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SOIL PH MEASUREMENT IN THE URBAN ENVIRONMENT OF BISTRIȚA: A CONTRIBUTION TO SUSTAINABLE DEVELOPMENT

Abstract. In the context of accelerated urbanisation and increasing environmental pressures, monitoring soil quality becomes essential to promote sustainable development. This study investigates soil pH variations in the urban and peri-urban areas of Bistrița (Unirea, Slătinița, Ghinda, Viișoara, Sigmir) to assess the impact of anthropogenic activities on soil balance and to identify potential risks to the health of urban ecosystems. The methodology included systematic sampling of soil from several representative locations, followed by pH value analysis using field survey methods, employing a pH meter. The results showed significant differences between central, industrial, residential, and peri-urban zones, indicating moderate acidification near pollution sources and a trend towards neutrality in urban green spaces and peripheral areas. These findings underscore the need for urban management policies that include regular soil monitoring and the integration of edaphic data into spatial planning. In conclusion, measuring soil pH in urban and peri-urban environments provides a valuable indicator for sustainability assessment, supporting strategic decisions that promote a healthier and more balanced urban ecosystem.

Keywords: soil pH measurement, urban and peri-urban areas of Bistrița, sustainable development

1. Introduction

Soil is increasingly recognised as an important non-renewable asset that must be properly managed and cared for. It is not only a vital carrier of

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biodiversity but also supports essential human needs such as food, clean water, and air. Soil fertility is defined as the capacity of soil to provide a suitable habitat for plants and to support the growth of crops (Edwin & Muthu, 2021).

Accelerated urbanisation and intensified anthropogenic activities have exerted significant pressure on soil quality, particularly in urban and peri-urban areas, where the edaphic balance is often disturbed. Among the key indicators of soil health, pH plays a central role, influencing nutrient availability, microbial activity, and the dynamics of heavy metals in soil (Rengel, 2011).

Cities and urban processes have had dramatic, yet varying, impacts on soil physical and biochemical properties and pollutant loads, all of which affect the life-supporting functions of soils (Marcotullio *et al.*, 2008). In the context of climate change and unsustainable urban development, monitoring soil pH becomes crucial for maintaining ecosystem functions and informing sustainable spatial planning decisions (Liu *et al.*, 2025).

Although the literature has emphasised the importance of pH in assessing soil fertility and buffering capacity (Zhang *et al.*, 2019), there are still gaps in studies applied to urban environments in specific geographical regions, such as Bistrița.

In the municipality of Bistrița, soil types differ from those in the peri-urban area, mainly due to the degree of urbanisation, anthropogenic intervention, and local natural characteristics.

Soils within the municipality of Bistrița:

Loamy or loamy-clay soils – predominant in residential and green areas (e.g., in front of apartment blocks), with good water retention capacity.

Acid brown soils – mainly found in less urbanised areas or parks.

Soils affected by urbanisation – compacted, poorly drained, often containing fill materials (rubble, gravel, construction debris).

Urban fill alters not only the texture but also the chemical properties of the soil (pH, heavy metal content, etc.).

Soils in the peri-urban area:

Reddish-brown and acid-brown soils – typical of hilly areas, formed on clayey or loamy substrates. These soils, being less affected by urbanisation, tend to have higher natural fertility.

These soil types directly influence the ecological regeneration capacity of cities and the potential for sustainable development, particularly in terms of green space management, urban agriculture, and green infrastructure (ICPA Soil Maps).

Functionally resilient urban soils play a pivotal role in mitigating the urban heat island effect, enhancing pollutant filtration, and facilitating carbon sequestration, thereby supporting climate regulation and ecological stability within metropolitan environments. They are essential for achieving the Sustainable Development Goals (SDGs), particularly SDG 11 – Sustainable Cities and Communities (Grigorescu *et al.*, 2019).

Moreover, the Bistrița urban system, characterised by a network of interconnected settlements and complex urban dynamics, provides an ideal framework for integrated analysis of soil as a strategic resource in sustainable spatial planning (Pop, 2016).

Studies show that pH analysis methods can yield different results depending on the extractant used, highlighting the need for standardisation to enable relevant comparisons between cities (Kalra, 1995). Moreover, urban vegetation – particularly the composition of tree species – exerts a significant influence on soil pH dynamics, with coniferous species generally contributing to increased soil acidification compared to deciduous species (Broschat, 2010).

Soil reaction, or pH (hydrogen potential), depends on the ratio between the concentration of H^+ and OH^- ions in the soil. A pH of 7 indicates neutrality; values below 7 indicate acidity, while those above 7 indicate alkalinity (agrobiznes.ro).

This paper aims to investigate the spatial distribution of soil pH in this emerging urban area, providing a scientific basis for sustainable development policies. The main conclusions highlight significant variations in pH depending on land use and emphasise the need to integrate edaphic data into ecological urban planning strategies.

2. Methodology

The information utilised in this study was extracted from pedological databases and maps available on the official website (icpa.ro) of the Research Institute for Soil Science and Agrochemistry (ICPA).

To ensure methodological coherence, the data were structured into the following subchapters:

A. Technical Specifications and Data Sources

Soil pH values were determined using a PH-98211 portable soil tester (Figure 1), with the following specifications:

- Device: PH-98211 soil tester
- Measurement range: 0.00–14.00 pH
- Resolution: 0.01 pH
- Accuracy: ±0.1 pH
- Dimensions: approx. 250 × 50 × 28 mm (supplied with calibration liquid)
- Display: 4-digit bright LCD
- Sensor type: conical crystal electrode

The use of a conical crystal pH electrode is scientifically validated for direct soil measurements, particularly in compact or semi-solid substrates. These probes are specifically designed for field applications, allowing accurate readings without the need for solution extraction. Automatic temperature compensation is essential to ensure measurement precision under variable environmental conditions.

Figure 1. Using the pH meter measuring set in the field
Source: Alexandru Marius Tătar

Experimental data were processed using MATLAB software, which enabled:

- Filtering and validation of recorded values
- Statistical computation of means and standard deviations
- Graphical representation of pH distribution by location and depth
- Correlation analysis with other relevant parameters (e.g., moisture content, soil type)

Before each measurement session, the device was calibrated at two reference points (pH 4.01 and pH 7.00) using standard buffer solutions, following the manufacturer's protocol. Field measurements were conducted under controlled conditions to minimise external variability (e.g., temperature, atmospheric humidity).

B. Soil Sampling Methodology for pH Determination

The study was conducted in the urban and peri-urban areas of Bistrița, located in Bistrița-Năsăud County, northern Romania. Sampling was carried out in four representative land-use categories: residential, parks, riverside, and industrial zones. Within each category, locations were selected based on accessibility and pedological representativeness.

Investigated areas

Residential zones: gardens, courtyards, and green spaces between apartment blocks. In peri-urban residential areas, samples were collected from the front yards of individual houses, including semi-managed green spaces. These sites were chosen for their moderate anthropogenic impact and relevance to domestic land use, offering a representative perspective on peri-urban soil quality.

- Parks: public green spaces with maintained vegetation.
- Riverside zones: banks and areas adjacent to watercourses.
- Industrial zones: active or abandoned industrial platforms.

Table 1

Depth of Soil pH Measurement in the Urban Area

Area type	Depth measured	Observations
Residential	10 cm	The layer is affected by human activities.
Parks	15 cm	Biologically active layer.
Near the river	10cm, 20cm, 30 cm	To capture pH variations in the alluvial profile, samples are taken at 10-20 cm and 20-30 cm for stratified analysis. Water-influenced alluvial soils
Industrial	10 cm	Surface layer exposed to contaminants.

Source: Alexandru Marius Tătar

Measurement depth varied by zone (Table 1). For each sample, the electrode was inserted into moist soil and left for 2–3 minutes to stabilise the pH reading. In compacted soils, a small amount of distilled water was added to ensure proper contact with the sensor.

Calibration and maintenance procedures included:

- Calibration before each measurement session
- Cleaning the electrode with distilled water after each use to prevent cross-contamination

Sampling period: April–May. This timeframe was selected for the following reasons:

- Post-winter biological activation: Soil begins to warm, enhancing microbial and chemical activity, thus offering a realistic snapshot of plant growth conditions.
- Optimal moisture levels: Spring soils typically exhibit balanced moisture, improving pH measurement accuracy.
- Urban redevelopment season: April–May coincides with gardening and green space maintenance, making pH data relevant for plant selection and soil treatment.
- Reduced external interference: March soils may be affected by de-icing salts, while June introduces variables such as fertilisation and irrigation. April–May offers a neutral window for reliable measurements.

The April–May period was selected as optimal for field measurements due to reduced external interferences. In March, soil conditions may be altered by residual de-icing salts from winter road maintenance, while in June, fertilisation and irrigation practices can significantly affect soil chemistry. Thus, April–May offers a more neutral and stable window for assessing soil pH under minimally disturbed conditions.

3. Results and discussion

In the residential area of Bistrița, soil pH levels were analysed based on a structured sampling strategy. The city was divided into five sectors: north, south, east, west, and centre. Two representative streets were selected from each sector.

Measurement points were chosen according to soil type, vegetation cover, and anthropogenic activity (e.g., green areas, private yards, wastelands).

A total of 10 measurement points per sector provided a representative overview of pH variation across the city (Figure 2).

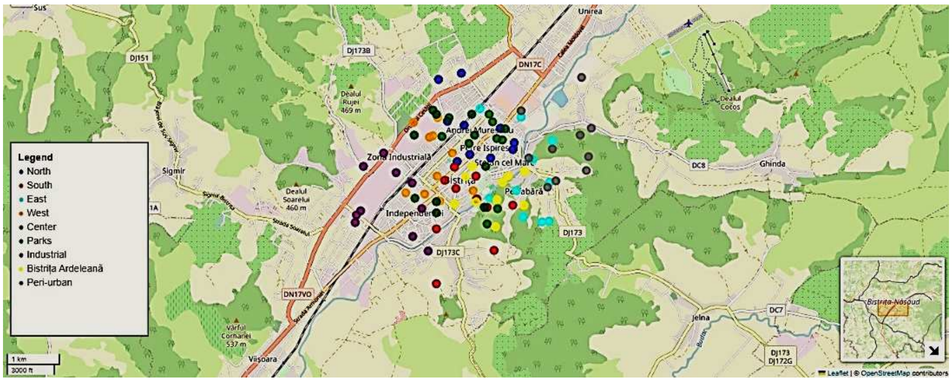

Figure 2. Bistrița soil sampling map
S*ource:* Alexandru Marius Tătar, OpenStreetMap

The southern sector of Bistrița is more urbanised and better integrated into the public transport and sustainable mobility infrastructure, which may influence the quality and distribution of public services, including water supply and sewage systems (Figure 3).

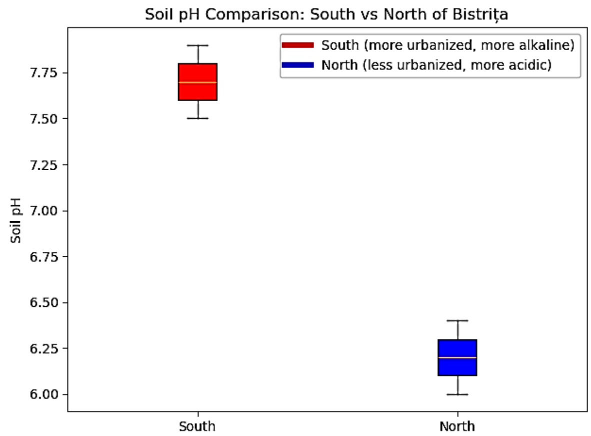

Figure 3. pH values in the North and South residential areas
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

More intense urbanisation in the southern part of Bistrița contributes to a more alkaline soil profile compared to the northern sector. Several factors may explain this:

a. **Influence of construction materials and urban infrastructure**. Urban soils are often affected by alkaline substances such as concrete, cement, and lime, which can elevate pH levels over time. Runoff water from impervious surfaces may transport these materials into the soil profile.
b. **Anthropogenic activities**. In the southern sector, characterised by increased economic and industrial activity (e.g., Bistrița Sud Industrial Park), chemical spills or seepage may alter soil chemistry. Additionally, the frequent application of alkaline amendments (e.g., lime, limestone) in urban gardens and green spaces can contribute to elevated pH levels.

The observed differences in soil alkalinity between the western and eastern sectors of Bistrița can be attributed to a combination of natural and anthropogenic factors (Figure 4). In the West, land is more intensively used for construction, light industry, and urban gardening, where alkaline fertilisers are commonly applied.

In contrast, the eastern sector is dominated by green and agricultural areas, where soil tends to be more acidic due to organic matter decomposition and nitrogen-based fertilisation.

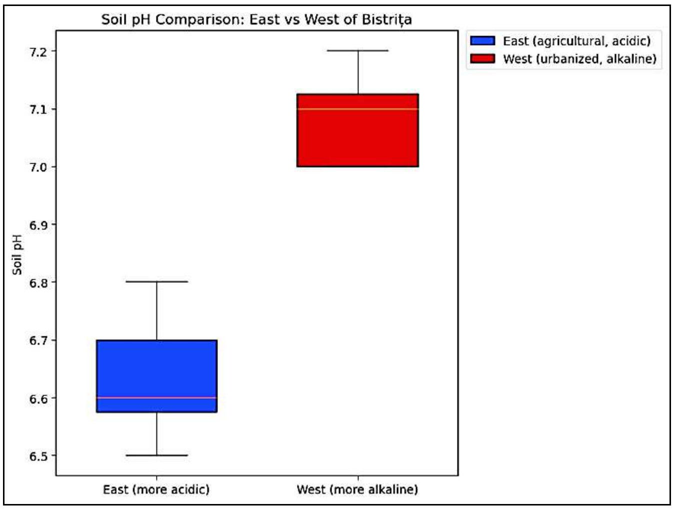

Figure 4. pH values in the East and West residential areas
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

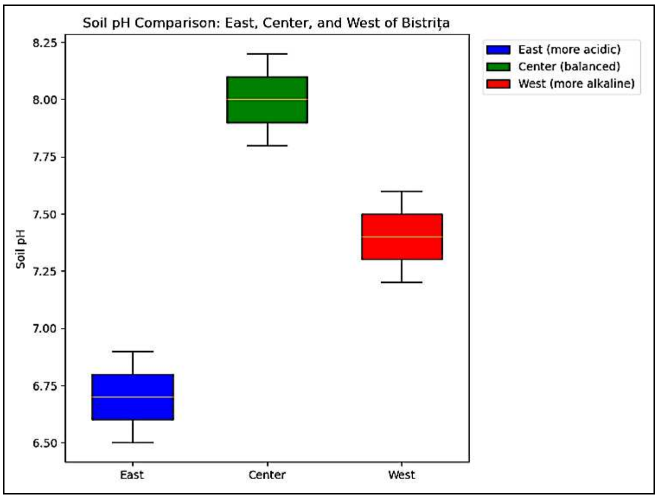

Figure 5. pH values in the Centre residential areas
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

Soils in the central area of Bistrița exhibit slightly alkaline characteristics, reflecting a balance between controlled urban interventions and limited industrial exposure. The centre is less acidic than the east and less influenced by industrial activities than the west (Figure 5).

Scientific Interpretation of Image Data

Group 1: Slătinița and Ghinda

- Median pH ≈ 5.8
- Interquartile Range (IQR): ~5.7–5.9
- Total Range: ~5.6–5.9+

→ Indicates a more acidic soil profile with slightly higher variability.

Group 2: Unirea, Viișoara, and Sigmir

- Median pH ≈ 6.0
- IQR: ~6.0–6.1+
- Total Range: ~5.9+–6.1+

→ Indicates soils closer to neutral, with a more compact distribution.

These differences may reflect variations in land use, soil type, and anthropogenic influence across the peri-urban landscape (Figure 6).

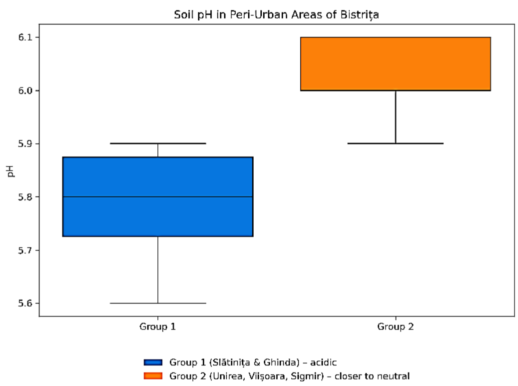

Figure 6. pH values in peri-urban residential areas
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

Soil pH in Urban Green Spaces

To assess soil pH in urban green spaces, two representative parks were selected: King Michael I Park and Avram Iancu Park No. 9. For each park, two soil samples were collected:

- One from the grass-covered area
- One from the shrub-covered area (Figure 7).

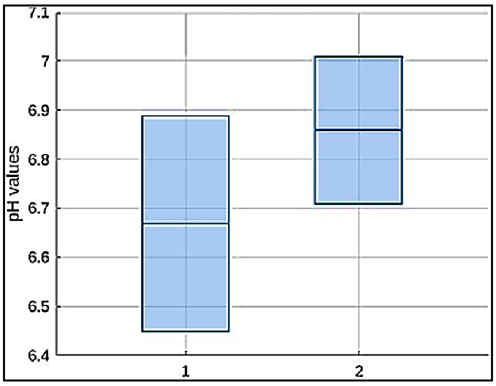

Figure 7. pH values in the green area of the city (park)
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

pH Values:

- Zone 1: pH ranges from ~6.5 to 6.9, median ≈ 6.7
- Zone 2: pH ranges from ~6.6 to nearly 7.0, median ≈ 6.8–6.9

The soils in both zones are weakly acidic to neutral, typical of well-maintained urban green spaces. Small differences between the two areas suggest uniformity in soil management practices (e.g., irrigation, fertilisation, vegetation type). Values close to pH 7 indicate favourable conditions for urban vegetation such as lawns and ornamental trees.

Both zones have an IQR of approximately 0.4, indicating moderate dispersion and uniform soil quality:

- Zone 1: Q1 ≈ 6.5; Q3 ≈ 6.9 → IQR = 0.4
- Zone 2: Q1 ≈ 6.6; Q3 ≈ 7.0 → IQR = 0.4

Soil pH Variation Near the Bistrița Ardeleană River

Soil pH variation near the Bistrița Ardeleană river was assessed at depths of 10 cm, 20 cm, and 30 cm, based on the typical behaviour of alluvial and hydromorphic soils (Table 2).

Table 2

Soil Characteristics According to Depth

Depth	Characteristics	Trend pH
10 cm	Surface layer, influenced by organic matter, fertilisation, and rainfall	Slightly acidic or neutral pH
20 cm	Middle layer, more stable, less influenced by external factors	Relative pH constant
30 cm	Lower layer, possibly with salt or mineral accumulations	pH slightly more alkaline or constant

Source: Alexandru Marius Tătar

The characteristics of urban soil near the river can be categorised into two main groups:

a. Anthropogenic Influences:

- Potential contamination from urban pollutants (e.g., heavy metals, hydrocarbons, waste)
- pH alterations due to sewage discharge or construction materials

b. Altered Stratification:

- Soil mixing and compaction in urbanised areas may disrupt natural pH gradients

pH Variation by Depth:

- 10 cm depth – Surface pollution influence
- pH decrease: ±0.3 to ±0.8 units

Causes: industrial dust, vehicle emissions, rainwater runoff, household waste

- 20 cm depth – Seepage and structural changes
- pH variation: ±0.2 to ±0.5 units

Causes: infiltration of contaminated water, reduced biological activity due to compaction

- 30 cm depth – Lower urban influence

Slight pH increases possible due to buried construction materials (e.g., concrete, limestone) (Figure 8).

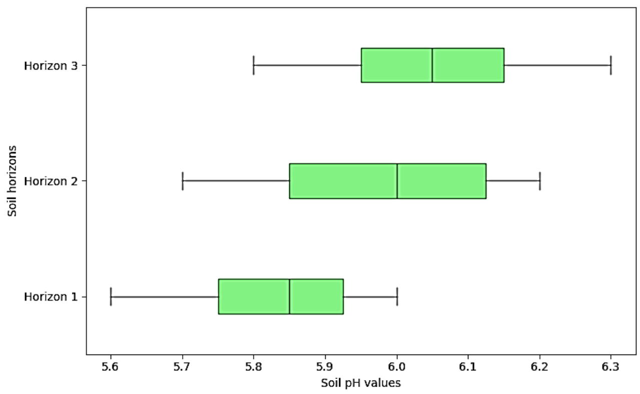

Figure 8. pH values in the Bistrița Ardeleană river area
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

Soil pH in the Industrial Area of Bistrița

Soils in the industrial area are influenced by both natural characteristics and historical/current industrial activities (Figure 9).
Identified Soil Types:

- Modified urban soils containing construction debris, slag, and heavy metals
- Acid brown soils or degraded chernozems, depending on location and industrial legacy

Sampling Methodology:

- Four locations were selected, with two representative samples per site
- Areas with visible construction debris or landfills were avoided to ensure data reliability

Results:

- pH values ranged from 6.1 to 6.5, indicating weakly acidic conditions
- This range is compatible with biological activity and suggests potential for soil reclamation
- Soils are not severely polluted and may be restored for agricultural, ecological, or industrial use with minimal corrective measures

All four locations exhibited an IQR of approximately 0.20, indicating low dispersion and consistent soil conditions. This uniformity may reflect similar substrate characteristics, pollution sources, and measurement methodology.

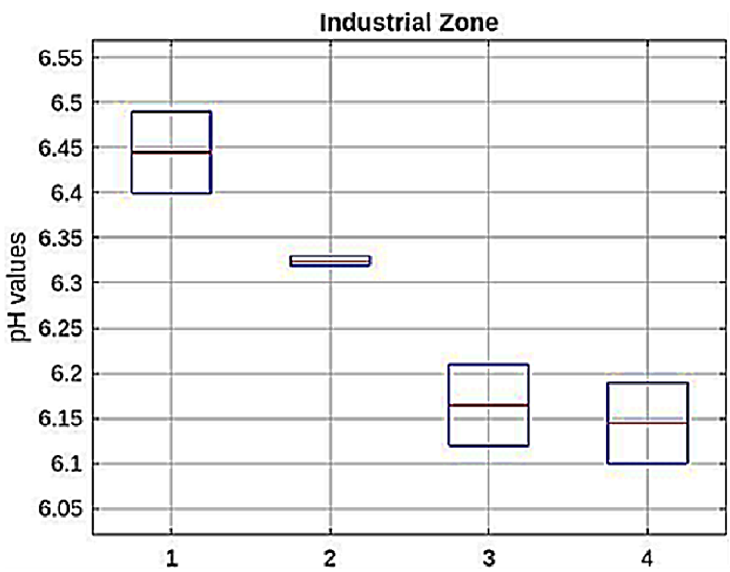

Figure 9. pH values in the Industrial zone
Source: Alexandru Marius Tătar, realised in https://matlab.mathworks.com/

According to Rengel (2011), soil pH is not only a determinant of nutrient solubility and uptake but also a key indicator of soil resilience and functionality under stress conditions.

1. Soil pH: Ecological and Agronomic Significance

The scientific literature emphasises that soil pH directly influences both biochemical and physico-chemical processes within the soil matrix. Acidic soils may limit the uptake of essential nutrients such as phosphorus, calcium, and magnesium, while alkaline soils may promote the accumulation and reduced mobility of certain toxic heavy metals.

In urban environments, pH variations can reflect a combination of natural factors and anthropogenic activities, thereby serving as an indirect indicator of environmental quality and soil health.

2. Urban Soil: Characteristics and Challenges

Urban soils are typically heterogeneous, structurally and chemically altered, and often exhibit high levels of compaction and contamination. Recent studies (e.g., Lehmann & Stahr, 2007; Pouyat *et al.*, 2010) demonstrate that urban soils exhibit substantial variability in pH, influenced by factors such as land use patterns, proximity to pollution sources, and the historical evolution of urban infrastructure.

In Romania, research on urban soils remains limited, particularly in small and medium-sized cities such as Bistrița. This gap underscores the need for applied studies that address urban soil dynamics in diverse geographical contexts. Urban development cannot be considered in isolation, but must be understood in the context of complex territorial relationships with rural areas, including soil characteristics, infrastructure and public services (Grigorescu *et al.*, 2019)

3. pH Measurement as a Tool for Sustainable Development

In the framework of the 2030 Agenda for Sustainable Development (UN SDGs), monitoring soil quality is essential for achieving objectives related to environmental health, urban agriculture, and responsible spatial planning (sdgs.un.org).

Soil pH measurements can:

- Identify areas at environmental risk;
- Inform ecological restoration and land management decisions;
- Support community awareness regarding the impact of human activities on soil and ecosystem health.

The results obtained from soil pH measurements in the urban environment of Bistrița reveal significant variability across different sectors of the city. These variations correlate with land use patterns and proximity to pollution sources. The findings are consistent with previous research (Lehmann & Stahr, 2007; Pouyat *et al.*, 2010), which emphasises the influence of anthropogenic pressures on urban soil quality.

4. Conclusion

The main contribution of this study is the provision of updated local data within a national context where research on urban soils remains limited. The findings underscore the importance of measuring soil pH in urban areas of the Bistrița urban system, highlighting the role of this indicator in assessing environmental quality and informing sustainable development strategies.

The results revealed significant variability in pH values, depending on the degree of urbanisation, land use type, and anthropogenic influences. These findings confirm the necessity of continuous and systematic monitoring of this parameter. Soil pH measurement is not merely a technical procedure, but a critical component in the decision-making process for urban sustainability. By integrating such data into public policy and interdisciplinary research, a robust framework can be established for greener, healthier, and more resilient cities.

Public Policy Recommendations for Sustainable Urban Soil Management:

- Implement an urban soil monitoring system with fixed sampling points and regular analysis of pH and other relevant parameters (e.g., heavy metal content, organic matter, salinity).
- Integrate soil quality data into general urban development plans (PUG) and local development strategies to prevent construction in areas with degraded or unstable soils.

Directions for Future Research:

- Extend the analysis to the regional level to compare the Bistrița urban system with other cities across Romania to identify common patterns or significant differences in soil pH.
- Develop predictive models using artificial intelligence and GIS to forecast pH changes under scenarios of urbanisation, climate change, or anthropogenic interventions.

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