Drone Imagery Combined With Soil Moisture Monitoring for Efficient Irrigation

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Abstract: Urban green infrastructure provide several benefits to inhabitants and helps cities adapt to climate change. This project aimed to develop a landscaping data integrator that provides smart data solutions for urban green infrastructure management, using soil, moisture sensors, and plant health imagery associated with workflow support for watering. Geostatistics was used to produce maps of soil moisture and compare them with thermal images taken by drones and the Normalized Difference Vegetation Index (NDVI) images of urban parks in Loule, south Portugal. The results revealed a linear regression with a coefficient of determination R^2 = 0.9607, R^2 = 0.9432, R^2 = 0.9523, respectively, for the months of August, September, and October. The method can be used to optimize urban green space management and assist in watering decisions.

Keywords: Green infrastructure, smart irrigation, NDVI, drone, geostatistics.

Introduction

Parks, gardens, lawns, urban forests, tree-lined streets and riverbanks support urban well-being by providing space for rest, relaxation and exercise, and by helping to combat adverse climate effects such as the urban heat island, especially during heatwaves (Panagopoulos et al 2020). Urban green infrastructure provides natural cooling of air and surfaces and supports water management in cities. The vegetation in these areas absorbs carbon dioxide, helping offset greenhouse gas emissions (Panagopoulos et al. 2016). Climate change is causing more severe and frequent heatwaves, drought, rainfall, and storms. Fight against urban heat islands by cooling the city by smart irrigation can be installed on all urban green spaces, parks, gardens, roadside, green roofs and walls.

A smart irrigation solution that meets the community's major challenges to save water in parks and gardens in increasing drought is a challenge. Smart urban irrigation involves applying the right amounts of water and nutrients to satisfy plant growth and vitality, at the right time. It involves using soil moisture sensors to improve water management, reduce irrigation rounds, and optimize costs by reducing plant mortality and water consumption. Drones using thermal or infrared cameras can provide a larger picture of water stress in urban green infrastructure and help reduce costs of plant replacement and water consumption.

Therefore, this research aims to compare soil moisture sensor data with NDVI and thermal imagery data to find a correlation that will assist in watering decisions.

Materials and Methods

The Communities Park of Almancil is located in Algarve, south Portugal (37°5'2"N; 8°2'0"W) (Figure 1). The park has been the target of several interventions to improve the integrated water and energy management at the site and enhance some of its environmental services, namely its capacity for carbon sequestration. The park has a total area of 2ha, including a child playground, a lake and other infrastructure. It is composed by tem lawns with a total area of 4.560 m2 formed by *Poa trivialis*, *Festuca arundinacea*, *Lolium perenne* and *Poa pratensis*. Several autochthonous shrub and tree species cover most of the park area (Belo et al 2020), but some Acacia spp can be found close to the Petagna playground. The most important tree species were a few *Populus* hybrids in the western part, *Olea europaea* and *Pinus pinea* at the center of the park, one *Ceratonia siliqua* and a *Salix babylonica* close to the lake, and *Cypreste* and Palm trees at the northern part of the park. From the shrub species, it should be mentioned the extensive use of *Nerium oleander* and several perennial flowers with high watering needs during summer.

The irrigation system is supported by four Rainbird boxes using 1800 and 5400 model springers. According to the municipality of Loule, on summer days, the communities park uses up to 7m^3 of water (irrigation during the night). A Desktop Lenovo ThinkStation P330 Gen2TW was used to store data and produce maps using the ArcGIS10 with geostatistical analyst software. A drone Dji Phantom4 and thermal and Rtk Multispectral cameras were used to capture RGB, soil surface temperature and NDVI images. A high Precision Gnss

Mobile Station Com and an Apple Ipad, together with a portable sensor Spectrum TDR-350 were used to register and georeferenced data of soil water content at 7.5cm depth. A meteorological station was used to collect data and correlated it to evapotranspiration. Following the study of Vaz et al (2022), several machine-learning models were developed to estimate reference evapotranspiration and solar radiation from a reduced feature dataset, such as temperature, humidity, and wind. They used experimental data collected from a weather station located in Vale do Lobo, south Portugal, and achieved the best result with a coefficient of determination R^2 0.975 over the test dataset.

Figure 1: Location and orthophoto of the community park in Almancil, South Portugal.

Results

A dataset of soil properties and NDVI was created with their georeferenced position in the field. Before creating surface diagrams, the distribution of data was analyzed. Kriging was used to produce maps of soil water content, soil electric conductivity and surface temperature in ArcGIS. The prediction map of each factor was calculated and the trend was added back to the output surface. Cross-validation and validation of the maps show that results were improved for electric conductivity, and pH but not for the other parameters. Following the procedure described by Panagopoulos et al. (2006) kriging cross-validation was used to estimate which of the semivariogram models could give the most accurate predictions of the unknown values of the field.

Data were collected monthly, but only the results taken on the 29th of August 2022 will be presented in this paper. Figure 2 shows a true color photo of the community park with lawns starting to suffer from the heat and the long drought. Figure 3 shows the result of NDVI image confirming that plants are starting to show water stress, while the comparison with the soil water content collected by the portable sensor confirms that the southern part of the park is in water stress. In the center of the park, the lake absorbs all radiation and had negative NDVI values. Green areas had high vitality and grey or cyan areas show the areas of the park without or low green cover.

Figure 4 shows that the lake and the large canopy trees help to cool the central and western part of the park, while the higher surface temperature in the northern part was influenced by the dark color of the materials at the children's playground.

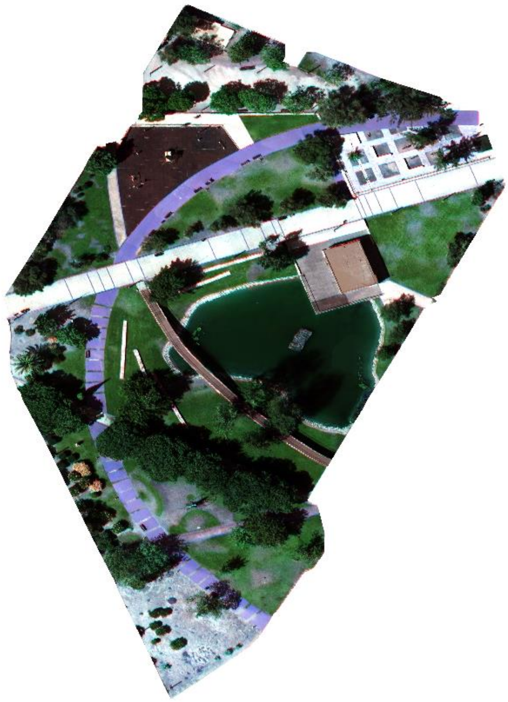

Figure 2: A true color RGB image of the Almancil, community park on 29th of August 2022.

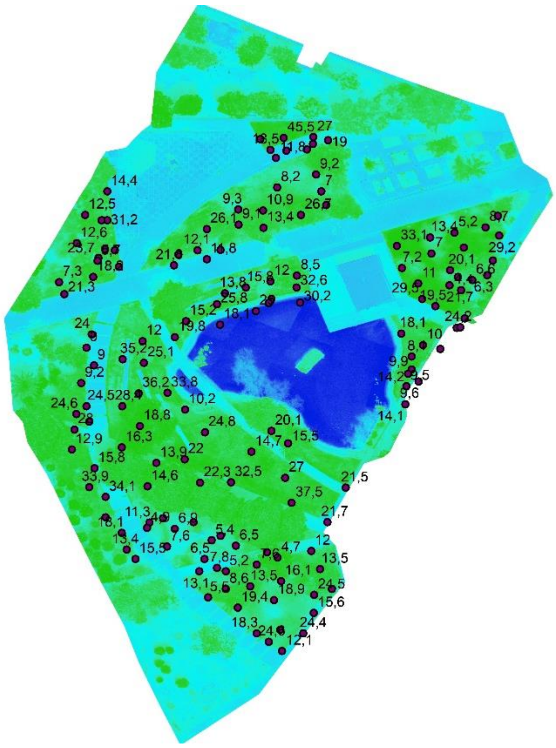

Figure 3: NDVI map superimposed on georeferenced sensors data of soil water content in the Almancil community park.

The low water content around the playground and at the southern part of the park was probably due to the lack of large canopy trees that could provide shadow (Figure 5).

The correlation of soil moisture with other meteorological factors revealed a strong relationship between soil water content and NDVI and, consequently, with the vitality of the park’s vegetation. Figure 6 shows that this correlation was strong with R2 = 0.9607.

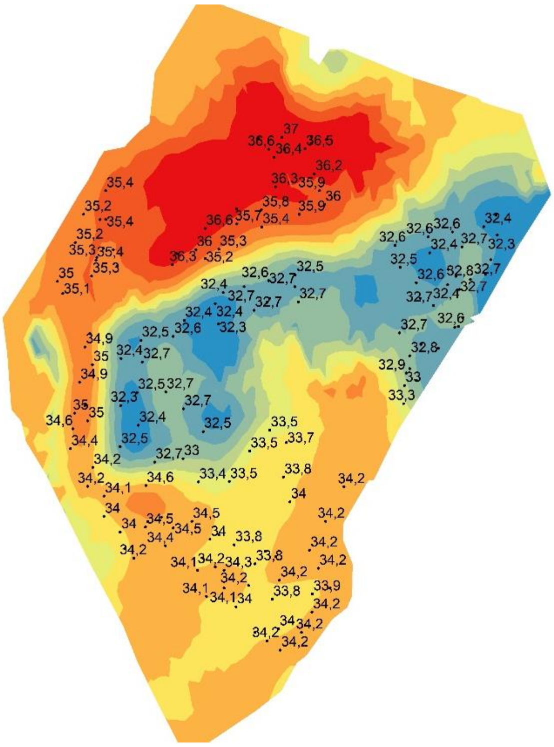

Figure 4: Surface temperature map of the Almancil community park.

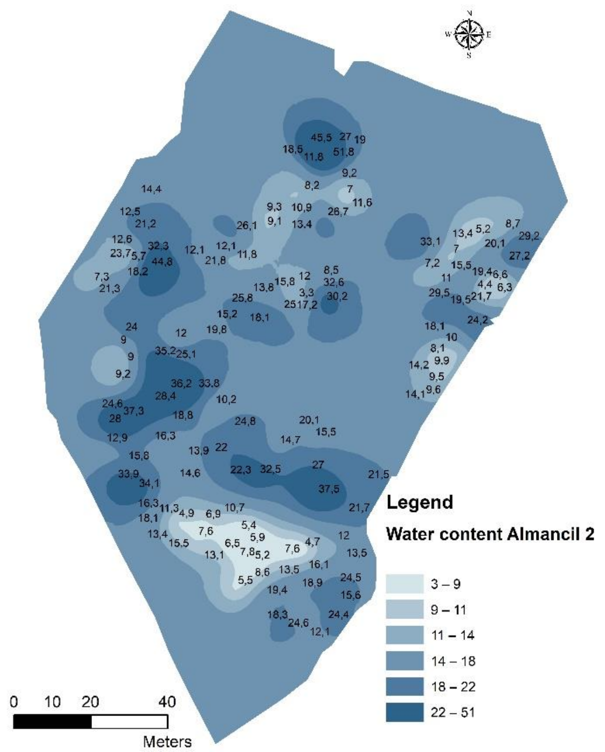

Figure 5: Soil water content map produced with geostatistics in the Almancil community park.

Similar results were also reported during the following months, with $R^2 = 0.9432$, $R^2 = 0.9523$, respectively, for September and October. The experiment was also repeated at the main park of Loule, showing similar results with R^2 varying between 0.87 to 0.92 with data collected on the same date as in the community park of Almancil.

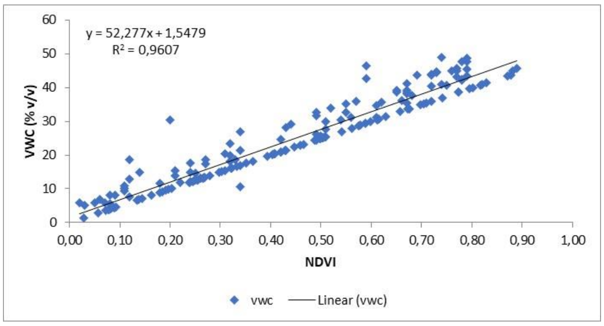

Figure 6: Linear regression between soil water content and NDVI data in the Almancil community park.

Conclusion

At the end of three months of data collection and choosing a sample in each of the months, it was revealed positive correlations between the soil moisture and the NDVI values of the existing lawn plots. In the communities park of Almancil, correlations with R^2 between 0.94 and 0.96 were recorded, while in the Municipal park of Loule the calculated correlations had R^2 values between 0.87 and 0.92. In both cases, the percentage of certainty in estimating soil moisture content through the use of NDVI maps was acceptable. The lowers values can be explained by the spatial variability influenced by the shade of large canopy trees and different lawn grass species. It was not possible to evaluate the correlation of live thermal imaging with vegetation vitality due to the shadows and the high variability of materials used in urban parks. Therefore, live drone NDVI imaging can be used to evaluate grass vitality in urban green spaces and assist in watering decisions of the urban green infrastructure.

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