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Factor analysis of organic soils for site discrimination in a forensic setting

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ABSTRACT

Organic soils are generally located in fluvial settings such as river floodplains that are commonly used for the disposal of bodies. Therefore, the aim of this study was to provide a protocol for the analysis of small amounts of organic soils for forensic purposes. The protocol was applied in five representative sites within the Curitiba metropolitan region (Brazil), with each site supplying four composite samples separated from one another by 3 m. The soil samples were collected at a depth of 0 to 5 cm. One gram of soil sample was used to determine the total elemental content and perform physical fractionation of the soil (>53 μm and <53 μm). For both soil size fractions, total C and N contents were determined, and the elements adsorbed to organic matter was determined only for the <53 μm size fraction (Na-pyrophosphate extraction). Chemometric multivariate analyses were conducted for the total data set, where more than 77% of the variation was explained by the first three factors. It was determined that Ca, Ba, and Mg adsorbed to organic matter, and total Ba, Ca, K, Mg, Mo, and C contents were most important in sample groupings. As expected in forensic science, the five sites were efficiently distinguishable from each other and the four replicates collected at the same individual site were clearly grouped. This protocol for sampling, chemical analysis, and data treatment of organic soils can be used in real crime situations.
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1. Introduction

Forensic investigations based on soil samples have benefited from the multidisciplinary nature of soil science, thereby allowing an association or dissociation to be ascertained between soils in a forensic context using particular samples [1,2]. The use of soil samples as trace evidence in criminal and civil matters has been increasingly adopted worldwide because each soil holds a multitude of fingerprint traits that make it distinctively unique and therefore highly useful in forensic investigations [3,4].

Another advantage of soil forensics is that it can potentially tap into the various physical, chemical, geochemical, and mineralogical analytical techniques currently established and used in soil science. Inorganic and organic characteristics of soil samples can be assessed by techniques such as spectral color [5], particle density distribution [6], particle size distribution [2,7], light and heavy mineral analysis [6], elemental analysis [2,6,8,9], organic matter pyrolysis [2], and mineralogical analysis [9].

However, the use of such soil analytical techniques for forensic purposes might prove challenging, considering that forensics requires a much higher degree of rigor in interpreting results than do either agricultural or environmental projects in which such techniques are also commonly employed. It is also challenging because usually only trace amounts of the soil sample material (<1.0 g) are collected for forensic investigations [10,11], and such limited amounts might not be sufficient for analysis under the conventional protocols of soil science. For forensic purposes, some adaptation and optimization of those techniques might therefore be required to make them reasonably time efficient and capable of delivering reliable and reproducible results from a small amount of soil sample, thereby achieving results that can efficiently differentiate samples from different sites or show similarities in samples from the same site [9].

Sites used for the disposal of bodies or for crimes are generally uninhabited, such as river floodplains, where the commonly occurring organic soils make the work of digging a pit and burying something inside it relatively simple. Soils in such areas are often classified as histosols, which, according to the Brazilian Soil Classification System, contain >80 g kg^{-1} of organic carbon and occur in areas of low temperatures and/or in wetlands [12].

In past forensic studies of soil traces, analysis of the inorganic mineral fraction has been prioritized [13–16], and no specific protocol for the analysis of the organic fraction of soil has been reported in the literature. The development of analytical protocols for examining and categorizing small amounts of organic matter

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would be highly valuable for the advancement of the area of forensics that addresses crimes committed at sites containing organic soils. By using quantitative variables gleaned from soil organic matter (SOM), it is possible to differentiate soils with essentially the same mineralogy. Therefore, the aim of this study is to provide a protocol for the analysis of small amounts of organic soil samples for forensic investigations by using physical fractionation and elemental analysis capable of differentiating samples from various sites.

2. Materials and methods

2.1. Study sites and soil samples

The study was conducted in the towns of Piraquara and Balsa Nova, which belong to the metropolitan region of Curitiba-PR, Brazil. Samples at a depth of 5 cm from the top of organic soils were collected from five representative sites along the Iguaçu riverbank, including three sites in Piraquara (sites 1–3) and two sites in Balsa Nova (sites 4 and 5) (Fig. 1 and Table 1). For each site, four soil samples (samples A–D) were collected and served as replicates. Each sample (~400 g) constituted a combination of four subsamples (~100 g of each sample) collected ~20 cm away from each corner of a delineated 3 × 3 m square (Fig. 1b). According to the site and replicate, composite samples were named as 1A–1D, . . . , 5A–5D.

Soil samples were air-dried, homogenized, and sieved to a fraction of <2 mm, so that roots and pebbles of size >2 mm were discarded. Samples were dried at 40 °C for 24 h. Considering that soil vestiges in forensic investigations are generally scarce, each dried sample was homogenized and quartered to obtain a 1 g

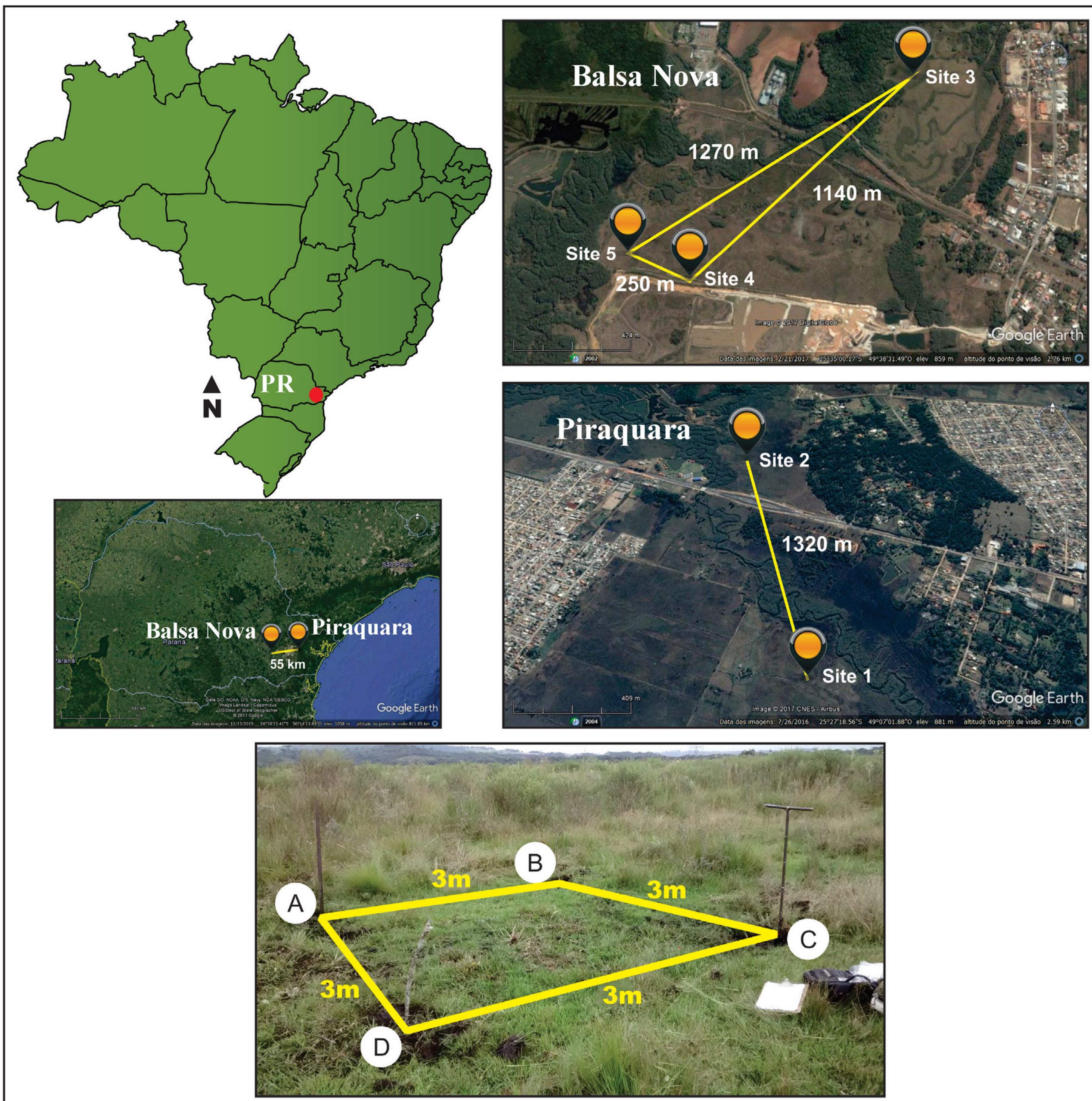

Fig. 1. Location of the study sites (Piraquara and Balsa Nova, Paraná State, Brazil) and schematic representation of sampling of the organic soil at each site. The five sites were located on riverbanks.

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