IV INOVAGRI INTERNATIONAL MEETING
XXVI CONIRD - CONGRESSO NACIONAL DE IRRIGAÇÃO E DRENAGEM
III SBS - SIMPÓSIO BRASILEIRO DE SALINIDADE

UAV AND TIRS-LANDSAT-8 USING FOR ACTUAL EVAPOTRANSPIRATION ESTIMATION ON CHARDONNAY VINEYARD IN PINTO BANDEIRA, RS, BRAZIL[1]

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ABSTRACT: The present study aims to obtain accurate data about the grape water requirement from the actual evapotranspiration estimation by combined sensors fixed under unmanned aerial vehicle (UAV) and LANDSAT-8 orbital sensor. The data were obtained by the TIRS sensor of the LANDSAT-8 satellite and by multispectral camera fixed to an UAV. Using the QGIS software, it was possible to implement the METRIC algorithm for the images processing. As results it was obtained net radiation, soil heat flux density, sensible heat flux and latent heat flux as information to actual evapotranspiration estimation by balance energy residual (LE = Rn – G – H). Even with loss of information with the use of LANDSAT-8 thermal (spatial resolution of 100 m) it was possible to reach precise values of evapotranspiration when combined orbital sensors with UAV-fixed-sensors. It was also observed that even in a small vineyard of 1.6 ha, there is considerable variability of water requirement. The challenge now is to understand this spatial variability associated with time variability. In this scope, our group is adjusting adequate mathematical algorithms to estimate this loss of water from the vineyard and to propose adequate strategies of water management.

KEYWORDS: *Vitis vinifera* L., irrigation management, unmanned aerial vehicle

USO DE UAV E LANDSAT-8 PARA ESTIMATIVA DA EVAPOTRANSPIRAÇÃO ATUAL EM VINHEDO CHARDONNAY EM PINTO BANDEIRA, RS, BRASIL

RESUMO: O presente estudo visa a obtenção de informações precisas sobre a demanda de água da uva a partir da estimativa da evapotranspiração atual da cultura por meio de sensores embarcados em drone e sensores orbitais. Os dados foram obtidos pelo sensor TIRS do satélite

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LANDSAT-8 e por uma câmera multiespectral acoplada a um veículo aéreo não tripulado (UAV). Com o uso do software QGIS foi possível implementar o algoritmo METRIC para o processamento das imagens. Como resultados foram obtidos o fluxo de calor sensível, fluxo de calor latente, fluxo de calor no solo e saldo de radiação para estimativa da evapotranspiração atual. Observou-se que, apesar da perda de informação com a utilização do termal do LANDSAT-8 devido à baixa resolução espacial de 100 m, é possível se chegar a valores precisos de evapotranspiração quando combinados aos embarcados em UAV. Observou-se, ainda, que mesmo num vinhedo pequeno de 1,6 ha, há uma variabilidade considerável de demanda hídrica. O desafio agora é compreender esta variabilidade espacial associada a temporal. Neste escopo, nosso grupo está ajustando algoritmos adequados para estimativa dessa perda de água do vinhedo e, com isso, propor estratégias adequadas de reposição de água (irrigação).
PALAVRA-CHAVE: *Vitis vinifera* L., manejo da irrigação, veículo aéreo não tripulado

INTRODUCTION

Remote sensing approaches for estimating evapotranspiration (ET) are gaining prominence for their large area coverage using a consistent dataset and the capability to map the spatial variability of ET at field scales. ET is an important process in the hydrologic cycle. Among the major water budget components, ET is in a gaseous state as opposed to precipitation and streamflow, making it the most difficult component to measure directly. ET comprises two subprocesses: (1) evaporation from the soil and vegetation surfaces and (2) transpiration from the plants. Consequently, ET plays a major role in the exchange of mass and energy between the soil-water-vegetation system and the atmosphere. Knowledge of the rate and amount of ET for a given location is an essential component in the design, development, and monitoring of hydrologic, agricultural, and environmental systems (Senay et al., 2016).

Traditional remote sensing approaches place remote sensors on towers over crop fields (thermal imagery, multi and hyper-spectral cameras, fluorometers, etc.) where the main limitation is the fixed position from which data is collected. Another traditional remote sensing technique is the use of aircrafts or satellites where the temporal and spatial resolution significantly limits their usefulness for agricultural assessments (it is important to consider the highly dynamic changes in vegetation in relation to the environment) (Moya et al., 2004; Louis et al., 2005; Berni et al., 2009a; Anderson and Gaston, 2013; Jones, 2014). In this context, UAVs (unmanned aerial vehicles) and remote sensing come into play useful tools because they are able to fill this important gap, coupled with aerial imagery and adequate computational efforts. In recent years, the use of UAVs for civilian purposes has begun to increase thanks to technological advances, cost reductions and the size of sensors related to the Global Position System (GPS), pre-programmed flights, IMUs (inertial movement units) and auto-pilots. In this sense, UAV technology can fill the gap of knowledge between the leaf and the canopy by improving both the spatial and the temporal resolution of the most common current remote sensing systems (Bernie et al., 2009b).

Modern optical remote sensors aboard an UAV provide the basis for the generation of very high spatial resolution images that can be used as inputs in the remote sensing energy balance algorithms to estimate spatial variability of energy balance components (Ortega et al., 2016). On this subject, multispectral camera placed on an UAV and thermal sensor from LANDSAT-8 could be a useful tool to advance our knowledge about the effect of intra-vineyard spatial variability on the partitioning of Rn into G, H and LE over Chardonnay vineyard whose row spacing is 2,2 m. Thus, the main objective of this research was to implement METRIC algorithm to estimate net radiation (Rn), sensible heat flux (H), soil heat flux (G) and latent heat flux (LE) over a young Chardonny vineyard using multispectral camera placed on a helicopter-based UAV and TIRS-sensor from LANDSAT-8.

MATERIAL AND METHODS

1. Experimental plot

The experimental plot selected was *Vitis vinifera* cv. Chardonnay rootstock Paulsen 1103 chosen among existing dry-farmed blocks in a 7 year-commercial vineyard in the Geisse Winery, “Serra Gaúcha” region (29°09'04”S; 51°25'38”W) and 740m above sea level. Soil texture of the 1.6 ha-selected-vineyard was silty clay loam with a 0.5 m maximum depth, medium water infiltration rate and water table within the reach of the roots. Soil water-holding capacity were taken according Richards (1965) among 6 points into the vineyard.

Grape Vertical Positioning System Vines were Guyot pruned about July/August and trained with a vertical shoot positioned trellis, with two fixed and two movable wires. Vine density was 4545 vines/ha with 2,2 m row spacing x 1,0 m between plants. Usually phenological phases dates are: budding at the end of August; flowering on middle of October; maturation start in January and leaf fall on April. The study covers 2014/2015 and 2015/2016 phenological cycles.

2. ET Remote Sensing data

Flights campaign collecting measurements were carried out on experimental vineyard that is relatively flat and uniform. It was used a helicopter-based unmanned aerial vehicle (UAV) from Aibotix® equipped with multispectral camera (Nikon CoolPixA®) for the generation of very high spatial resolution images that can be used as inputs in the remote sensing energy balance algorithms to estimate spatial variability of energy balance components. In this study was used METRIC algorithm and TIRS-LANDSAT-8 sensor to ET assessment.

Using QGIS software it was possible to implement the METRIC algorithm equations for the UAV and orbital images (Figure 1). First, it was applied the radiometric and atmospheric corrections using the SCP (Semi-Automatic Classification Plugin) to both images, obtaining an output image representing the spectral radiance of the surface. From this image, it were calculated the vegetation indexes, the NDVI (Normalized Difference Vegetation Index), the SAVI (Soil Adjusted Vegetation Index), and the LAI (Leaf Area Index). From this indexes and the image data, it was calculated emissivity (ε), surface temperature (T_S), and albedo (α), allowing the calculation of the surface net radiation (Rn), heat flux into the soil (G), sensible heat flux (H) and, finally, the instant latent heat flux (λET) through the equation:

$$\lambda ET = R_n - H - G \quad (1)$$

The λET was used to estimate the daily evapotranspiration dividing by the latent heat of vaporization (L=2.45 MJ m^{-2} mm^{-1}).

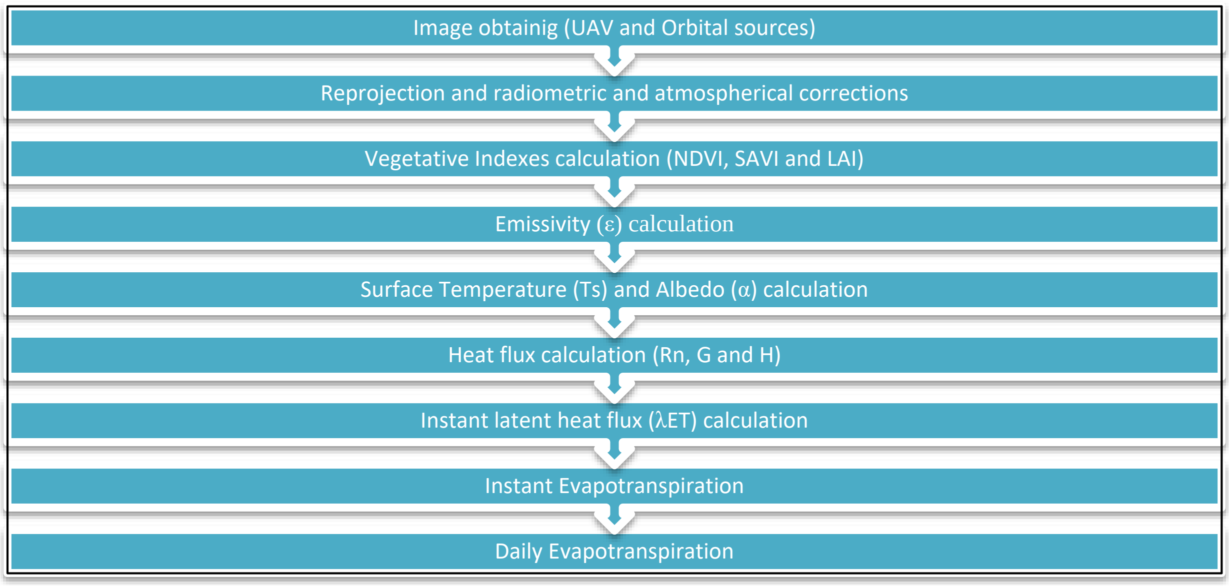

Figure 1. Images processing approach

3. Meteorological data

An automatic micrometeorological station was installed on September, 2014 closed to experimental vineyard to take half-hourly air temperature (Celsius), air relative humidity (%), wind speed (m s^{-1}), solar radiation, Rs (W m^{-2}) and rainfall (mm) and compared to 1961-1990 climatological averages and ET remote sensing approach proposed in this study. It was used FAO56 approach to net radiation (Rn) and soil heat flux (G) calculations and then reference crop evapotranspiration (ETo) calculation by Penman-Monteith equation (Allen et al., 1998) and actual evapotranspiration (ETc) calculated by multiplying the ETo by a crop coefficient (Kc):

$$ET_c = ET_o \, . \, K_c \qquad (01)$$

where:

ET_c crop evapotranspiration [mm d^{-1}];

ET_o reference crop evapotranspiration [mm d^{-1}];

Kc crop coefficient [dimensionless].

It was used Kc values according to Conceição and Mandelli (2007) who recommend $Kc_{initial}$, Kc_{medium} and Kc_{final} values, respectively, at 0.30; 0.70 and 0.45 for grape vertical positioning system which are according to reported by FAO56 (Allen et al., 1998). Based on 10 years-phenology studies of the Chardonnay variety (Mandelli et al., 2003, it was adopted Kc values mentioned above at the appropriate phenological stages (dates).

3. Soil water moisture measurements and water balance modelling

Soil moisture content was taken periodically to the crop water balance approach (Rolim et al., 1998). The measurements were taken from 0.10m, 0.20m, 0.30m and 0.40m soil depth by PR2/4 Profile Probe used within access tubes inserted into augered holes in the soil to produce optimal contact between the soil and the wall of the access tube.

4. Vine water status

Vine water status was assessed with the pressure chamber technique (Scholander et al., 1965). Stem water potential (Choné et al., 2001) was measured with a pressure chamber in one of the water requirement critical phenological phase. The measurements were taken on exposed and shaded leaves covered with an opaque plastic bag one hour prior to measurement. Each measurement was replicated 6 times, on 6 individual vines.

RESULTS AND DISCUSSION

Meteorological data obtained at the time of UAV overpasses indicated a wet and hot atmospheric conditions during the campaign where values of Rs, temperature (Ta), air humidity (RH), wind speed (u) and vapor pressure deficit (VPD) ranged between 315–549 W m^{-2}, 22.8–23.2°C, 71.2%–77.0%, 1.15–1.71 m s^{-1} and 2.31–2.35 kPa, respectively. Within these atmospheric environments, values of midday stem water potential (ψ_x) ranged between -0.61 and -0.96 MPa indicating that the Chardonnay vineyard was maintained under non and moderate water stress conditions during the study period.

1. NDVI

The intra-vineyard spatial variability of NDVI indicated in Figure 2 based on multispectral imagery collected by the helicopter-based UAV and thermal by TIRS-LANDSAT. This Figure confirms the degree that $NDVI_c$ (canopy) was larger than $NDVI_s$ (soil surface), showing averaged values of $NDVI_c$ and $NDVI_s$ ranged between 0.55–0.68 and 0.10 – 0.15, respectively. These results indicate that spatial variability of NDVI may explain the variability of the energy balance components from the soil and from the canopy. These results are similar to those indicated in literature for spacer canopies when using satellite-based remote sensing (SBRS) models.

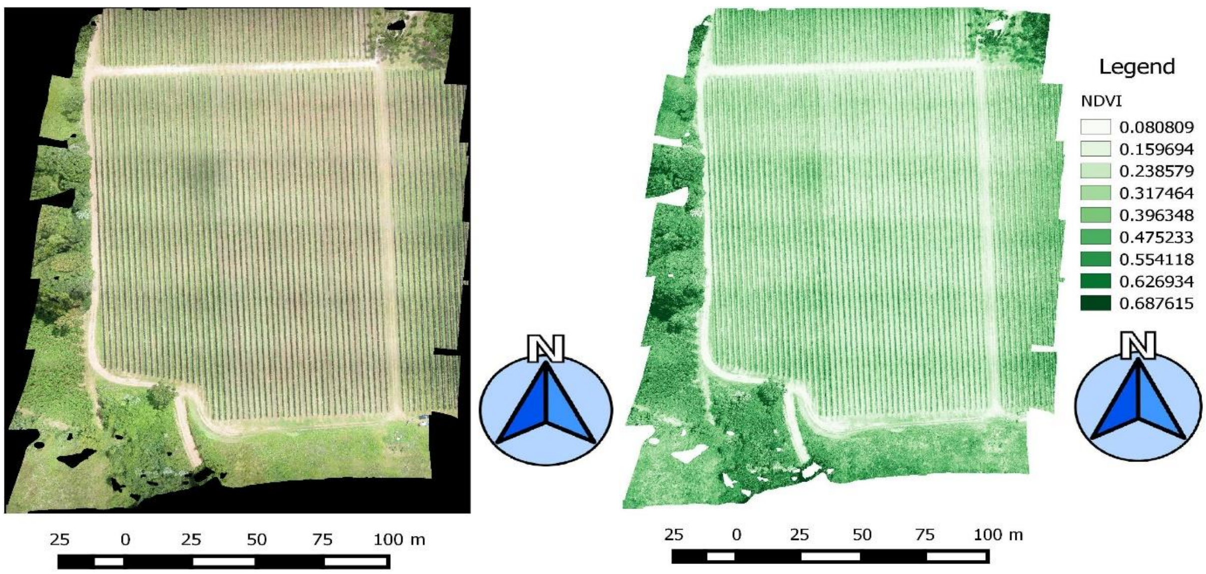

Figure 2. Intra-vineyard spatial variability of NDVI

2. Energy balance components

At the time of UAV overpasses (near solar noon) the energy balance components ranged between 248 – 501 W m^{-2}, 0.8 – 110.4 W m^{-2}, 129.7 – 410.1 W m^{-2} and 2 – 86.3 W m^{-2}, respectively for Rn, G, H and LE (Figure 3). Mean values of LE accounted for 12% of Rn while those of H were between 52% and 81% of Rn. The analysis indicated that the main component of the surface energy balance over the young-Chardonnay vineyard was H. Rn/Rsi and G/Rn ratios were very stable during the study period with mean values of 0.68 and 0.15, respectively. Results are similar to those found by Ortega-Farías et al. (2016) who indicated that daytime values of LE, H and G were between 15%–21%, 54%–60% and 24%–25% of Rn, respectively, while ratios of transpiration and soil evaporation to ETa ranged between 0.64–0.74 and 0.26–0.36, respectively.

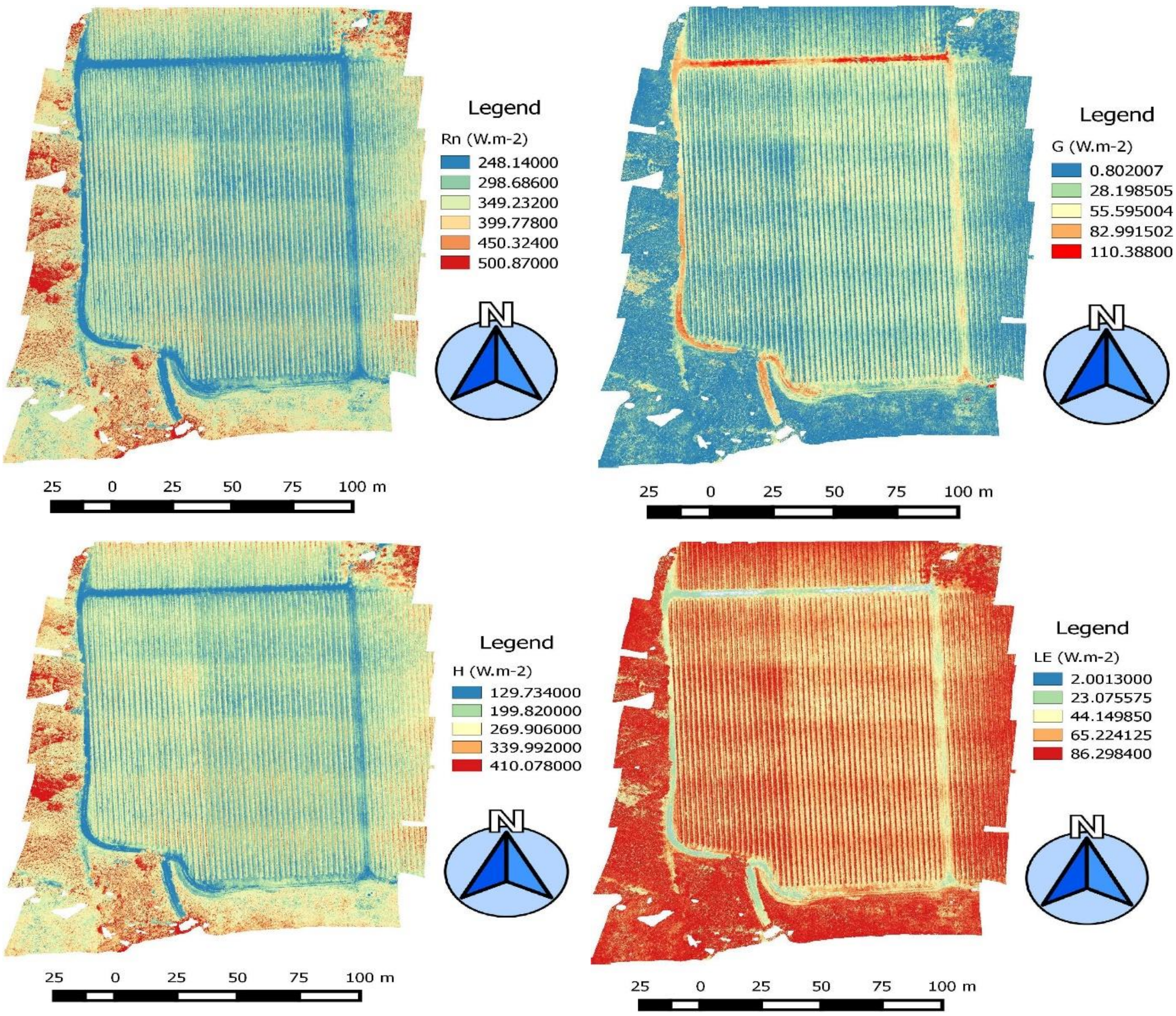

Figure 3. Energy balance components over a young-vineyard based on multispectral imagery collected by the helicopter-based UAV and thermal by TIRS-LANDSAT

3. High spatial resolution ETa

Actual evapotranspiration (ET_a) ranged between 0 – 2.9 mm dia^{-1} (Figure 4) which was similar to 0.9 – 2.9 mm dia^{-1} by the ET_a field measurements. These results indicate a spatial variability in water requirements into the young-Chardonnay-vineyard and shows that UAV could be a useful complement to current satellite platforms for estimating intra-field spatial variability of the energy balance components in order to improve the estimation of water requirements of sparse or complex canopies such as vineyards which, in turn, present different plant densities and fractional covers.

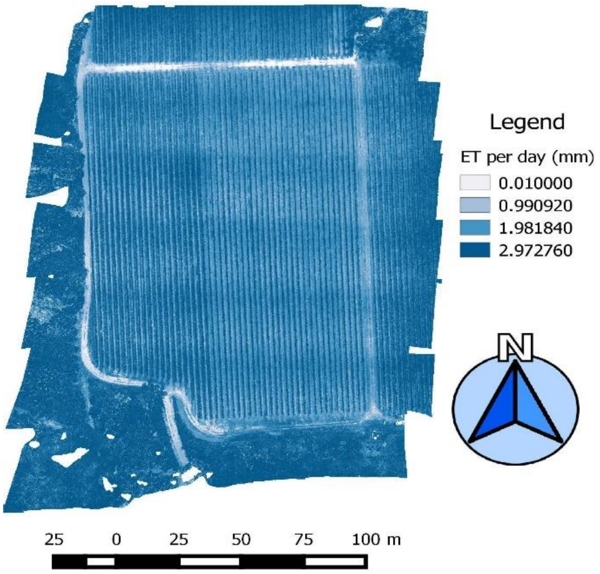

Figure 4. Actual evapotranspiration over a young-vineyard based on multispectral imagery collected by the helicopter-based UAV and thermal by TIRS-LANDSAT

CONCLUSIONS

This study demonstrated that multispectral camera placed on an UAV combined to TIRS-LANDSAT-8 could provide a good tool to evaluate the effects of spatial variability on the partitioning of Rn into G, H and LE over heterogeneous vineyards. The water requirements require a good knowledge of H/Rn, G/Rn and LE/Rn rations, wich depends of tree vigor. Future improvements will incorporate spatially distributed multispectral and thermal data into the adjusting adequate mathematical algorithms to this heterogeneous and sparse vineyard.

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