Evaluation of tree root depth and piezometric level in a historical botanical urban garden in Lisbon city, Portugal

Maria Paula MENDES[1], Ana Paula FALCÃO[1], Nuno AFONSO[1], Miguel ESTEVES[2], Maria Catarina PAZ[3]

[1]CERIS, Instituto Superior Técnico, Universidade de Lisboa, Portugal
mpaulamendes@tecnico.ulisboa.pt
ana.p.falcao@tecnico.ulisboa.pt
nunofafonso@tecnico.ulisboa.pt

[2]CEG, Instituto de Geografía e Ordenamento do territorio, Universidade de Lisboa, Portugal
m.esteves@ciencias.ulisboa.pt

[3]ESTBarreiro, Instituto Politécnico de Setúbal, Portugal
catarina.paz@estbarreiro.ips.pt

ABSTRACT

The Lisbon botanical Garden, dating back to the 19th century, is home to nearly 18,000 of plants species from around the world. As construction work is being planned that involves soil excavation near the garden boundaries, it is crucial to establish whether tree roots can access the groundwater level in the area potentially affected by this work. Given the garden´s natural and historical significance, our research was conducted using non-invasive techniques, such as near-surface geophysics. Specifically, electrical resistivity tomography (ERT) and ground-penetrating radar (GPR) were employed to assess tree root depth and establish the saturated zone, respectively. The applied methodology allowed us to determine that: (1) groundwater levels were higher in May 2021 compared to October 2020, ranging between 3 and 2.7 meters, and 4 and 3 meters, and (2) the mean root system depth is approximately between 2.5 and 3.0 meters. The results obtained will assist in defining mitigation measures and guidelines to prevent the loss of these important species.

1. Introduction

Situated in the heart of Lisbon, in the Príncipe Real district, the 1878 Lisbon Botanical Garden is home to an enormous diversity of plants, and it is particularly rich in tropical species from New Zealand, Australia, China, Japan, and South America. Preserving the *in-situ* conditions of certain collections, notably palm trees and cycads, is of utmost importance due to their significance.

Lisbon enjoys a mild Mediterranean climate, characterized by a dry period of five months from May to September. The garden's terrain features rough and irregular relief, a result of its natural geomorphological evolution. A prior survey identified an upper landfill layer, with maximum depth of 13 m, consisting of sandy-clay deposits containing limestone and basalt fragments/blocks, fossil remnants, and various materials (e.g., plastic, wood, bricks). Our study is focused on this layer, as it encompasses the root zone and the upper phreatic zone. These landfill deposits are recharged by precipitation, irrigation water, and seepage from the water and sewage distribution networks.

Electrical resistivity tomography (ERT) is a non-invasive approach that is well-suited for assessing root zone. It relies on the sensitivity of soil resistivity to factors such as moisture content, density, lithology, and the presence root. ERT can provide valuable insights while causing minimal disruption to the site, as indicated in previous studies (Nijland et al., 2009; Octavian et al., 2020; Vanderborght et al., 2013). Ground-penetrating radar (GPR) is another non-invasive technique that proves useful for determining groundwater table, particularly in garden pathways (Essam et al., 2020; Paz et al., 2017). GPR operates by emitting electromagnetic radar pulses within a frequency of 10–1000 MHz to create subsurface images.

In order to determine whether tree roots can access the groundwater table in two plots, we conducted a total of two Electrical Resistivity Tomography (ERT) profiles and three Ground-Penetrating Radar (GPR) profiles on two separate dates: 17 October 2020 and 7 May 2021. This research is of utmost importance in ensuring

the protection of the trees, especially given the construction plans that involve soil excavation near the garden's vicinity. These construction activities could potentially alter the groundwater flow, making the study essential for safeguarding the trees' well-being.

2. Results

The three GPR profiles showed that the groundwater levels were higher in May 2021 compared to October 2020, ranging between 3 and 2.7 meters, and 4 and 3 meters, respectively (Fig. 1). These values align with previous studies that utilized piezometers to measure groundwater levels and obtained similar results within this range. The three ERT profiles provided insight into the depth of the root zone, which was found to be approximately between 2.5 and 3.0 meters deep. This implies that nearly all the roots in the two plots can access the water table during the springtime. An example of the ERT profile obtained in October 2020 is depicted in Fig. 1, where the root zone is characterized by higher resistivity values (40 ohm m and 140 ohm m).

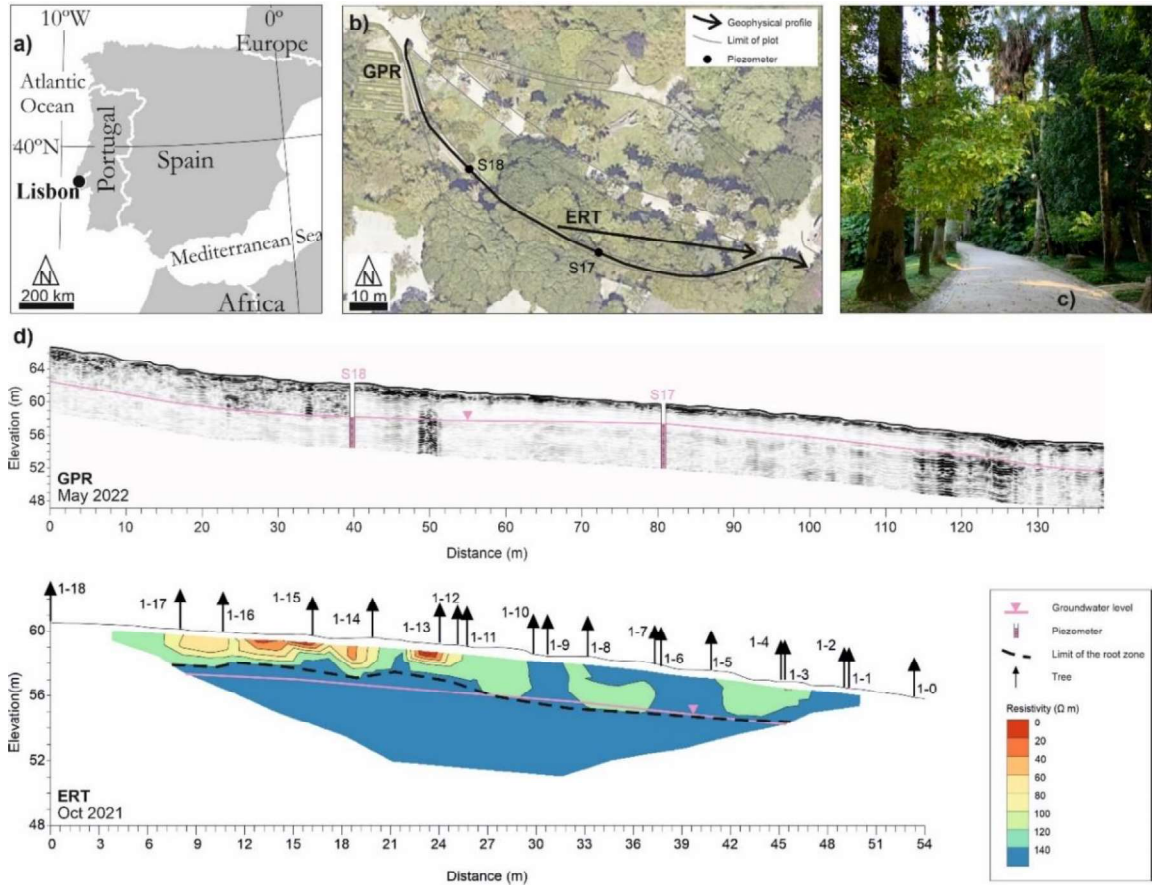

Fig. 1. a) Location of Lisbon Botanical Garden; b) detail of Lisbon Botanical Garden with the location of the geophysical profiles; c) example of trees and pathways of the garden; d) ground penetrating radar (GPR) and electrical resistivity tomography (ERT) models.

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