# Geochemical characterization and spatial variability of urban soils under anthropogenic pressure as a baseline for nature-based solutions

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Urban areas are increasingly exposed to the impacts of climate change, including rising temperatures, extreme weather events, flooding, drought, and deteriorating air quality [1]. The concentration of population, infrastructure, and economic activities amplifies environmental pressures and vulnerability, positioning cities as critical hotspots for both ecological and socio-economic risks [2]. In this context, Nature-Based Solutions (NbS) have emerged as an integrated framework for climate change mitigation and adaptation, aiming to enhance urban resilience while delivering ecosystem services, biodiversity support, and human well-being [3]. As defined by IUCN, NbS are actions that protect, restore, and sustainably manage ecosystems to address societal challenges in an effective and adaptive manner [4]. However, the success of urban NbS interventions is strongly influenced by baseline environmental conditions, including soil quality, which remains an often underassessed component in urban ecological restoration planning.

The aim of this study was to investigate the baseline chemical composition and spatial variability of urban soils across different environmental pressure contexts within the city of Brasov, Romania, in order to support the implementation of Nature-Based Solutions (NbS) in the urban fabric. The research aims to identify patterns of elemental distribution in areas characterized by traffic intensity, industrial activity, proximity to air quality monitoring stations, proposed ecological restoration sites, and reference locations with lower anthropogenic influence. By examining soil quality as a foundational environmental layer, the study seeks to determine how existing geochemical conditions may influence the suitability, safety, and long-term effectiveness of ecological restoration interventions implemented as Nature-Based Solutions.

To operationalize this assessment, soil elemental concentrations were measured in situ at 74 locations across the urban area using a portable X-ray fluorescence (pXRF) analyzer (Thermo Scientific XL2 Plus). The instrument enabled rapid, non-destructive quantification of multiple elements directly in the field, including barium (Ba), zinc (Zn), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), and cobalt (Co), which are commonly associated with traffic- and industry-related environmental pressures [5]. The collected measurements were subsequently structured and comparatively analyzed to identify distribution patterns and relative differences in elemental concentrations across the investigated locations, forming a consistent baseline dataset for evaluating soil-related constraints and opportunities in future NbS interventions.

Sampling locations were georeferenced and integrated into a GIS environment to enable spatial visualization and analysis of soil elemental distribution across the urban area. Proximity analysis was conducted to evaluate the distance of sampling points to major traffic corridors, while spatial distribution patterns were examined to identify potential pressure hotspots associated with traffic and industrial activities. This spatial component supported the interpretation of geochemical variability in relation to urban environmental stressors and strengthened the evidence base for context-sensitive NbS planning.

This study demonstrates that urban soils exhibit measurable differences in elemental composition depending on local environmental pressures, with elevated concentrations of traffic- and industry-associated elements observed in more exposed areas compared to reference locations. These findings highlight the importance of baseline geochemical assessment in understanding site-specific constraints and opportunities for the context-sensitive implementation of Nature-Based Solutions in heterogeneous urban environments.

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