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Aplicação da deteção remota para avaliar o consumo de agua nas paisagens do sul de Portugal

The remote sensing approach to assess the water demand in landscapes in the southern of Portugal

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Palavras-Chave
índices de vegetação
relva
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evapotranspiração
paisagem

RESUMO
A gestão da rega num espaço verde é um fator importante para a conservação da água, especialmente no clima mediterrâneo, com verões secos e quentes, onde a temperatura média anual é de 17° C e a precipitação anual raramente excede 700 mm por ano. A otimização do uso da água é obtida pela aplicação da quantidade correta de água, mantendo a qualidade visual das plantas, sem que ocorra perdas excessivas quer devido ao escoamento superficial quer à percolação. Na ausência de registos de consumo de água da paisagem, os índices de vegetação ajudam a determinar o gasto de água na paisagem. A deteção remota é uma ferramenta que permite avaliar a evolução da qualidade verde na paisagem. Este estudo visa avaliar o gasto de água nos espaços verdes urbanos do Algarve em 2016. Foram utilizadas imagens aéreas de alta resolução e dados climáticos para: i) identificar e medir a área da paisagem irrigada; ii) diferenciar as hidrozonas, que são áreas cobertas por plantas com necessidades hídricas semelhantes que foram identificadas por cor ou padronização; e iii) comparar o gasto de água da paisagem medida nessas áreas com índices de vegetação. Combinando toda a informação, foi conseguida uma melhor compreensão das tendências no consumo de água nos espaços verdes urbanos do Algarve. Este estudo é importante devido ao potencial de mudanças climáticas e projeções para o aumento da seca.

Key-word
vegetation indexes
turfgrass
hydrozones
evapotranspiration
landscape

ABSTRACTS
Landscape irrigation management is an important factor for water conservation, especially in Mediterranean climate with dry and warm summers where the annual average temperature is 17º C and annual rainfall rarely exceeds 700 mm per year. A proper landscape irrigation management to optimize the water use efficiency is achieved by applying the correct amount of water to maintain visual quality of the plants without excessive losses due to deep percolation or runoff. In the absence of landscape water consumption records, vegetation indexes help to determine landscape water demand. Remote sensing provides a tool to assess the evolution of green quality in the landscape. This study aims to evaluate water demand in the Algarve urban landscape in 2016. High-resolution aerial images and climatic records were used to: i) identify and measure the irrigated landscape area; ii) differentiate hydrozones, which are areas covered by plants with similar water needs that were identified by color or patterning; and iii) compare the measured landscape water demand in those areas with vegetation indexes. Combining all information, a better understanding of trends in water demand for Algarve urban landscape was achieved. This is relevant due to the potential for climate change and projections for increasing drought.

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Introduction

The Algarve province, located in southern Portugal, is an excellent region for practicing outdoor sports. Golf is a popular sport in the area, the sport generally requires a green turfgrass land cover.

Mild winters with light rainfall and hot and dry summers are the main climate characteristics of this region. In recent decades, the golf course area has grown dramatically in Algarve.

Currently, Algarve contains half of the existing golf courses in Portugal. Figure 1 shows the golf course area trend for 1960-2014.

This rapid expansion of irrigated landscape area in the last two decades has created huge demands for water and pressure to use water resources wisely.

Figure 1 - The irrigated area and the number of golf courses built from 1960 in Portugal.

Source: Author (2018)

Efficient landscape water management is achieved by applying the correct amount of water to maintain plant health and good appearance without excessive losses to deep percolation or runoff. After identifying areas with similar water needs, hydrozones, it is possible to achieve higher water use efficiency. (GIMENO et al., 2015; SNYDER et al., 2015).

For each hydrozone, the objective was to: (a) optimize the irrigation system distribution uniformity; (b) use the proper application rate and run-time; and (c) apply the correct amount of water to meet the plant needs. The correct amount of water to apply depends on accurate measurement or estimation of potential landscape evapotranspiration (ET_L), which can be achieved using a vegetation index, e.g., the *Normalized Difference Vegetation Index* (*NDVI*).

The *NDVI* depends on differences in spectral reflectance between the red (*RED*) and near-infrared (*NIR*) radiation wavelengths (ROUSE, 1973).

In addition to estimate ET_L, some authors reported significant correlations between *NDVI* and turfgrass visual quality (ANDERSON and FERMANIAN, 2008; BREMER et al., 2011). They found that the visual leaf quality can be estimated by *RED* reflectance, which depends on chlorophyll content, and *NIR* reflectance, which is affected by light scattering within plant cells (leaf structure).

RED light influences cell production and, consequently, this affects the reflectance in the *NIR*. BREMER et al. (2011) reported that reflectance in the

RED and *NIR* are distinct biophysical phenomena that may respond differently to environmental factors such as water stress. Remote sensing can provide real-time information on many aspects of turfgrass quality that are important for the decision of turf managers.

Historical water consumption records are difficult to obtain, so remote sensing provides an important technique to estimate water demand in large areas of landscape.

The purpose of this work was to evaluate the ability to use *NDVI* and climate data to estimate landscape water consumption of a golf course in Algarve, Portugal in 2016.

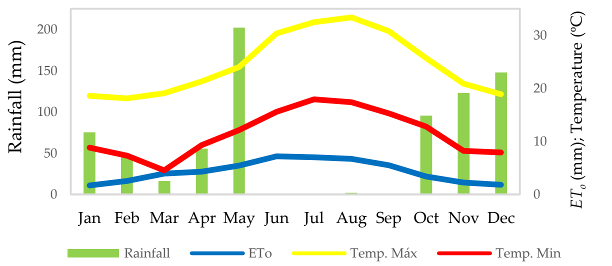
Materials and Methods

The landscape study was carried out in a golf course, Vale do Lobo, Faro district, Portugal (N37^{0}2.7' to N37^{0}3.8'; W8^{0}2.8' to W8^{0}3.8'). The soil type is a Regosol (CARDOSO, 1974) and the majority of the study areas (98%) is covered by *Festuca ruba L.*, *Poa pratensis L.*, *Lolium perenne L.* About 2% of the area is covered by *Agrostis stolonifera L.* (not evaluated in this study).

In nearby Faro, Portugal, the 2016 mean annual temperature was 17^0 C and annual rainfall was less than 700 mm year^{-1} (Figure 2).

Since most of the rainfall occurs in the winter, irrigation is needed mainly during the remaining months of the year to meet the plant water demand.

Figure 2 - The rainfall, reference evapotranspiration (ET_o), maximum and minimum temperature and rainfall in Faro, Portugal (DRAPALG, 2017).

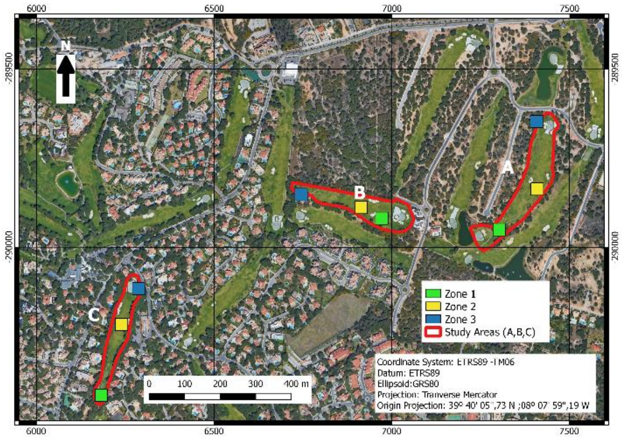


Source: Author (2018)

In this study were analysed three areas of the golf course (A = 21089 m^2, B = 21024 m^2, and C = 12781 m^2) delimited by the red lines in Figure 3. The weather stations were in Zone 1.

The Zone 2 was in the middle of each golf course area and the Zone 3 was located in the border of each golf course area. The weather station located in study area A had sensors to determine ET_o and ET_L, but in B and C only had sensors for ET_o.

Figure 3 - The locations of the three study areas (A, B and C) and the Zones (1, 2 and 3) in Vale de Lobo, Portugal.



Source: Author (2018)

Aerial landscape images were collected using a *Canon PowerShot SX260 HS* digital camera (Figure 4), with a resolution of 12.1 Megapixel (4000×3000 pixel), installed on an *Unmanned Aerial Vehicles* (UAV). The camera had a GPS receiver, which provided automatic georeferencing of the images.

Figure 4 - The UAV, *Phantom2 DJI,* and the camera, *Cannon Power Shot SX 260 HS*.

Source: Author (2018)

To perform the photogrammetric coverage of the study area, *DJI Ground Station 4.0* software was used to characterize the flight plan based on the following parameters: (i) study area (about 50 ha); (ii) focal length (4.5 mm); (iii) sensor height of the camera (6.16 mm); (iv) sensor width of the camera (4.62 mm); (v) flight height (100 m); (vi) height overlap (75%); (vii) width overlap (75%), (viii) horizontal speed (3.18 m s^{-1}); and (ix) vertical speed (6 ms^{-1}). After defining the number and position of the lines, the number of photos (200) with 3 cm of spatial resolution, the time of flight (14 min) and the total distance travelled (4 km) were determined.

The camera was modified (CRESS et al., 2015) to capture infrared wavelength and the *NDVI* images. Monthly *NDVI* images were compared each other to evaluate and understand the differences the NDVI average between studied zones (1, 2, and 3), which were inside or near the areas A, B, and C. (Figure 3).

The orthophoto mosaic from each location was built using the *Agisoft Photoscan 1.1.0* software.

These orthophoto mosaics were georeferenced at the *TM06-ETRS89* coordinate system, with *ArcGIS 10.2* software. *NDVI* was calculated using the following Equation 1:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \qquad \text{(Eq. 1)}$$

Where, ρ_{NIR} and ρ_{RED} are the near-infrared (*NIR*) and red (*RED*) reflectance's, respectively. In the modified camera, the ρ_{RED} was replaced by the ρ_{BLUE} reflectance. An ET_o map was developed from the interpolation of climatic data, by the *Inverse Distance Weighted* method (*IDW*), of the weather stations distributed in the study area.

The landscape evapotranspiration (ET_L) of a golf course could be estimate by the Surface Renewal (SR) method (SNYDER et al., 2008). Early studies showed the potential of this SR method to accurately estimate the ET_L (SNYDER et al., 2015). The reference evapotranspiration (ET_o) was determined by *Penman-Monteith* method (ALLEN et al., 1998, 2005). The latent heat flux (*LE*) was determined using the *SR* method (QUI et al., 1995) by estimating sensible heat flux density (*H*), net radiation (R_n) and soil heat flux (*G*) data. The *LE* was calculated as the residual of the energy balance (Equation 2):

$$LE = R_n - G - H \qquad \text{(Eq. 2)}$$

The ET_L is estimated, by dividing *LE* by the latent heat of vaporization (L = 2.45 MJ m^{-2} mm^{-1}). More details on the surface renewal measurements and analysis are provided in SHAPLAND et al., (2013).

To optimize efficient water use, it is necessary to understand the relationship between landscape performance under well-watered and drought stress conditions based on the areal imagery and ET_L analyses. This knowledge provides information for irrigation design and management to reduce environmental impact and maintain a health appearance of the landscape.

The landscape coefficient in study area A was estimated by Equation 3:

$$K_L = \frac{ET_L}{ET_o} \qquad \text{(Eq.3)}$$

The vegetation coefficient was estimated following Equation 4:

$$K_V = \frac{K_L}{K_m} \qquad \text{(Eq. 4)}$$

Where K_m is a microclimate coefficient (Equation 5):

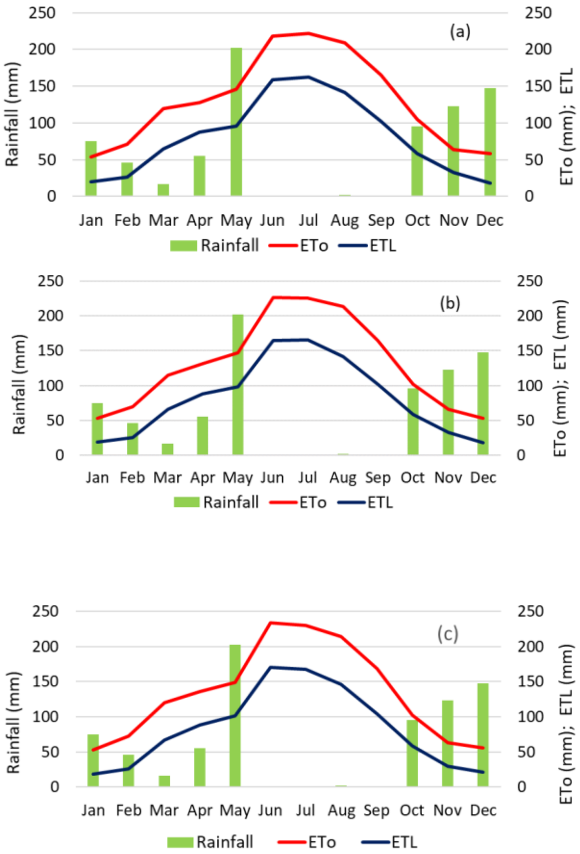
$$K_m = \frac{ET_{om}}{ET_0} \qquad \text{(Eq. 5)}$$

The ET_o is the reference ET representing the region (from A) and ET_{om} is the ET_o at the local stations (B and C), which might have different microclimate than the regional station at A. It is assumed that the K_V is similar in all microclimates (K_m). Based on K_V it is possible to determine the ET_L for all the study areas (B and C).

Results and discussion

The Figure 5 shows the rainfall, ET_o and ET_L in the study areas A, B and C, obtained in 2016. The difference between ET_L at the three areas and the rainfall (from nearby Faro) were 203.9 mm year^{-1}, 215.4 mm year^{-1} and 235.0 mm year^{-1}, respectively. The percentage of the deficit between ET_L and rainfall was 21%, 22% and 24%, in study areas A, B and C, respectively.

Figure 5 - The rainfall, landscape evapotranspiration (ET_L) and reference evapotranspiration (ET_o), in 2016, for the study areas A, B and C (a, b and c, respectively).



Source: Author (2018)

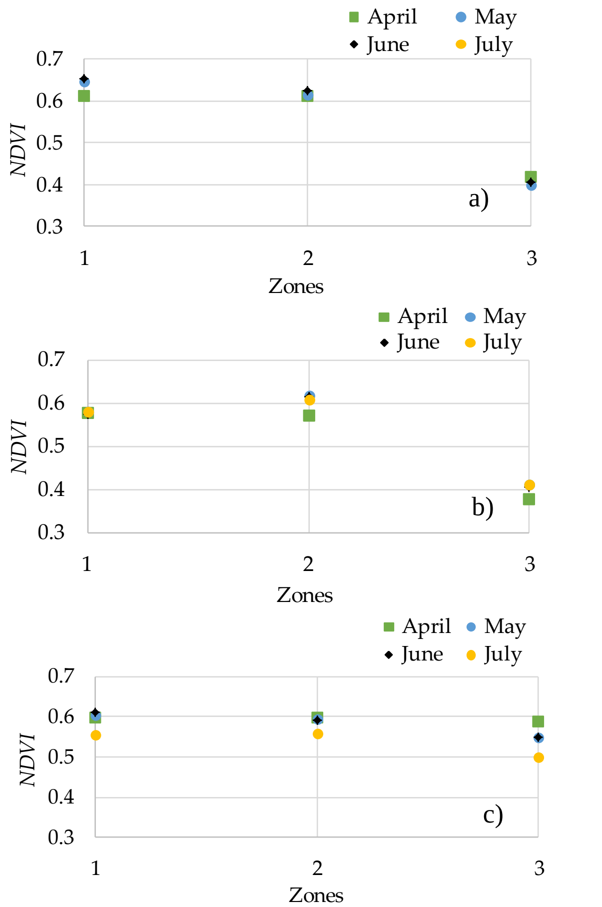
The average *NDVI* values from the three zones in the study areas, obtained between April and July, are shown in Figure 6. The *NDVI* values do not show significant differences between the spring and the summer.

In the month with no rainfall (July), to reach those *NDVI* values, irrigation was needed. Zone 1 and 2 present the highest *NDVI* values in all months implying that they were less stressed than zone 3, which was located in the boundary of the study areas where there was less irrigation. Thus, the *NDVI* values did give an indication of water stress differences.

May and June present the highest values of *NDVI* (about 0.6) in the zone 1 and zone 2. The *NDVI* values are similar, partly because the UAV flights took place in very close dates (17th of May and 2nd of June), and also because May was the month with more rainfall (200 mm). If the flight was carried out in the end of June, instead of June 2nd, the *NDVI* values similar to July (0.58) might be expected.

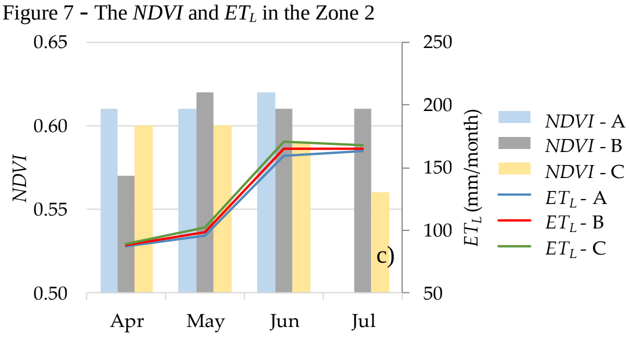
The ET_L was compared to the *NDVI* for the largest watered zone (Zone 2), from April to July (Figure 7).

Figure 6 - The *NDVI*, in 2016, of the Zones 1, 2 and 3 in the study areas A, B and C (a, b and c, respectively).



Source: Author (2018)

Figure 7 - The *NDVI* and ET_L in the Zone 2



Source: Author (2018)

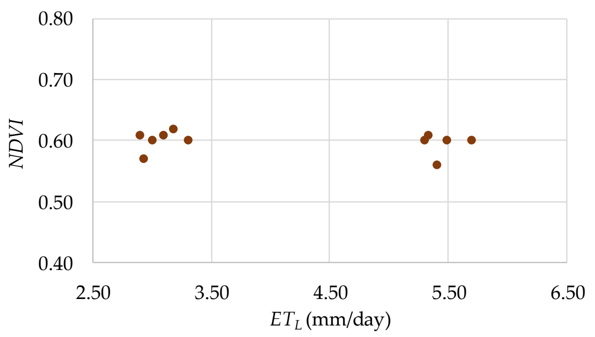
In March (16.4 mm) and April (55 mm) the rainfall records were lower than the crop water requirements in all study areas (about 65 mm and 90 mm, respectively) but the *NDVI* in April was about 0.6, which suggests that the study areas were irrigated in those months.

In May, the irrigation water requirements (about 100 mm) was lower than the rainfall (about 200 mm), which explains the high values of *NDVI* (approximately 0.6).

In June and July, the ET_L values were similar but the *NDVI* in June was higher than in July. The reason for this difference is explained above.

Some studies have found strong correlation between *NDVI*-ET_L (JOHNSON and BELITZ, 2012; GLENN et al., 2013). However, the results from April to July for the zone 2 show that, when irrigation is applied, the ET_L and *NDVI* are independent (Figure 8).

Figure 8 - Scatterplot of *NDVI* and ET_L in the Zone 2.



Source: Author (2018)

The irrigation adopted in the study areas aimed to achieve an *NDVI* ≈ 0.6.

In the absence of irrigation records, which were difficult to obtain, the *NDVI* approach is useful to better understand how the greenkeepers have dealt with the irrigation water management. Since the irrigation management resulted in an *NDVI* ≈ 0.6, it seems that the greenkeepers were promoting a good visual appearance.

Conclusions

This study illustrated the advantages from using remote sensing approach to evaluate the water demand in the Algarve landscape in 2016. The aerial images, collected from an *Unmanned Aerial Vehicle* (UAV), were used to measure the irrigated areas and to calculate vegetation indexes. These results provided information to assess the greenness quality of the landscape. The plant water requirements were obtained from climate records of three weather stations installed in different sites of the field. The results showed that irrigation strategies based on an *NDVI* ≈ 0.6 target achieved acceptable aesthetic conditions. Thus, remote sensing has the potential to quantify if irrigation applications are sufficient to give good quality turfgrass in a quick, accurate, low-cost way.

Further research in this scientific area will enhance the development of information to improve the beneficial use of water in landscapes especially with projected climate change and the tendency for more drought.

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