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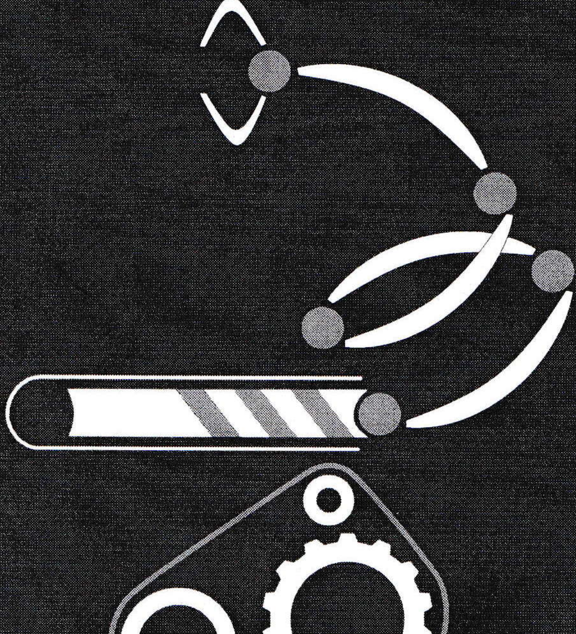

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ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY TO ASSIST THE LANDSCAPE PROJECT AT THE MACEDONIA CAMPUS AREA, EDIRNE, NW TURKEY

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Abstract

An electrical resistivity tomography (ERT) method yielding an information on resistivity changes in both vertical and lateral directions has been applied to contribute to landscape design by investigating groundwater potential in the Macedonia Campus area (Edirne, north-western Turkey). The ERT studies were performed using a Wenner–Schlumberger electrode array along 24 profiles in the directions of N–S and E–W. The ERT tomograms obtained by 2-D inversion of apparent-resistivity data clearly identified shallow subsurface conditions of the survey area. Based on the results, we can conclude that groundwater level has not been observed in the area since shallow subsurface is dominated by high clay content. Therefore, it is suggested that when preparing the landscape design project for the area green infrastructure and xeriscaping will be used.

Keywords: Electrical resistivity, groundwater, xeriscaping, green infrastructure, landscape project, Edirne.

INTRODUCTION

The water shortages, drought and desertification caused by global climate change, causes negative effects on ecosystem structure and function and the deterioration of the natural landscape. Mainly due to increasing population and urban construction over the world are experiencing severe water shortages and natural water balance is affected negatively. Up to 2% of the rainfall in a natural basin flows into local waterways; the remaining amount is filtered into the ground or is used by plants. Due to impervious surfaces such as buildings, pedestrian and vehicle in built-up areas, 95% amount of rainwater flows as the free surface water or enters to sewage system. Water scarcity requires the efficient management of water. Acquisition of rainwater in water management issues for a sustainable environment, used / waste water recycling, protection of the quality and quantity of groundwater, conservation of natural water corridors (streams and rivers), creation of sustainable landscapes, issues such as minimizing the use of potable water is located [1, 2, 3, 4, 5].

A water-wise landscape requires a minimal amount of supplemental water from irrigation. When irrigation is used, water is applied efficiently and effectively to make every drop count. Using irrigation water efficiently also requires us to select the appropriate type of irrigation for the plants and for each area of the landscape. Trees and shrubs in the low water-use zone would need supplemental water only during establishment (first 8 to 10 weeks after transplanting); plants in moderate water-use zones require water only during periods of limited rainfall when they show signs of stress. For these plants, a temporary system such as a soaker hose or hand watering may be all that is required. On the other hand, high water-use zones require frequent watering and may warrant a permanent system with automatic controls [6].

Near-surface geophysical methods displaying a non-invasive character are widely used to investigate geological, environmental and engineering problems such as groundwater explorations, defining physical properties of soil, waste-disposal site investigations, landslides and detection of faults [7, 8]. Among these, geo-electrical (i.e., direct current electrical resistivity, DCR) methods based on the apparent resistivity measurements along the earth surface are commonly used for investigating various environmental problems [9, 10, 11].

Nowadays, electrical resistivity tomography (ERT) technique achieved by a multi-electrode resistivity equipment following recent developments in the data acquisition is a standard tool in near-surface geophysical investigations [8]. Since two-dimensional (2-D) inversion of ERT data can provide very useful information on vertical and horizontal extends of geologic units and subsurface water content, it has various applications in the groundwater exploration, landslide studies, investigation of the waste disposal areas and archaeological prospection [12, 13, 14, 15].

Green infrastructure is a term used by United States Environmental Protection Agency (USEPA) describes products, engineering systems and applications that use natural systems to improve the quality of environment. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments [16]. Green infrastructure systems, particularly, have been widely used in environmentally sensitive countries such as the US, Canada, Australia and New Zealand since the early 1990s and are recognized as a valuable tool to adapt to the irreversible effects caused by the climate changes [16, 17, 18, 19]. This applications provide many environmental and economic benefits such as reducing the negative impacts to the ecosystem of the runoff (floods, the deterioration in water quality, high cost), saving energy and water, improvement of air quality and the increasing the be used of local materials [1, 3, 4, 5, 16, 20, 21, 22, 23].

There are different application methods depending on the usage and purpose of green infrastructure. Green infrastructure techniques used for sustainable stormwater management contain; green roofs, rain gutters, rainwater storage and handling systems (rain barrels, flower beds), bioretention applications, rain gardens, effective landscape design and irrigation (xeriscaping, native planting) and increasing permeable surfaces by reducing impervious surfaces (permeable asphalt, concrete and structural grass- coating systems) encompasses [4, 16, 24].

A number of terms describe waterconserving landscaping. Among them are "xeriscaping," "low water use," "droughttolerant," waterwise," and "desert" landscaping. The term Xeriscape comes from the Greek word xeros, meaning dry. The concept originated in Denver, Colorado, USA in the early 1980s. Drought-tolerant indicates the ability of a plant to survive on limited water, although these plants usually look better as water is increased. With improper watering, a drought-resistant plant may become a water guzzler in the landscape. As a result, vegetation in yards withered, a landscaping approach that uses small amounts of water but maintains a traditional look. The goal of a xeriscape is to create a visually attractive landscape that uses plants selected for their water efficiency. The seven water-saving principles of Xeriscape landscaping are; planning and design, soil analysis, practical turf areas, appropriate plant selection, efficient irrigation, use of mulches, appropriate maintenance. Properly maintained, a xeriscape can easily use less than one-half the water of a traditional landscape. Once established, a xeriscape should require less maintenance than turf landscape. A Xeriscape-type landscape can reduce outdoor water consumption by as much as 50 percent without sacrificing the quality and beauty of your home environment. It is also an environmentally sound landscape, requiring less fertilizer and fewer chemicals. And a Xeriscape-type landscape is low maintenance, saving time, effort and money. In urban areas, about 25 percent of the water supply is used to water landscapes and gardens. In the summer, as much as 60 percent of the water the average household uses may be for landscape maintenance. Many traditional landscapes require large amounts of water, and much of this water is applied inefficiently. Aside from occasional pruning and weeding, maintenance is minimal. Watering requirements are low, and can be met with simple irrigation systems. Using plants native to your area will eliminate the need for chemical supplements. Sufficient nutrients are provided by healthy organic soil. Fossil fuel consumption from gas mowers is minimized or eliminated with minimal turf areas. Use of native plants, shrubs and trees offer a familiar and varied habitat for local wildlife [6].

In this study an electrical resistivity tomography (ERT) method yielding an information on resistivity changes in both vertical and lateral directions has been applied to contribute to landscape design by investigating groundwater potential in the Macedonia Campus area and landscape project principles have been suggested for he campus.

EXPOSITION

The main material of the research is Macedonia Campus. It was completed in Sultan Abdulaziz period in 1871 and was used as one of the main military buildings in Edirne until 1877, with the name Harbiye Kışlası/ War Barracks. It was used as Military Hospital in the period Ottoman-Russian War between 1877-78, Girls Primary School between the years 1927-30, and after 1949 Gendarmerie School [25]. Trakya University has used the building since 2008, and it has been used as the Faculty of Architecture since 2012 (Figure 1).

The total area of Macedonia Campus is 19870 m^2. The area has a generally flat and moderately sloping topography. Medium slow permeability of the sandy-clay-loam soil is observed. The summer is very hot and the highest average temperature is 32°C in Edirne city. And the average annual amount of precipitation is about 700 mm [1].

Trakya University Macedonia Campus is an ideal study area for shallow geophysical researches. In addition to the structure used for the education and belonging to the Ottoman Empire period, it is still estimated to be the remains of the wall from the Ottoman period in this area. The control of groundwater and determination of ancient walls for providing conservation of them is an unavoidable necessity. Shallow groundwater should be determined as a result of geophysical applications, according to landscape design projects to be prepared to be used in irrigation and water demonstration area will also be taken to protect the remains of ancient buildings.

Fig. 1. The location and boundaries of Macedonia Campus

As is known, especially in the success of irrigation design in landscape design project is vital requirement. However, the use of drinking water in the landscaping is not desirable due to its high economical cost.

Therefore, it is preferred to perform irrigation by using surface or groundwater. Determination of shallow groundwater level will impact the irrigation projects, water demonstration areas and plant species selection of the landscape design. Implementation of landscape project with control of groundwater will also protect Ottoman buildings on campus. Because of shallow groundwater level can increase primarily the potential of corrosion effect on the building foundations. Secondly, groundwater rising by means of walls from the foundation due to capillarity causes a decrease in strength of the walls in a short time. An even greater risk is the soil liquefaction occurred in the presence of the building located in the earthquake zone. All of these effects lead to shortening of the building service life or the loss of building.

In this study an electrical resistivity tomography (ERT) method yielding an information on resistivity change in both vertical and lateral directions has been applied to contribute to landscape design in the Macedonia Campus area (Figure 2).

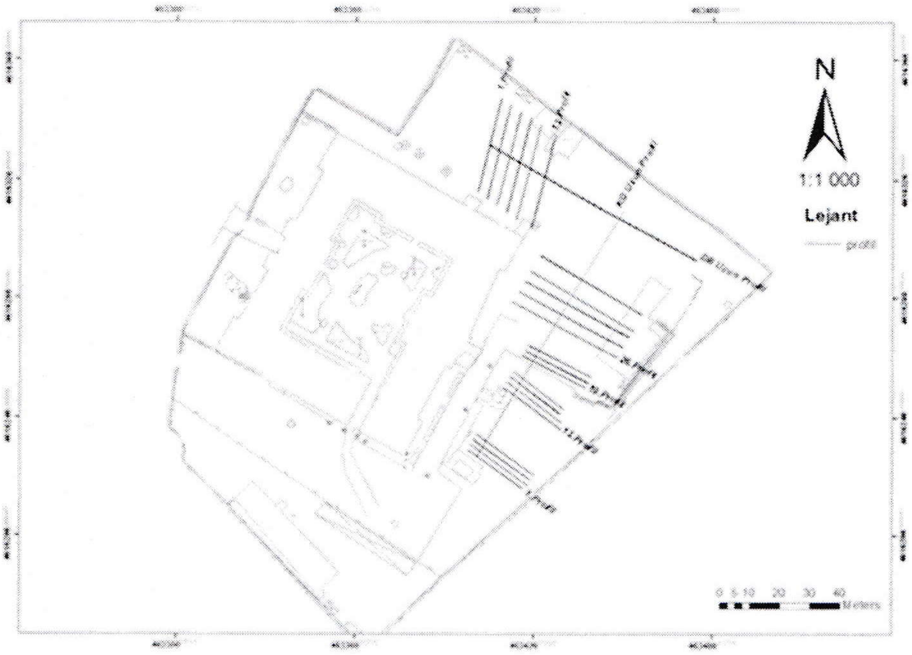

Fig. 2. *The site location map of the research*

The ERT studies were performed using a Wenner–Schlumberger electrode array along 24 profiles in the directions of N–S and E–W. The electrical resistivity tomograms obtained by 2-D inversion of data [26] clearly imaged the shallow subsurface conditions of the survey area. Figure 3a-c presents tomograms along the profiles 1, 16 and 21, respectively. RMS errors are in the range of 2.3-4.4%. Black dashed lines on the tomograms indicates the zones originated from clay content characterized by small resistivity values (ie., <30 ohm.m). Relatively higher resistivity values changing from 30 to 250 ohm.m represent normally consolidated clay zones and/or dry soil on the surface. High-resistive zones (i.e., > 400 ohm.m) in the NW part of the profile 3 caused from actual concrete basis in the area.

Whether or not enough water in the campus is one of the most important factors for designing of the landscape project of Macedonia Campus. On the basis of the groundwater level is not convenient for irrigation; it has become clear that landscape project of the campus will be designed according to xeriscaping and green infrastructure principles. Plant species in Table 1 will be used.

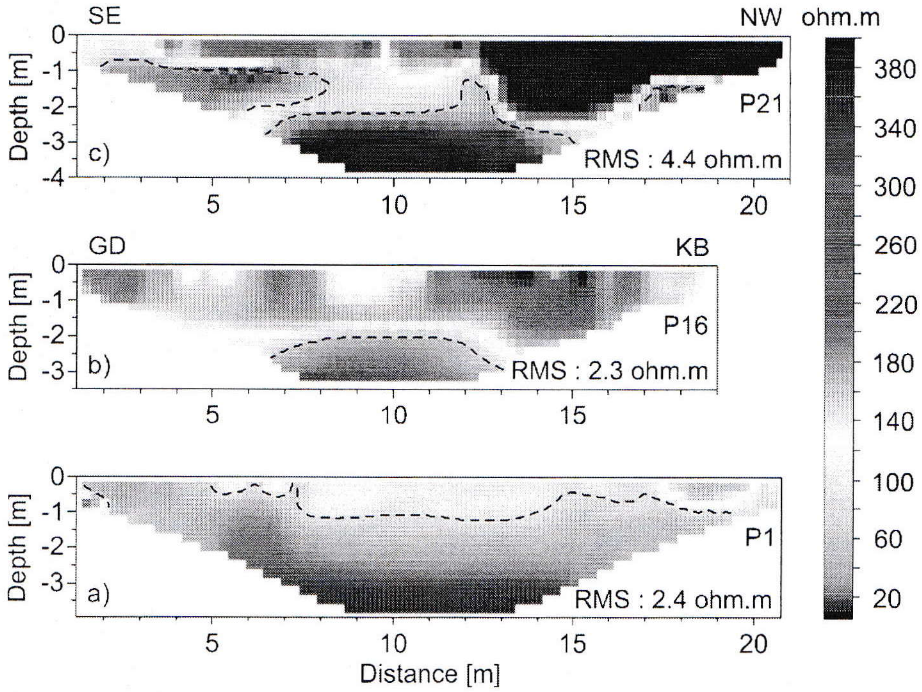

Fig 3. *Electrical resistivity tomograms along the profiles 1 (a), 16 (b) and 21 (c), respectively. RMS errors of each tomogram are also shown on the panels.*

Table 1. *Succulent Plant Species for Macedonia Campus*

Ground Covers	**Ivies and Climbing Plants**
Aizoaceae	*Campsis spp.*
Gazania spp.	*Hedera helix*
Sedum spp.	*Lonicera spp.*
Agropyron cristatum	*Parthenocissus tricuspidata*
Festuca arundinacea	*Polygonum spp.*
Poa pratensis	*Trachelospermum jasminoides*
	Vitis spp.
Trees	**Shrubs**
Acer campestre	*Berberis spp.*
Albizzia julibrissin	*Caragana arborescens*
Fraxinus americana	*Cotoneaster*
Cercis siliquastrum	*Cytisus spp.*
Lagerstroemia indica	*Eleagnus angustifolia*
Ligustrum japonica	*Hypericum calycinum*
Malus spp.	*Juniperus spp.*
Ginkgo biloba	*Lantana spp.*
Quercus pedunculata	*Lonicera tatarica*
Crataegus spp	*Mahonya aquifolium*
Sophora japonica	*Pitosporum tobira*
Arbutus spp.	*Pyracantha spp.*
Koelreuteria paniculata	*Rosmarinus officinalis*
Cedrus deodora	*Spartium junseum*
Celtis orientalis	*Vibirnum prunifolium*
Taxus baccata	*Spiria vanhouttei*
Tamarix spp.	
Rhus typhina	
Gleditschia triacanthos	

CONCLUSION

The results of 2-D inversion of apparent-resistivity data clearly indicates that groundwater level has not been observed and clay mainly dominates the Macedonia Campus area. With realization of applications of xeriscaping and green infrastructures, through the integrated stormwater management, environmental conservation, reducing the impact on the residential area of water, pollutant removal, water natural movement in ecosystems and the basin will be will be ensured in the boundary of Macedonia Campus. The study will be set a sustainable campus example for other settlements and campuses. Also, for Landscape Architecture and Architecture departments students studying in Macedonia Campus will be created an application laboratory.

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