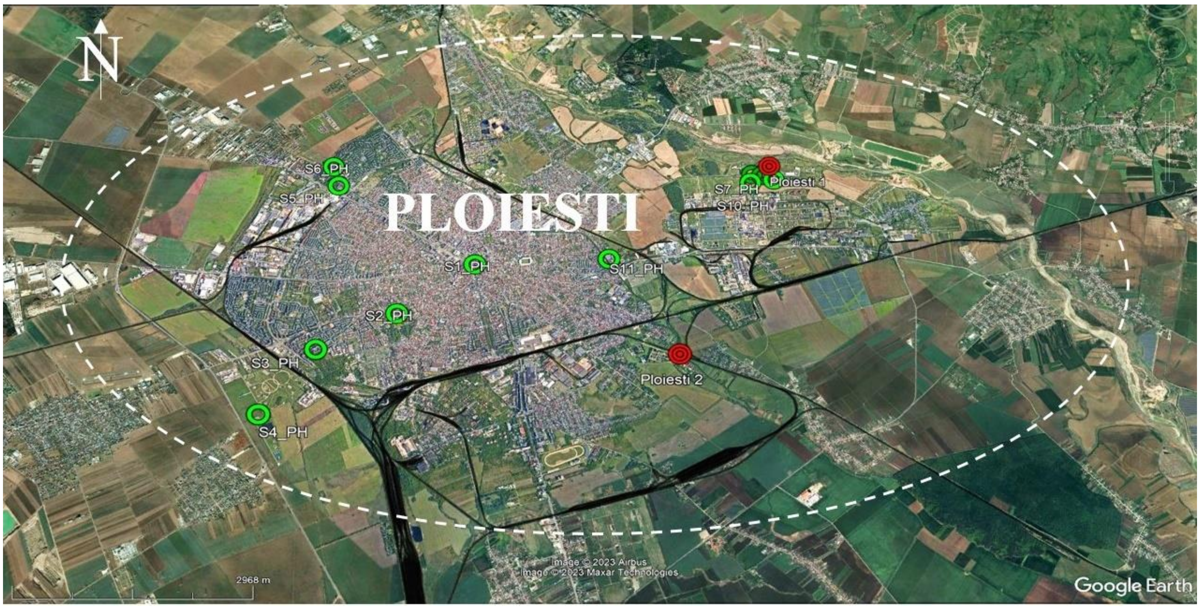

Fig. 4. Soil sampling points in Ploiesti Municipality [earth.google.com]

Table 3. Sampling points for soil in Ploiesti Municipality and GPS coordinates

Soil sample ID	Description of the sampling location	GPS coordinates (WGS'84) GPS Garmin – Montana 610 model	
		Latitude	Longitude
S1_PH	Park in the Independentei Square	44°56'20.88"N	26° 1'31.37"E
S2_PH	Park „Sports Hall"	44°55'53.47"N	26° 0'43.06"E
S3_PH	Area of the old industrial area, Astra Refinery, located in the vicinity of a residential area, Sondelor street and CFR Hospital	44°55'34.49"N	25°59'54.01"E
S4_PH	West Municipal Park area	44°55'1.13"N	25°59'23.82"E
S5_PH	The northern area of the park located opposite Unilever, the area with heavy road traffic	44°57'9.10"N	25°59'56.57"E
S6_PH	The North area, the residential area of Cameliei street, a kindergarten in the vicinity	44°57'21.18"N	25°59'51.68"E
S7_PH	Site situated in the NE area of Ploiesti, north of the Lukoil refinery, reported as potentially contaminated site	44°57'10.01"N	26° 4'52.30"E
S8_PH		44°57'12.92"N	26° 4'44.65"E
S9_PH		44°57'13.46"N	26° 4'37.71"E
S10_PH		44°57'8.41"N	26° 4'36.22"E
S11_PH	Neighborhood Mihai Bravu (near Dambu river)	44°57'8.41"N	26° 4'36.22"E

Sensors

Two different sensors were used, for air and soil quality control monitoring.

Efento wireless sensors for air. The sensor measure temperature (range: -35ºC. to +70ºC), humidity (range: 0...100% RH) and atmospheric pressure (range: 300 hPa...1100hPa). The other caracteristics of the sensor are: 60,000 measurements local data storage, transmission of data to a dedicated online platform, with the possibility of remote monitoring of the sensor, based on access with username and password.

Efento wireless sensor for soil. The sensor measure humidity in soil (range: 0...200 kPa) and temperature in ºC.

Analytical methods

The testing laboratory applied standardized test methods for determination of selected metals and metaloid (As, Cd, Cu, Pb, Zn, Mn and Cr). A high-performance inductively coupled plasma mass spectrometer ICP-MS Agilent 7900 equipment was used. The samples preparation step was performed with a microwave digestion system type Ethos-Up (Milestone, Italy). Two different certified reference materials were used (10 mg/L Li, Ca, Mg, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Mo, Co Sb, Ti, Pb), one for the calibration curves and the other one for the quality control of the results.

Legislations

The reference values for traces of chemical elements in soils are presented in table 4, in accordance with the Romanian in force Legislation, Order no. 756/1997 for the approval of the Regulation on the assessment of environmental pollution, with subsequent amendments and additions.

Table 4. Compliance limits for the content of metals in the soil in accordance with Order 756/1997

Parameter, mg/kg d.m.*	Normal values	Sensitive use of the land		Less sensitive use of the land	
		Alert Threshold	Intervention Threshold	Alert Threshold	Intervention Threshold
Arsenic	5	15	25	25	50
Cadmium	1	3	5	5	10
Copper	20	100	200	250	500
Lead	20	50	100	250	1000
Zinc	100	300	600	700	1500
Manganese	900	1500	2500	2000	4000
Chromium	30	100	300	300	600

*Dry matter

Conceptual model

For the study of the three urban areas, a conceptual model was designed which is presented in figure 5. The results obtained at the end of the study in 2026 will provide a database with relevant information regarding the evolution of environmental factors and the vulnerabilities identified against the background of changes induced by climate changes.

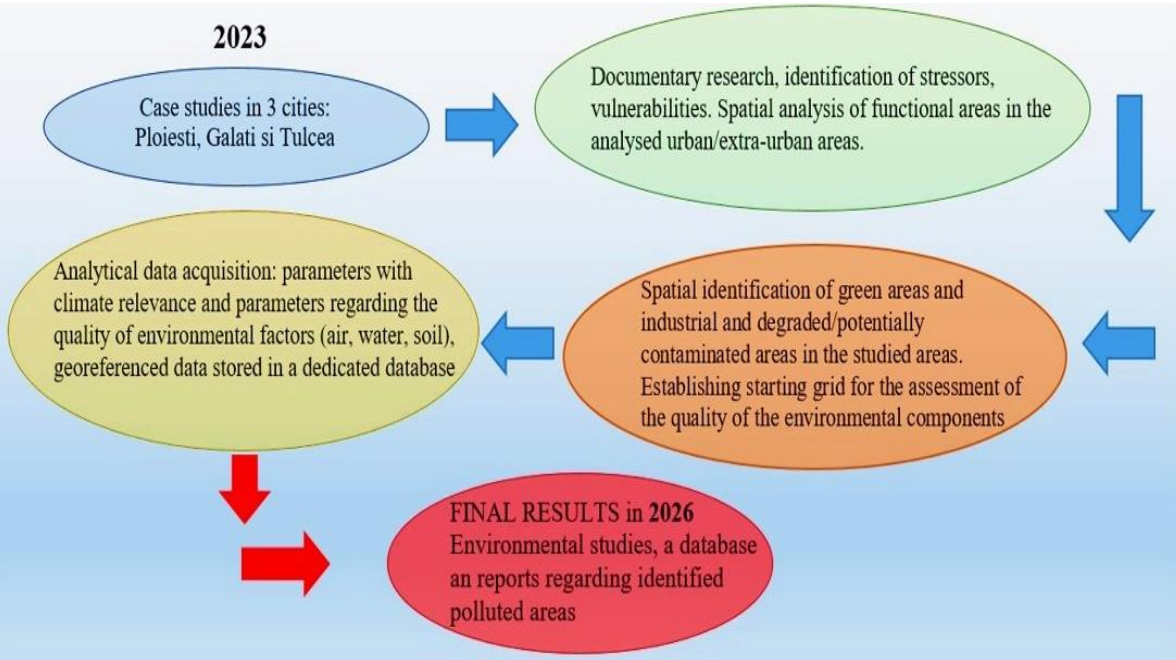

Fig. 5. Conceptual Model regarding assessment of the 3 cities from Romania

RESULTS AND DISCUSSIONS

In the following tables are presented the results of the tests carried out for the soil environmental factor for a selected metals and metaloid (tables 5, 6 and 7), which highlight their spread in the urban environment in different functional areas of the 3 analyzed cities: from recreational areas (parks) up to heavily road traffic areas and zones in the vicinity of old or current industrial sites. A distinct situation is represented by the presence of industrial waste dumps, such as those in Tulcea.

Table 5. Results of metals to establish a background in Tulcea Municipality

Soil sample ID Tulcea	Parameter / Metal / mg/kg d.m.						
	Arsenic	Cadmium	Copper	Lead	Zinc	Manganese	Chromium
S1_TL	2.45	0.07	8.43	4.82	28.51	170.78	13.11
S2_TL	2.68	0.06	8.48	3.08	25.01	219.16	12.93
S3_TL	3.22	0.08	10.47	2.69	30.11	317.36	18.45
S4_TL	3.17	0.11	18.20	6.67	126.3	404.71	32.18
S5_TL	3.30	0.08	11.22	3.34	45.09	341.21	19.13
S6_TL	14.00	1.09	23.90	30.00	219.0	5683.69	171.2
S7_TL	13.72	0.99	21.69	97.28	240.1	5446.00	52.88
S8_TL	2.84	0.09	8.42	3.43	30.76	423.60	15.02
S9_TL	6.62	0.30	17.89	20.58	79.24	4649.11	87.38
S10_TL	2.99	0.16	14.42	15.58	106.6	426.43	18.21
S11_TL	2.95	0.07	11.25	4.53	36.98	389.70	17.46

Table 6. Results of metals to establish a background in Galati Municipality

Soil sample ID Galati	Parameter / Metal / mg/kg d.m.						
	Arsenic	Cadmium	Copper	Lead	Zinc	Manganese	Chromium
S1_GL	2.42	0.14	9.03	9.02	26.44	351.43	12.02
S2_GL	2.59	0.11	9.77	9.12	27.63	322.48	12.90
S3_GL	2.84	0.27	19.95	23.03	59.02	540.83	15.00
S4_GL	2.60	0.17	15.13	14.59	49.02	385.31	15.90
S5_GL	2.23	0.21	14.22	25.27	206.95	345.35	13.99
S6_GL	2.27	0.38	39.07	34.78	159.05	601.10	30.02
S7_GL	5.87	1.62	79.48	199.53	448.15	627.64	29.87
S8_GL	2.57	0.12	11.08	11.01	40.20	332.56	10.84
S9_GL	2.22	0.11	14.54	12.55	47.08	327.59	11.84
S10_GL	2.26	0.13	12.58	14.13	46.87	368.64	13.63
S11_GL	2.29	0.21	14.40	23.85	106.62	346.70	13.52
S12_GL	2.30	0.14	12.34	10.98	43.01	325.10	13.54

Table 7. Results of metals to establish a background in Ploiesti Municipality

Soil sample ID Ploiesti	Parameter / Metal / mg/kg d.m.						
	Arsenic	Cadmium	Copper	Lead	Zinc	Manganese	Chromium
S1_PH	3.73	0.14	15.17	17.77	56.77	344.40	14.25
S2_PH	1.43	0.16	9.00	49.32	44.03	325.04	7.84
S3_PH	2.43	0.11	12.77	17.82	51.16	376.76	13.03
S4_PH	1.35	0.08	9.05	8.27	33.40	374.31	9.91
S5_PH	1.80	0.06	10.07	8.29	29.98	450.76	12.42
S6_PH	3.30	0.16	14.45	14.77	83.63	392.55	16.00
S7_PH	3.44	0.11	14.89	2.22	39.93	303.71	12.57
S8_PH	5.00	0.27	23.70	14.80	63.47	477.35	21.38
S9_PH	4.75	0.15	20.77	15.34	53.29	424.41	20.31
S10_PH	2.33	0.11	10.17	9.49	36.63	296.10	9.15
S11_PH	3.43	0.28	19.58	22.28	91.35	412.59	13.59

Important variations of the measured values are observed, traces of metals in the soil are present in larger quantities, especially in the vicinity of industrial areas or industrial waste storage areas.

In addition, in the situation of Galati, it is observed that the highest concentrations of heavy metals, lead, zinc and manganese are located in the vicinity of industrial areas.
The concentrations of heavy metals identified within city limits of Ploiesti are recorded within normal values, without highlighting areas that lead to anomalies that would require special attention for further clarifications. It should be mentioned that the city of Ploiesti has an industrial profile, mainly related on oil processing.
In the following, a series of graphical representations (figures 6÷14 for Arsenic, Lead and Manganese) are presented through which the measured concentrations can be visualized in relation to the normal values or Thresholds established in the specific legislation in Romania, for the soil environmental factor.

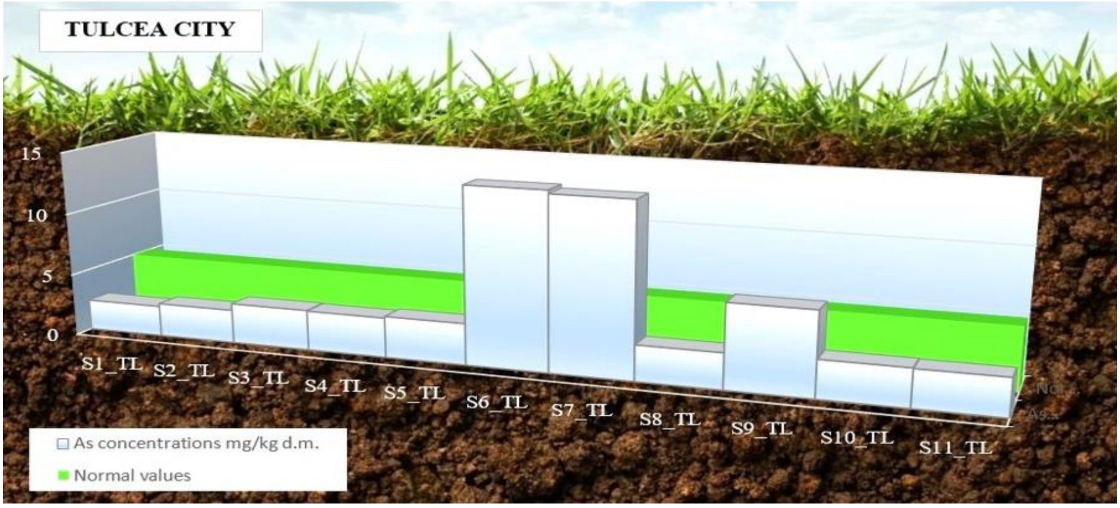

Fig. 6. Arsenic concentrations in Tulcea Municipality

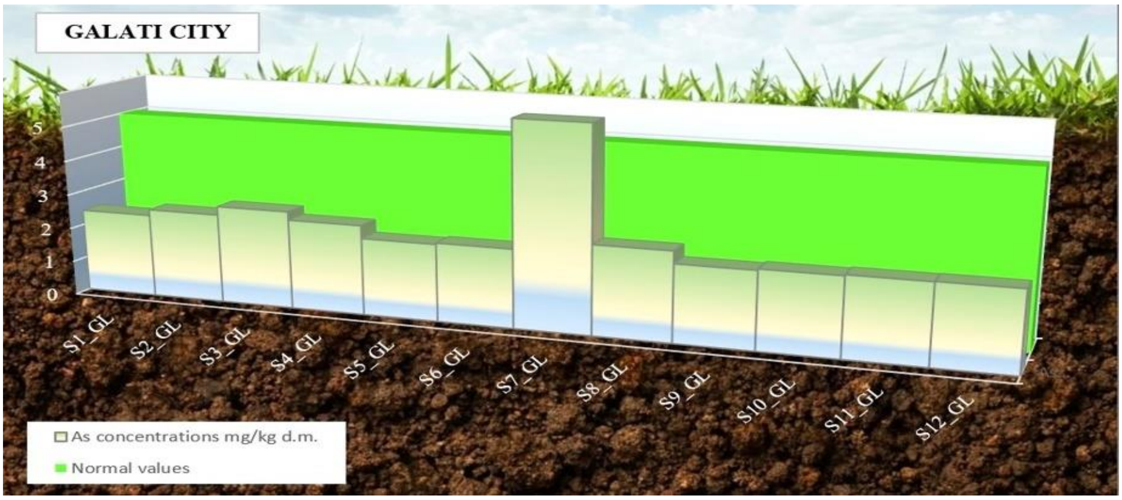

Fig. 7. Arsenic concentrations in Galati Municipality

It is observed that the values identified for the Arsenic indicator, exceed the normal values in areas identified as being under the influence of old industrial areas, with a high potential for heavy metal pollution, due to the open storage of large quantities of slag, specific to the metallurgical industry.
In the case of Galati Municipality, only one point exceeds the normal value established for Arsenic (5 mg/kg d.m.) in the vicinity of the shipyard in the city.
The results obtained for Arsenic in Ploiesti highlight a high degree of compliance, without exceeding the normal values.

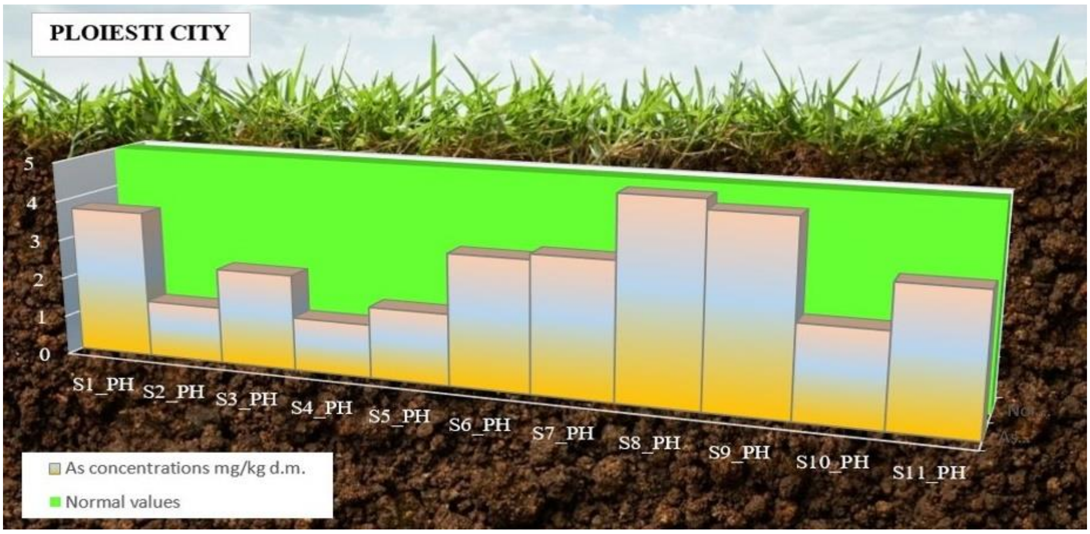

Fig. 8. Arsenic concentrations in Ploiesti Municipality

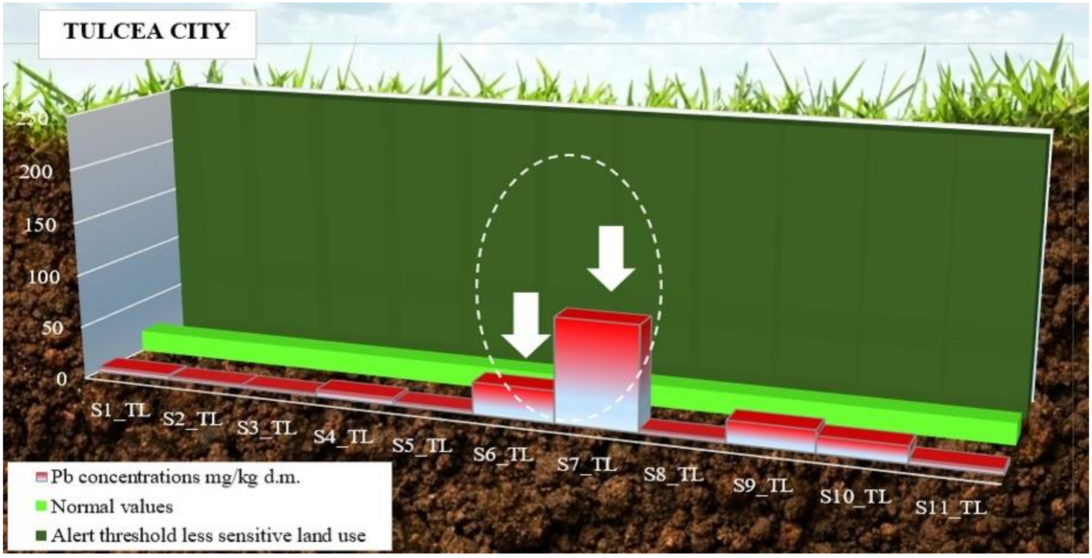

Fig. 9. Lead concentrations in Tulcea Municipality

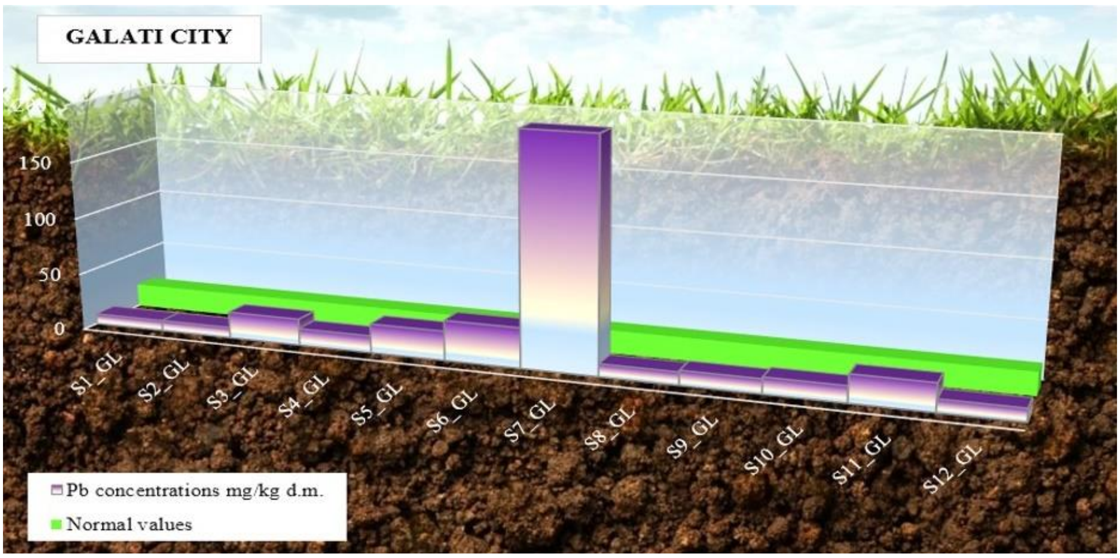

Fig. 10. Lead concentrations in Galati Municipality

Lead exceeds the normal values in the soil in those points under the influence of the old industrial areas of the city, and under the influence of the slag deposit in the western part of the city. It is known that the potential of this deposit is high, because the powdery material can be carried by the

wind, transported and deposited directly on the soil level at appreciable distances from the place of the storage.
In the case of Galati, the value recorded for Lead is the highest among all samples analyzed; this exceeds the normal value, but without exceeding the alert threshold value for the less sensitive land use category. The area is with heavy road traffic, a industrial zone, which explains the higher lead concentration in this area.

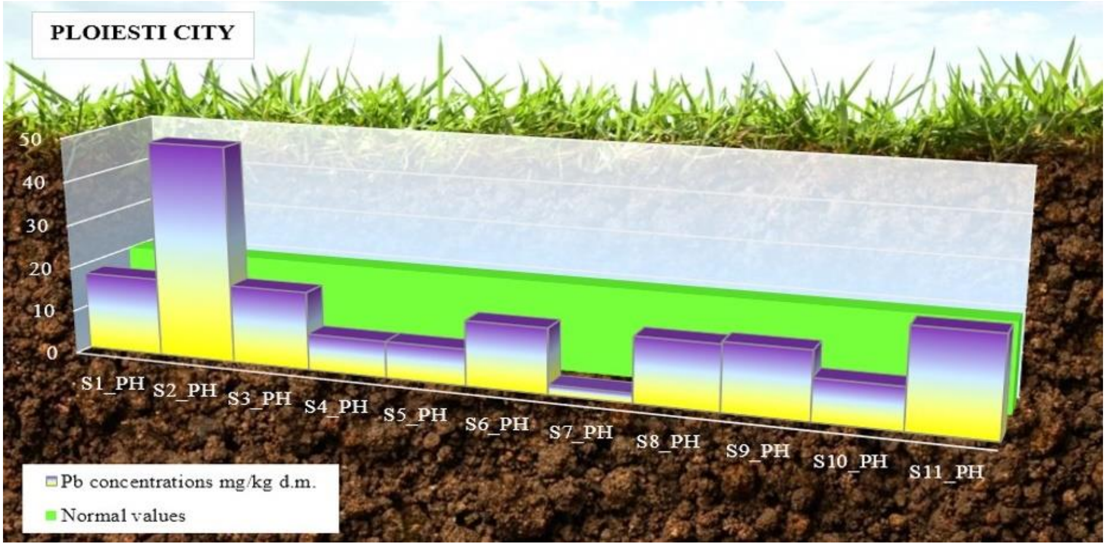

Fig. 11. Lead concentrations in Ploiesti Municipality

The values recorded in the city of Ploiesti for lead show a high degree of compliance, being within normal limits. The exception is in sampling point no. 2, located in the area of the Sports Hall park, where the normal value is exceeded, but without exceeding the alert threshold for the sensitive land use category.
The points that are found are the influence of the slag and red mud storage areas (sampling points S6, S7 and S9) show a high load of manganese, exceeding the threshold for intervention. Among all the investigated metals, manganese stands out as a specific pollutant for areas in the city of Tulcea that have the industrial footprint of the activities carried out here and marked by the presence of industrial waste deposits with metal content stored on large terrain surfaces.

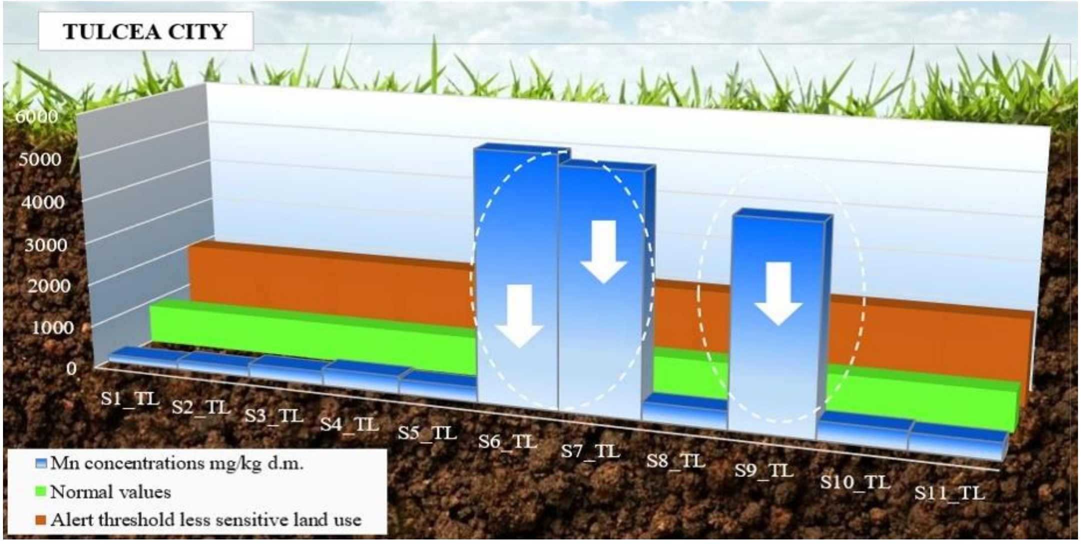

Fig. 12. Manganese concentrations in Tulcea Municipality

The investigations carried out in the city of Galati regarding the manganese content show that the normal values are not exceeded in any of the analyzed samples.

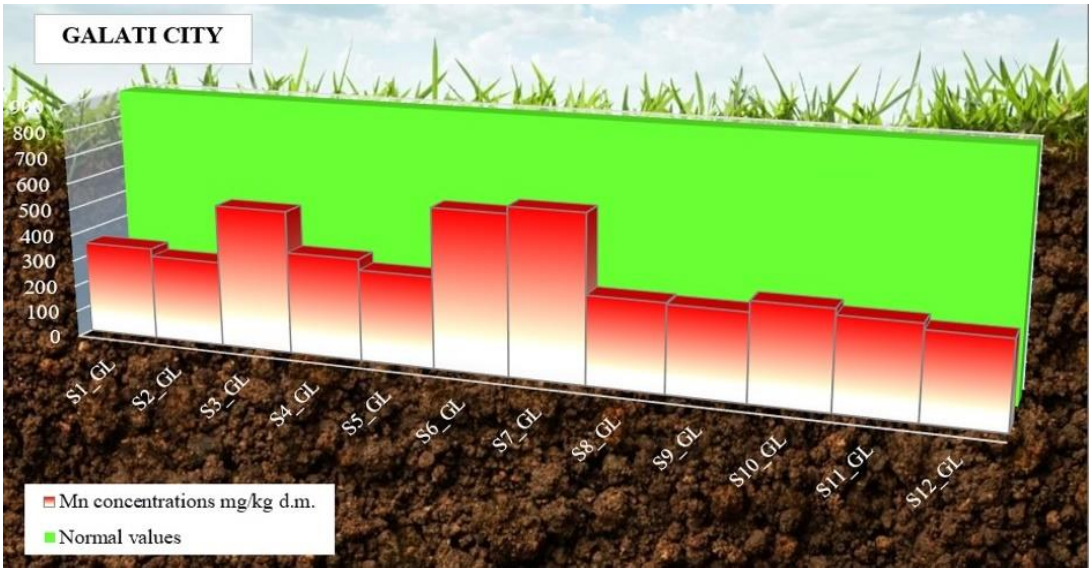

Fig. 13. Manganese concentrations in Galati Municipality

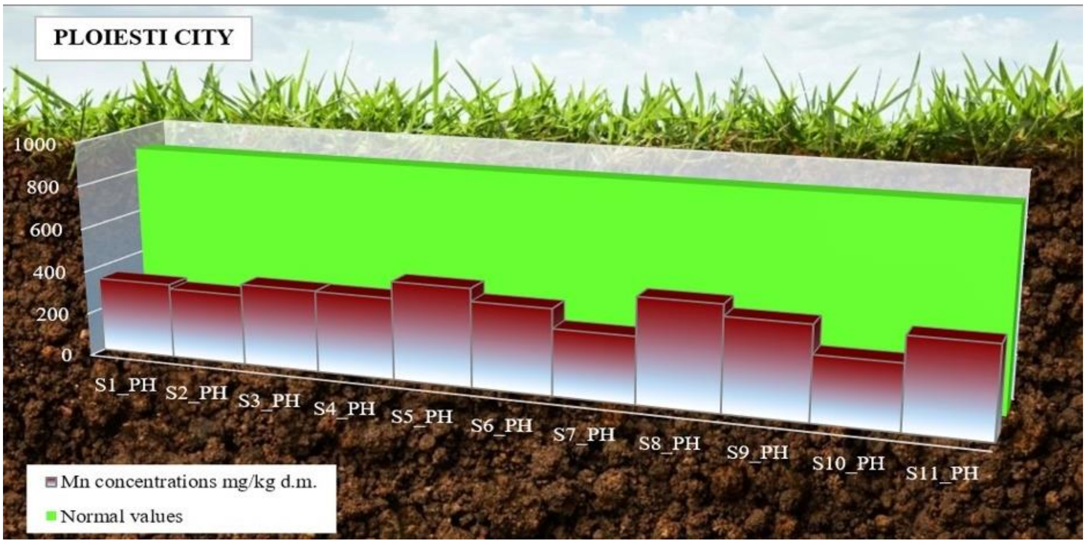

Fig. 14. Manganese concentrations in Ploiesti Municipality

Manganese in Ploiesti in all investigated soil samples is found within the limits of the normal value, respectively below the value of 900 mg/kg d.m.

CONCLUSIONS

The results presented in this paper are part of a prospective study regarding the implementation of an experimental field that includes the 3 cities chosen as case studies, areas for which a seasonal assessment of the quality of the soil, water and air environmental factors will be carried out. The results presented for the soil environmental factor are intended to show the current situation, at the level of 2023, of the main functional areas in the analyzed urban environments, in relation to the degree of loading of the soil with metals, the evaluation being carried out comparatively by reference to the values of the reference from the environmental legislation. From these first investigations performed, it can be seen that the industrial footprint, specific to the analyzed cities, together with the industrial profile specific to each city, justify the higher loading of the soil with metals in the areas near these industrial areas. The data obtained are considered important and relevant to the proposed goal regarding the evaluation and highlighting of vulnerabilities in urban and peri-urban systems in Romania, as a result of the manifestation of the effects of climate change.

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