The Usefulness of Drone Imagery and Remote Sensing Methods for Monitoring Turfgrass Irrigation

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Abstract. Irrigation is an essential input for grasslands sustainability, especially in seasons where rainfall is not regular and insufficient. The scarcity of water in many regions of the world decreases timing and quantity of irrigation and affect the grasslands quality. The use of the remote sensing techniques as precise methods to control the efficiency and the management of irrigation contribute to the more sustainability of grasslands. Vegetation indices and canopy temperature are the most common remote sensing approaches used for a correct irrigation scheduling. In this study, we evaluated the green area vegetation index (GA) calculated from RGB (red, green, blue) drone images and the plant water status obtained through the canopy temperature (CT) measured by infrared thermometer and drone thermal imagery of turfgrass species growing under different water regimes (limited and high irrigation). Experimental plots soil moisture (SM) was controlled by soil sensors humidity. Both RGB and thermal images taken by drone showed a heterogeneity in turfgrass growth, with dries zones and absence of vegetation observed under limited irrigation. Under reduced irrigation conditions, lower SM and GA and higher CT were observed. Whereas, under the high irrigation values of SM and GA increased, while CT decreased. The soil moisture data correlated highly with both vegetation index and canopy temperature. This study highlights the usefulness of drones and sensors to evaluate turfgrass growth and irrigation efficiency.

Keywords: Remote sensing· Irrigation· Drone imagery· Vegetation indices· Canopy temperature· Soil moisture· Turfgrass sustainability.

1 Introduction

Irrigation is one of the important requirements for grasslands sustainability. The adequate maintenance of green space requires regular and optimum irrigation, which is difficult to apply in many regions where drought and high temperatures are frequent.

The authors of [1] reported that one of the main obstacles to establishing and maintaining green space is the scarcity of water, reduced rainfall affected strongly the quality of urban green spaces [2]. Given the high level of water deficiency in many urban areas and the high consumption of water by lawns, remote sensing techniques at the canopy level have become valuable tools for precision grasslands management. The utilization of remotely sensed data is a powerful device that can help in the development of management practices that save water and maintain a high turfgrass quality [3]. In this way, these techniques can help to the sustainability of green space, minimizing risks of decreasing grassland quality by providing (whenever possible) irrigation needed (adequate quantity of water, supplied in the correct time) to preserve the stay green of the grasslands. Recently, the advances in remote sensing instrumentation and unmanned aerial vehicle (UAV) provide an efficient process for the early detection of drought and the correct management of turfgrass irrigation [4]. The authors of [5] reported that for turfgrass growth supervision, the UAV are the best used as a platform for collecting aerial imagery, which can provide real-time information on many aspects of turf quality. Data derived from drone RGB images allows estimation of a wide range of parameters of turf quality like the plants vigor, leaf senescence and the total biomass. Furthermore, UAV thermal imaging also offers important information to improve water management in turfgrass [6]. Thermal imaging (i.e. thermography) is a good alternative to measure plant temperature, associated with transpiration at the canopy level [7,8]. Additionally, ground measurement of canopy temperature with infrared thermometry, has also been proposed in crop management to enable scheduling of support irrigation [9,10]. Soil moisture sensors can also help in crop irrigation management. These promising technology could lead to a complete automation of irrigation and to attain important water savings [11]. In this study we have evaluated data obtained from the drone imagery (RGB and thermal images), the infrared thermometer and the soil moisture sensors to assess the response of turfgrass plants to contrasting level of irrigation (limited and high irrigation). The main objective was to examine the effectiveness of drone imagery, infrared thermometer and soil moisture sensors as indicators of turfgrass quality under different water regime and to confirm the usefulness of these remote sensing techniques as key in the management and efficiency of turfgrass irrigation. The introduction of this study, presented in the section 1, explain the importance of these remote sensing techniques in the crops irrigation management, followed by related work in the section 2. The different techniques used are explained in the section 3. However, all results and discussion are presented in the section 4 and finally, the conclusions are displayed in the section 5.

2 Related work

In the present, digital imagery analysis has been successfully used to assess turfgrass colour and the percentage of green cover [12,13]. The digital images can be examined with computer software and used to quantify turf water and biomass status. The green area (GA) is one of the vegetation indices derived from red, green, blue images (RGB) analysis using the BreedPix open access software, the GA is considerate as a good indicator of green biomass status [14]. Similar work using RGB image to evaluate the plant performance under different water regime was also reported in wheat by [15,16], maize [17] and turfgrass [18,19].

Moreover, other works specificities that the use of spectral vegetation indices derived from UAV imagery is becoming a rapid and cost-efficient approach for crop management [20]. Many low cost drones with an integrated simple RGB camera are now accessible, allowing to take in a short time images of large turfgrass surfaces. In this context, the study [21] reported that unmanned aerial vehicle (UAV) imagery is considered as powerful tool used to evaluate turfgrass performance, with a high efficacy of data collection in relatively large trials.

Furthermore, many studies confirm the usefulness of the canopy temperature in crop irrigation supervision. An extensively used method for detecting water stress caused by stomatal closure is measuring the canopy temperature using thermal imagery [6] or the infrared thermometry [22]. The authors of [10] has reviewed the use of remotely sensed canopy temperature as a potential tool for irrigation management. When plant evapotranspiration is reduced, such as by soil water reduction, the rate of heat removal is reduced and the canopy temperature increases. Moreover, the authors of [23] reported that responses of turfgrass to water deficit conditions can be assessed by canopy temperature. The authors of [24] reported that thermal remote sensing techniques can be used by turf managers in a reliable manner to evaluate the irrigation needs of turfgrass, earlier than stress affect aggressively plants and the symptoms become perceptible to human eyes. Additionally, many other works highlight the sue of soil sensors moisture in detection of soil water status and crop irrigation management. The moisture sensors are among the most used strategies to manage crop irrigation schemes and to improve irrigation efficiency in grasses [25]. The importance in irrigation planning based on information provided by soil moisture sensors has been improved by technological advances in sensorization and communications [26]. In turfgrass, feasibility of soil moisture sensing devices has been indicated for the irrigation management of Bermuda grass [27]. Moreover, other authors [28] informed that for turfgrass management, the use of soil moisture sensors are efficient tools for the irrigation supervision, because they afford quantitative measurements of soil water in the active root zone.

3 Material and Methods

3.1 Material vegetal and growing conditions

Field trials were conducted during 2019 at the Madrid Institute for Rural, Agrarian and Food Research and Development (IMIDRA) in the area of Alcala de Henares, Madrid. Three C_3-C_4 turfgrass mixtures formed by *Poa pratensis* as C_3 turf and the *Cynodon dactylon*, *Buchloe dactyloides* and *Zoysia japónica* as C_4 plants were assayed in a with 75:25 ratio of C_3 to C_4. A total of 9 plots (three turfgrass mixtures and three replicates per mixtures) measuring 3 m × 1.5 m were planted on 4 April 2020. Irrigation was achieved by sprinkler in blocks connected by valves and controlled by the program of Rain Bird system irrigation (ESP-LXME Model). Two different irrigation regimes were assayed (limited and high irrigation) by controlling the soil moisture (Fig. 1) and the valve pressure of the irrigation system.

Soil moisture was controlled by sensors (Plantae station, Plantae, Spain) placed in the experimental plots and in the root active zone (at a depth of 10 cm). Water deficit was imposed for one months after plant germination by decreasing the amount of water applied. Irrigation was then increased to reach a high soil moisture content (Fig. 1), which was maintained for the following one months. Measures were taken during the periods of limited and high irrigation.

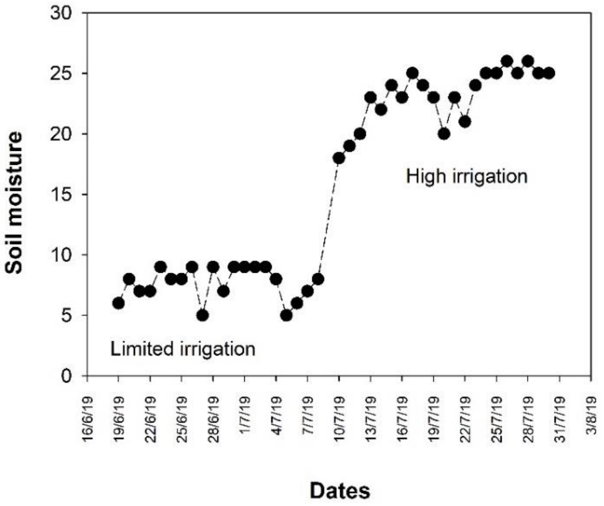

Fig. 1. Daily soil moisture collected by Plantae Sensor

3.2 Drone Flight and cameras

The drone used in this study was BEBOP-PRO THERMAL (Parrot, Paris, France), equipped with two cameras, the FLIR One Pro thermal camera and the RGB camera. The drone (Fig. 2) has 25 minutes of flight for each battery and 2 km of range. Drone flights were realized every 15 days.

3.3 Vegetation index and thermal imagery

RGB (red, green, blue) image were taken by drone camera for each plot. The pictures processing was achieved by the BreedPix 0.2 free-access software established for digital image processing [18]. The vegetation index calculated by the software was the green area (GA; portion of pixels with $60 < \text{Hue} < 120$ from the total amount of pixels). For each plot a thermal image was also taken by the drone thermal camera.

Fig. 2. BEBOP-PRO THERMAL drone used in this study.

3.4 Canopy temperature

Canopy temperature (CT) was measured on the same day of the drone flight, using an infrared thermometer (Fluke 561 sensor, China). Measurements were taken above the plants, pointing the thermometer laser in the direction of the canopy and with one meter of distance approximately.

3.5 Soil moisture

Soil moisture was controlled by sensors (Plantae station, Plantae, Spain), placed in each replicate of the experimentation and in the active zone of the root (at 10 cm deep). The soil moisture (with the specification of soil water status) was logged daily online on the Plantae Manager Website.

3.6 Statistical analysis

Data were subjected to factorial ANOVA to test the effects of irrigation on the turfgrass green area and canopy temperature. Pearson correlation coefficients between soil moisture and vegetation index and canopy temperature were calculated. Data were analysed using IBM SPSS Statistics 24 (SPSS Inc., Chicago, IL, USA). Figures were created using Sigma-Plot 11.0 for Windows (Systat Software Inc., Point Richmond, CA, USA).

4. Results and Discussion

4.1 Drone RGB and thermal imagery as irrigation indictors

The indeed of the use of UAV for monitoring and assessing crops has been growing steadily during the last decade, especially for the management of water stress [29]. Nowadays, both RGB and thermal imagery obtained by drone’s camera is essential water management of various crops and grasslands. In this context, our results confirm the useful of RGB drone imagery for detecting turf water stress. In this study, the drone RGB images taken under limited irrigation showed a heterogeneity in turfgrass biomass covering (Fig. 3A). The lack of irrigation provoked dry zones in the plot and absence of vegetation. Likewise, the thermal images taken by the drone (under water deficit) showed zones with higher canopy temperature in turfgrass plots (Fig. 3A). However, RGB and thermal images taken by drone when we applied high irrigation, displayed a high and uniform green biomass of turf plot and lower canopy temperature (Fig. 3B). According to this, [30] explained that the drone imaging can help to identify lawn stress more efficiently than the images taken from the ground. In addition, [29] reported that the conventional RGB cameras can deliver very high spatial resolutions even with UAV’s flying high, and they tend to be much more affordable than other types of sensor.

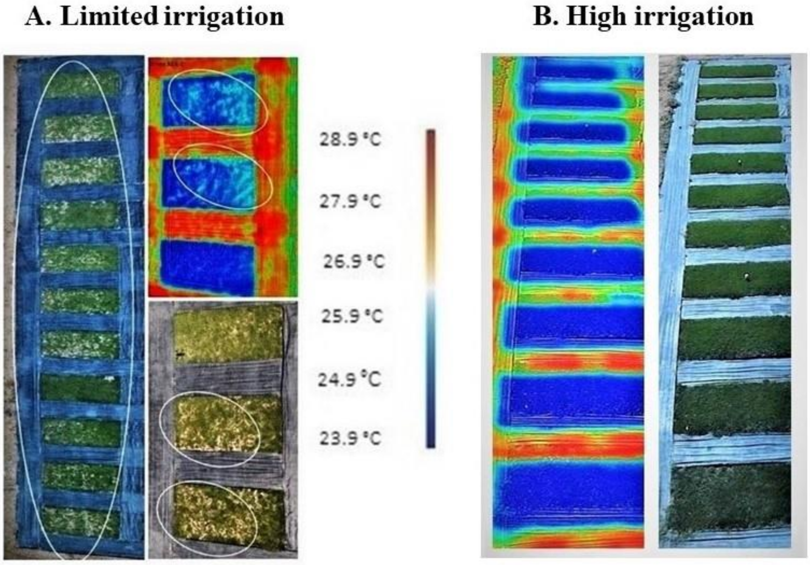

Fig. 3. RGB and thermal images taken by drone of turfgrass plots growing under limited and high irrigation.

4.2 RGB vegetation indices and irrigation management

Vegetation indices obtained by digital RGB (red green blue) images could inform on green biomass status [13,18]. In accordance, the green area (GA, calculated from drone RGB images in this study) was significantly ($p<0.000$) different between the two water regimes assayed (Fig. 4), with lower values observed under limited irrigation compared to high irrigation. This result is also in accordance with prior research in wheat [16] and in turfgrass [13] growing under different levels of irrigation. The absence of vegetation caused by the lack of water under reduced irrigation was reflected in a reduction of percentage of green biomass index (GA) obtained by remotely sensing imagery data. The study of [19] reported that the application of vegetation indices helps to highlight spectral differences including turf quality and colour. Actually, remote sensing technologies as vegetation indices obtained by drone have begun to be widely used for managing irrigation [31]. Proximal sensors would need to be complemented with special cameras on board UAVs to monitor the entire surface of large areas [32].

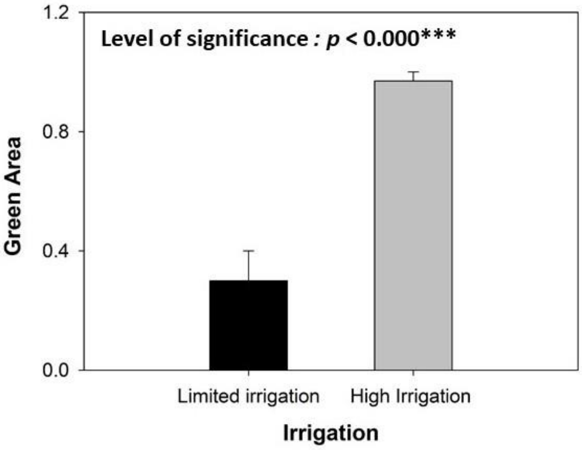

Fig. 4. Values of green area index under different water irrigation.

4.3 Potential of the canopy temperature detecting turfgrass water status

Water regime affected significantly turfgrass canopy temperature (CT) ($p < 0.000$) measured by the infrared thermometer (Fig. 5). Under high irrigation CT decreased, whereas it's increased under limited irrigation. As water stress occurs, transpiration and its cooling effects are reduced by stomatal closure, which results in an increase in CT [33,34]. in this context, it has been long known that plant temperature may represent a valuable index to detect differences in plant water regimes [35], and it is a useful tool for assessing turfgrass water stress [33,34], with less laborious work and more rapid response than other traditional techniques [36].

Moreover, and according to other studies [37], we observed that CT was strongly related to the vegetation indices (r= -0.82***). In this regard, lower CTs are strongly associated with higher green biomass, and can help to identify turf biomass and water status for a better irrigation prevision.

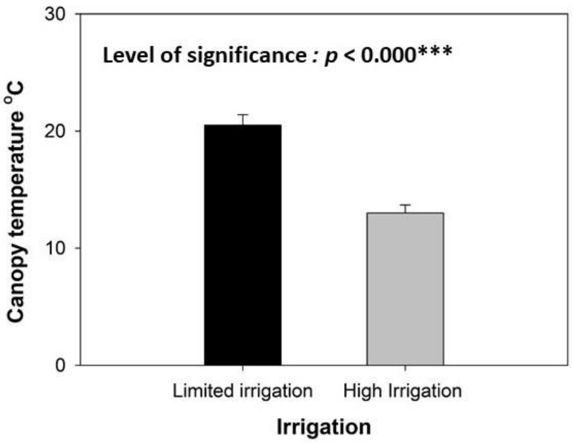

Fig. 5. Values of canopy temperature under different water irrigation.

4.4 Soil moisture

Data of sensors soil moisture of this study reflect reliably the differences between the two water regime assayed. Soil moisture was very lower (around 5%) under reduced irrigation (Fig. 1), whereas under the high irrigation soil sensors collected higher values of moisture (around 25%). In this context, the authors of [28] reported that soil humidity sensors can indicate when the soil profile is full of water or dry, and therefore maintained the high quality of turf by avoiding plant stress caused by the lack or excess of water. Thus, the advances in soil moisture sensors help to improve irrigation efficiency, by the collection of critical information in the active root zone, which can use in the irrigation management decisions [28]. Additionally, the soil moisture (SM) values found in this study were significant and highly correlated with the green area index and with the canopy temperature (Table 1).

Table 1. Correlation coefficients of the linear regression between the soil moisture and the green area and the canopy temperature. Significance levels: ***$p < 0.001$.

	SM versus GA	*SM versus CT*
Correlation Coefficient	0.92	-0.88
Level of significance	0.000^{***}	0.000^{***}

This results valid the usefulness of SM values as indirect measures to evaluate the performance of turfgrass species. In this context, as SM decreases, plants show a decrease in tissue moisture content, which in turn influences their reflectance properties [67].

5 Conclusions

One of the essential requirement for grasslands sustainability is the regular irrigation. However, in the last decade, the high need of turfgrass to water resources represents an important difficulty due to the lack and costs of water. For this reason, efficient management of water irrigation (adequate amount of water irrigation contributed at the right time) is required to maintain the quality and sustainability of grassland. This study showed the efficacy of the use of economical remote sensing devices for turfgrass irrigation management. The important relations found among the vegetation index (derived from drone digital camera), canopy temperature (measured by infrared thermometry) and soil moisture (obtained by soil sensors) under different water regime confirm the efficiency of these devices in turfgrass crop maintenance. Therefore, the accessibility, easy use and low cost of the infrared thermometer, drone aerial image process and soils sensors makes them a perfect device for turfgrass water management and green biomass estimation, mainly under limited growing conditions, when plants suffer an aggressive water stress. Moreover, in these lasts years, the real-time monitoring of crops growth by drone aerial imagery is considered as accessible technique and not so expensive (low cost drones). Drone can flight big surface of grassland in a little time and diagnose the dry areas due to lack of irrigation or the over-irrigated areas due to inefficiency irrigation. This study highlights the use of remote sensing devices in grasslands water management, strategies that can contribute in grassland sustainability and environment protection.

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