Unmanned Aerial Vehicle with Thermal Imaging for Automating Water Status in Vineyard

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Abstract

Thermal imaging is utilized as a technique in agricultural crop water management due to its efficiency in estimating canopy surface temperature and the ability to predict crop water levels. Thermal imaging was considered as a beneficial integration in Unmanned Aerial Vehicle (UAV) for agricultural and civil engineering purposes with the reduced weight of thermal imaging systems and increased resolution. When implemented on-site, this technique was able to address a number of difficulties, including estimation of water in the plant in farms or fields, while considering officially induced variability or naturally existing water level. The proposed effort aims to determine the amount of water content in a vineyard using the high-resolution thermal imaging. This research work has developed an unmanned aerial vehicle (UAV) that is particularly intended to display high-resolution images. This approach will be able to generate crop water stress index (CWSI) by utilizing a thermal imaging system on a clear-sky day. The measured values were compared to the estimated stomatal conductance (sg) and stem water (s) potential along the Vineyard at the same time. To evaluate the performance of the proposed work, special modelling approach was used to identify the pattern of variation in water level. Based on the observation, it was concluded that both 'sg' and 's' value have correlated well with the CWSI value by indicating a great potential to monitor instantaneous changes in water level. However, based on seasonal changes in water status, it was discovered that the recorded thermal images did not correspond to seasonal variations in water status.

1. Introduction

Precision viticulture is one of the most recent terms to emerge from the inclusion of viticulture into precision agricultural techniques, and it has received good feedback in recent years [1]. Precision viticulture has made a commitment to establish management zones, such as recognizing and classifying homogeneous Vineyard regions distinct from others in the same Vineyard. This methodology is recommended for high value crops like grapevine and when it is used by grape growing companies, it will incorporate site specific cultural practices for every categorized area [2]. This method may be utilized, so that when a new generation of rape harvesters is available, the UAV will be able to separate the grapes in the same field based on their ripening pace by increasing wine quality [3]-[4]. The most common information regarding zone delineation of field spatial variability are as follows:

- After a sampling grid, the data will be gathered

- Soil apparent resistivity or conductivity

- Vegetation indices are gathered from multispectral cameras in airborne monitoring vehicles

The disadvantage of these techniques is that they are not connected to plant water status, which is critical in influencing berry composition and grape yield [5]. Furthermore, climate changes will have an influence on water status, particularly in cold locations, where water deficit times are expected [6]. Hence, there is a need for monitoring the availability of water at a regular basis [7]. The use of thermal cameras to capture the entire field image fruits to be highly efficient as it gives an estimate of canopy temperature that connects the plants transpiration living to water status of the plant [8]-[9]. Unmanned aerial vehicles carry high-resolution thermal cameras to significantly improve the spatial and spectral resolution with the

outstanding performance of sensors in terms of lower weight and size. The level of ground resolution is impeccable with a reach of centimetres by using the latest thermal cameras and it can also be used to provide a high level of accuracy [10]. This will be critical in analysing discontinuous crops in rows such as fruit trees and grape vines. They are also emerging as a potential instrument in a variety of agricultural and irrigation management applications [11].

In viticulture, proximate thermal sensing has been proven to be the best technique for estimating plant water status [12]. These methods employ a thermal camera mounted on a crane or a shaft to observe zenithal view or is directly utilized to acquire lateral vision [13]. A strike of balance is established between somatic conductance or plant water potential and canopy temperature derived indices. However, UAV based thermal imaging solutions in viticulture is a feel that is yet to be explored due to the resolution requirement, which should ensure the avoidance of mixed vegetation/soil pixels and enable pure canopy pixels [14]. This is especially made up of high concern in vineyards due to the structure of crops on narrow rows. In [15], the authors observed the water status variability of a vineyard that was rain-fed commercially with the help of a UAV. However, they identified that certain vegetation indices based on the thermal images were not as well correlated to leaf water potential and stomatal conductance as the multispectral images [16]. Similarly, another group of authors studied the correlation between leaf water potential and crop water stress index which observed that there was a positive improvement in correlation around 12:00 p.m. it also indicated positive scope for or defining threshold which will be suitable for scheduling irrigation. The authors in [17]-[18] described the requirement using a UAV to monitor the water stress level:

Quick processing and turnaround acquisition times to help farmers make instant decisions using the real-time water status map.

- Using individual flights to evaluate the entire field

- Spatial resolution fixed onto the vehicle must be enough to avoid which vegetation soil pixel and focus on pure canopy pixel

- Establishment of a proper correlation between actual water stress and stress indices recorded.

The purpose of this work is to estimate the interest of high-resolution UAV-based thermal imaging waiting what is status of plants in a vineyard [19]. In this work we have used a high resolution thermal image, which is used at a commercially realistic scale and is examined to determine the extent of data gathered during a single flight campaign with respect to spatial variability of water over the seasons [20].

2. Proposed Methodology

2.1 Vineyard Layout

This work was carried out in a vineyard located in Coimbatore, Tamil Nadu, India exposed to a climatic condition of hot semi-arid climate. In the vineyard, we have placed a total of 15 buds for every meter, in a row with a spacing of 1 meters within the rows and a spacing of 4 meters between adjacent rows [21]-[23]. At the start of the experiment, the vineyard was 25 years old and followed standards practiced that that particular area such that the vines were not infected and were not exposed or affected by diseases or pests [24]-[25]. Only about 1.8% of the total plantation showed symptoms of moderate ESCA. Two sampling grids have been setup in the Vineyard based on spatial variability. The first grid uses and irregular pattern with status measurement points of 14 and I used for vine water status characterization [26]. The second grade is made up of 98 sampling points and arranged in a regular pattern with a mean distance between the sampling points of 30 x 30 m. This grid is used for agronomical vineyard characterization. At every water status point and sampling point, 12 vines are situated in neighbouring rows are identified. These vines are used for sampling procedures and experimental measures. Apart from agronomic measurements, the water potential of stem at noon and mid-morning are also measured [27]-[29]. At the time of harvest in 2019 and 2020, measurements of the fruits were taken at a 15-day interval. Leaves were chosen and taken in zip-lock bags 90 minutes before measurement. These zip-lock bags were then carefully placed

inside a high-density polyethylene reflective film. During measurement, data regarding plant cell density vegetation index and soil electric conductivity should also be gathered.
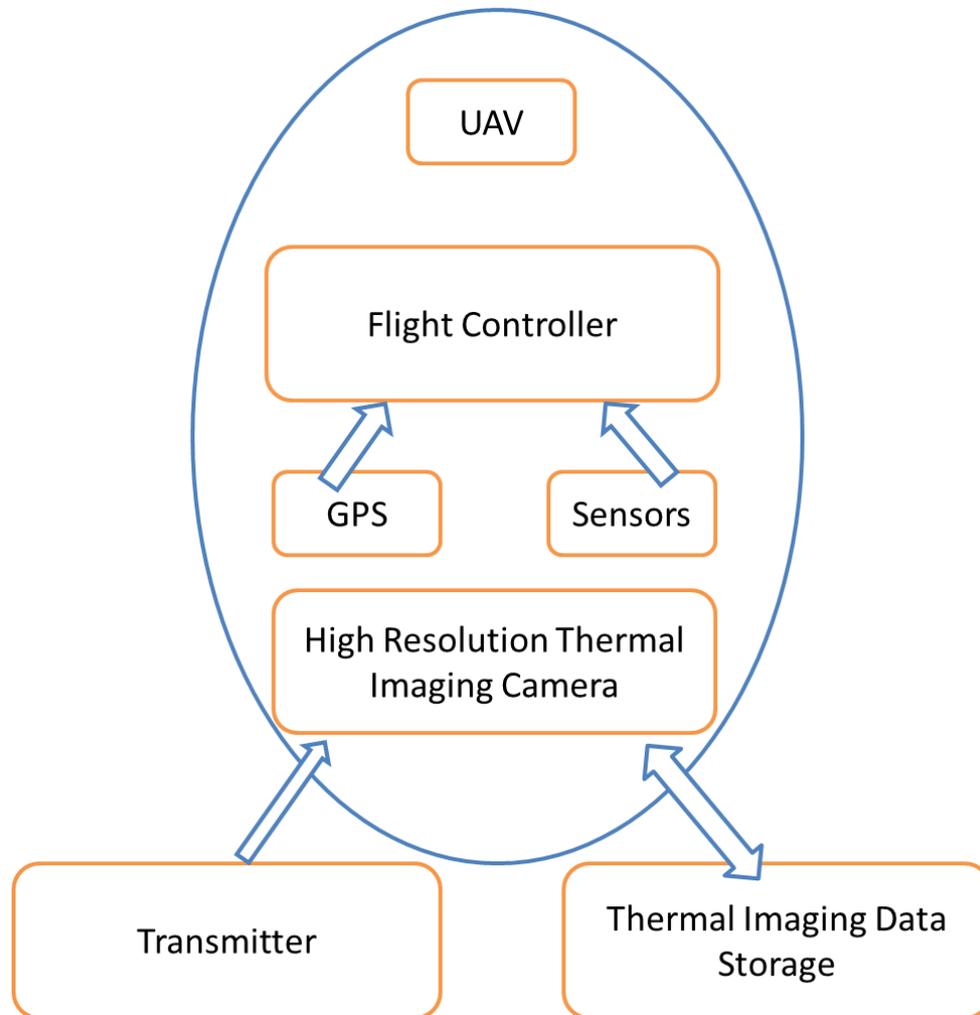

Figure 1. Layout of UAV with Thermal Imaging Sensors

2.2 Unmanned Aerial Vehicle Configuration

The proposed work uses a UAV platform that is capable of carrying a payload of 2 Kg for a period of 20 minutes flight time. The hardware of the UAV includes GPS V2.0 module, pre-assembled hardware and modified multi-rotor vehicle that work on an open-source project.

A radio link of 2.4 GHZ is used for communicating flight parameters with the ground operator. Another link of 5.8 GHz is used to transmit the remote sensing data. Using a two-wire bi-directional serial bus, communication between ATMega1284 microcontroller and the brushless controllers take place in a smooth manner. It uses a 3-axis accelerometers and pressure sensor to estimate and design the UAV with respect to gravity. The navigation control board is used to control the flight mechanism with a memory card and an ARM microcontroller. Similarly, autonomous flight can be monitored by using a LEA-6 GPS module and a 3D digital compass with navigation sensor system. It provides a leverage of 2m circular error, which paves way to autonomous fights at various levels. A total of 8 ATMEGA8 cards are used to control the brushless motor in an efficient manner with immediate response time.

The flight plan may be laid out using the proper motor software to provide users with a trail of waypoints while considering the degree of overlap in images, sensor Field of View, and necessary resolution at ground level. A total of 4 servomotors are used to guide the mounted universal camera to capture an accurate image acquisition on correcting the rolling and tilt effects. The utilized sensor has optimal configuration in weight and size at 72g and 45×45×30 mm respectively. The sensor has a fixed focal length of 19 mm, 324×256 pixels and a FOV of 24°×18° with 0.14 m/pixel resolution at a ground level of 40×30 m and a flight altitude of 100 m. At a spectral range of 7.5-13 m, the uncooled sensor in the camera is capable of measuring the long-wave radiation. In the laboratory, radiometric calibration was conducted with the help of blackbodies in ambient temperature and varying targets to design the radiometric calibration algorithm.

2.3 Enhancement of Energy Efficiency and Security

Using thermal image, the leaf emissivity is determined to enable the calculation of water stress using Crop water stress index with respect to the leaf temperature.

$$CWSI = \frac{Temp_{leaf} - Temp_{wet}}{Temp_{dry} - Temp_{wet}}$$

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Where, Temp$_{wet}$ and Temp$_{dry}$ represent the temperature for wet leaf and dry lead respectively. Similarly, Temp$_{leaf}$ indicates the surface temperature of leaf. The reference targets have a temperature of 35°C, 55°C and 65°C. In this work, we have incorporated Herrero Langreo et al methodology, which uses a set of predefined steps. Carbon isotope ratio is taken at 100 SP and the reference site is taken as the most stressed WSP. The model is executed and experimented by using the 's' parameter measurement at every ESP by considering the reading taken on a weekly basis during the years 2019 and 2020. The model can also be used to determine the average leaf water potential at every SP. According to Acevedo-Opazo et al, the following equation is used for spatial model testing.

$$\hat{\varphi}(s_x, t_y) = (b_0 + b_1 \delta^{13}C(s_x)). \varphi(s_{re}, t_y)$$

Where, $\delta^{13}C(s_x)$ represents the auxiliary variable $\delta^{13}C$, s_x and s_{re} correspond to the location of $\delta^{13}C$ and reference site at which φ is measured. t_y represents 20 dates when φ is measured.

3. Results and Discussion

It is essential to evaluate the instantaneous correspondence that takes place in water by using the thermal images to determine the values of stomatal conductance and stem water potential as observed in Fig.2 and Fig.3 respectively. Regression analysis is used to determine the readings recorded and identify the water status of the vineyard.
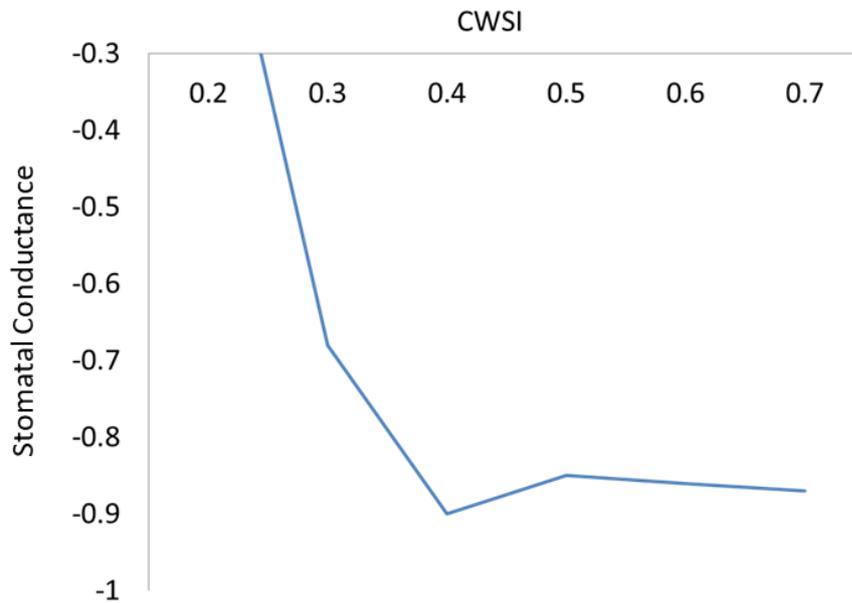
Figure 2. Stomatal Conductance Vs. CWSI

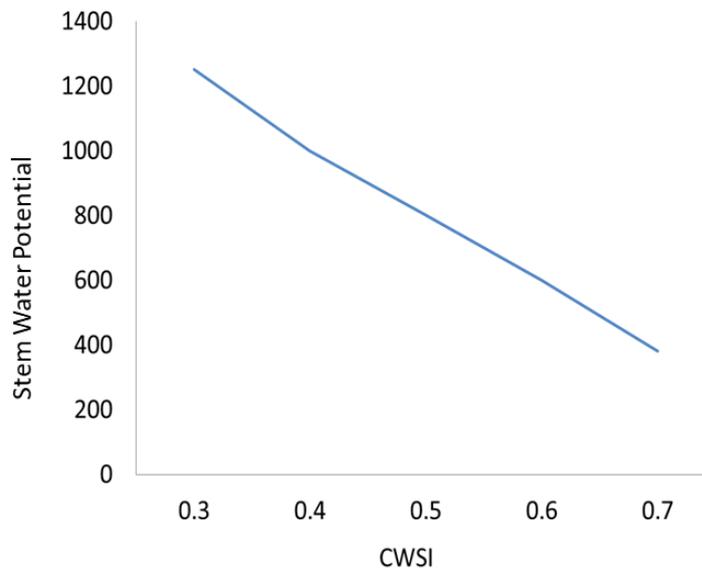Fig.4 shows a comparative study on the accuracy of thermal images, when compared with the previously existing methods.

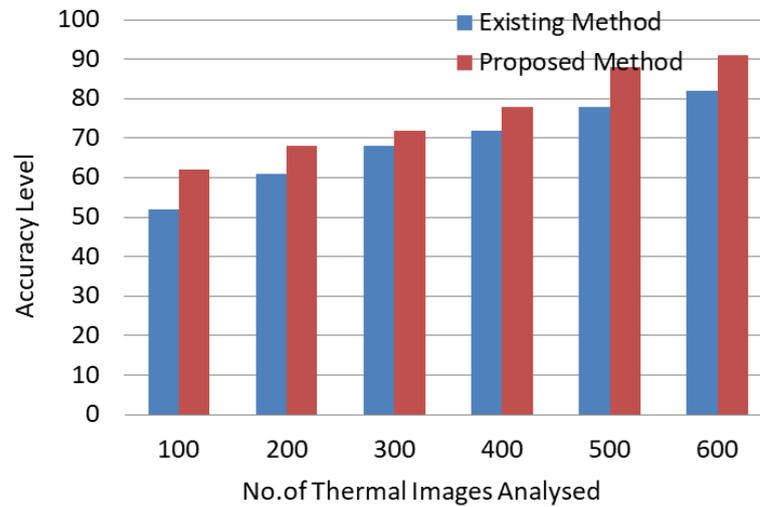**Figure 3.** Stem Water Potential Vs. CWSI

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Figure 4. Accuracy of Data using Thermal Images

4. Conclusion

The proposed work uses a UAV with thermal imagery that captures images of the area under consideration, in our case the vineyard. This methodology has been proved as an excellent mechanism to determine the water status in a vineyard by using high resolution thermal imaging camera mounted on the UAV. The captured image is transmitted with the help of sensor and then it is analysed to determine the water status. Even though, there is a slight variation in the observed water status values with respect to the changing seasons on a seasonal scale, these images are proved to be more reliable with the ability to identify physiological processing that occur at ripening time. Henceforth, in order to identify the water status, it is essential to obtain thermal images along with various dates during the particular season in order to arrive at a concrete solution for determining water status variation.

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