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Estimation of evapotranspiration of forage corn supported with an Unmanned Aerial Vehicle (UAV) in the Comarca Lagunera

Estimación de la evapotranspiración en maíz forrajero mediante vehículos aéreos no tripulados (VANT) en la Comarca Lagunera

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Abstract

Conocer las necesidades de agua de los cultivos contribuye a ahorrar considerables volúmenes de agua. En los últimos años, el uso de sensores remotos se ha convertido en una herramienta básica para estimar el uso del agua para los cultivos. Los Vehículos Aéreos No Tripulados (VANTs) perfilan ser una herramienta con un gran potencial para utilizarse en actividades de planeación, monitoreo y control de actividades agrícolas incluyendo la Evapotranspiracion. El objetivo del presente trabajo fue implementar la metodología de dos pasos (KCNDVI-ETo) para estimar la ET con imágenes VANTs en cultivo de maíz forrajero en la Comarca Lagunera para las condiciones locales. Los valores de ET obtenidos varían desde 5.79 y 8.97 mmdía^{-1}. Su evolución con el uso de la imagen es congruente de acuerdo con las fases de desarrollo del cultivo. El uso de esta metodología usando imágenes de VANTs puede ser una herramienta prometedora para que los agricultores estimen el consumo de agua en el cultivo de maíz forrajero bajo condiciones de riegos superficial.

Evapotranspiracion, Vehículos Aéreos No Tripulados (VANTs), Maíz

Resumen

Knowing the water needs of crops contributes to saving considerable volumes of water. In recent years, the use of remote sensing has become a basic tool for estimating water use for crops. Unmanned Aerial Vehicles (UAVs) are emerging as a tool with great potential to be used in planning, monitoring and control activities of agricultural activities including Evapotranspiration. The objective of the present work was to implement the two-step methodology (KCNDVI-ETo) to estimate ET with UAV images in forage corn crops in the Lagunera Region for local conditions. The ET values obtained vary from 5.79 and 8.97 mmday^{-1}. Its evolution with the use of the image is congruent according to the development phases of the crop. The use of this methodology using UAV images can be a promising tool for farmers to estimate water consumption in growing forage corn under surface irrigated conditions.

Evapotranspiration, Unmanned Aerial Vehicles (UAVs), Corn

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Introduction

Water is becoming an increasingly scarce resource on a daily basis, so in order to guarantee food production for both humans and animals, the efficient use of water in the field is essential (Alvarez, 2011), since agriculture is the largest consumer of water worldwide (Gontia, 2010). Knowing the water needs of crops not only allows for better crop quality, but also achieves higher yields and contributes to saving considerable volumes of water (IMTA, 1995b).

Evapotranspiration (ET) is a variable that helps us to know when and how much to irrigate in irrigation engineering (Montemayor, 2016). With the application of new technologies, agricultural management practices have improved, including water resources, which has given rise to the field of precision agriculture (Balboltin, 2016), whose purpose is to improve crop yields, optimise the use of resources, reduce environmental impact and facilitate strategic and economic decision-making (Silva, 2010).

In recent years, the use of remote sensors such as satellite images with moderate resolution (LandSat, SPOT, AVHRR) have become a basic tool for estimating crop water use. An alternative to the use of satellites for remote data acquisition are Unmanned Aerial Vehicles (UAVs), colloquially known as drones or UAVs (Unmanned Aerial Vehicles). The use of UAVs facilitates frequent monitoring of crop parameters, which was previously restricted through satellite imagery. The applications of UAVs in agriculture are diverse, and current needs outline this tool with great potential for use in planning, monitoring and control of agricultural activities. (Ojeda, 2017). With the use of UAV images applying the two-step method (Delgado, 2019) we can estimate ET variations, and thus plan and efficiently manage the use of water resources in agricultural areas, especially in arid and semi-arid regions of the country where water is the main constraint for agricultural production.

The objective of the present work is to implement the two-step KCNDVI-ETo methodology to estimate ET with VANTs images in forage maize crop in the Comarca Lagunera for local conditions.

Methodology

Description of the study area

The study was carried out in an agricultural production unit located in Francisco I. Madero Coahuila with coordinates 25°46'53.2" North 103°18'28.0" West, and 1109 masl.

The crop sown is forage maize, distributed in seven tables. The study area was 52.6 hectares, the crop was sown at a row spacing of 76 cm, and an approximate density of 105 600 plants ha^{-1}. The irrigation system was surface irrigation, using river water and water from a waterwheel.

Figure 1 Study area, located in the municipality of Francisco I. Madero, Coahuila
Source: Own elaboration

Required data

For this study we used images obtained by the eBee senseFly fixed-wing UAV, equipped with a Parrot Sequio+ sensor, which allows autonomous flights based on a route previously programmed in the eMotion software. This software allows the height, resolution and also the overlapping of scenes to be specified. For this study, the flight plan was carried out at an altitude of 150 m.

Image acquisition was controlled by the flight configuration, for each image the GPS position, height, time and date were recorded.

The flights were carried out during a period from 04 to 28 May 2020 at variable intervals, with a total of six flights, between 9:00 a.m. and 11:00 a.m. to obtain good lighting conditions.

Data from a DAVIS Ventage pro 2 plus weather station was used.

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Image processing

Six orthomosaics were generated by processing the images acquired by the drone-mounted sensor with Pix4D software (Pix4D SA, Lausanne, Switzerland) using the image analysis method known as structure-from-motion. The resolution of the ortho-mosaics generated from the images captured in each flight was 18 cm.

The QGIS3 3.12 software was used to estimate the variables.

Normalised Vegetation Index (NDVI)

Vegetation indices are used with the aim of highlighting the characteristics of healthy, developed vegetation against the ground.

One of these indices is the NDVI, this parameter measures the relative photosynthetic fraction of the canopy, values range from 0.14 to 0.91, the former for bare soil and the latter for dense green canopies (Calera, 2016).

NDVI, according to Rouse, 1974, is estimated as follows:

$$NDVI = \frac{(IRC-R)}{(IRC+R)} \quad (1)$$

Where:

NIR = is the reflectivity measured in the near infrared.

R = refers to the reflectivity in the red band.

Obtaining Kc from NDVI

The estimation of Kc as a function of NDVI was in accordance with Calera (2016), whose formula for its estimation, valid mainly for annual crops, is:

$$Kc = 1.15NDVI + 0.17 \quad (2)$$

According to the author, the equation has a series of limitations that it is important to take into account when applying it to calculate evapotranspiration (ETc) and the water needs of the crops under study.

The formula was applied for each of the images mentioned above.

Crop evapotranspiration estimation

The formula "Crop coefficient - Reference evapotranspiration (Kc-ETo) of FAO-56 (2006) was used to estimate the evapotranspiration of the fodder corn crop.

$$ETc = ETo * Kc \quad (3)$$

Where:

ETo= Is the reference evapotranspiration obtained at the meteorological station.

Kc= The estimated values of Kc as a function of NDVI.

Results

Table 1 shows the ETo data obtained with the data from the weather station installed on the farm, for the month of May 2020. These data are calculated according to the FAO 56 method, with the Penman-Monteith equation. The highest ETo was recorded for Julian day 128 with 7.29 mm/day[1].

Date	Julian Day	Eto (mm/day^{-1})
04/05/2020	125	6.37
07/05/2020	128	7.29
12/05/2020	133	6.76
15/05/2020	136	6.81
18/05/2020	139	7.14
28/05/2020	149	6.67

Table 1 ETo values calculated by FAO method 56
Source: "Own elaboration"

Table 2 shows the days after planting for each table according to the date on which the flights were made.

Date	Days after sowing (DDS)					
	Table 1	Table 2	Table 3	Table 4	Table 5	Table 6
04/05/2020	61	59	54	52	47	45
07/05/2020	64	62	57	55	50	48
12/05/2020	69	67	62	60	55	53
15/05/2020	72	70	65	63	58	56
18/05/2020	75	73	68	66	61	59
28/05/2020	85	83	78	76	71	69

Table 2 Days after planting of each table according to the dates of the flights
Source: "Own elaboration"

Table 3 shows the NDVI values obtained from each of the field tables. It can be observed in the table that the NDVI values are consistent according to the days after sowing, with higher values for table 1, since it was the first to be sown. And with lower values for table 6, which has 24 DDS less than table 1. The data obtained are very similar to those reported by Delgado in 2018, where the ranges go from 0.12 to 0.89 in conditions very similar to those of this study.

Date	04/05/20	07/05/20	12/05/20	15/05/20	18/05/20	28/05/20
Julian day	125	128	133	136	139	149
Table 1	0.8849	0.8784	0.8733	0.8537	0.8625	0.8262
Table 2	0.8795	0.8715	0.8716	0.8764	0.8721	0.837
Table 3	0.8967	0.8842	0.8802	0.8699	0.8815	0.8555
Table 4	0.8332	0.875	0.8622	0.8655	0.8756	0.8493
Table 5	0.8542	0.8836	0.8529	0.8763	0.89	0.8305
Table 6	0.8322	0.6845	0.8568	0.8799	0.8918	0.8664

Table 3 NDVI values for the maize crop
Source: "Own elaboration"

Figure 2 shows the NDVI variation maps for the study month.

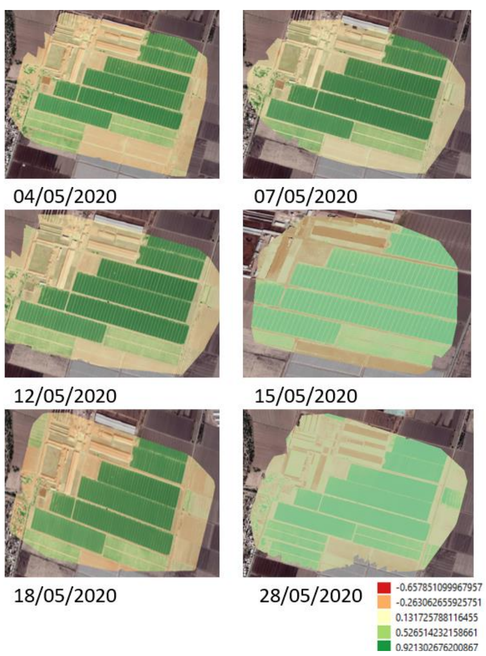

Figure 2 Maps of NDVI variation in the study month
Source: Own elaboration

Table 4 shows the results of the average crop evapotranspiration (ETc) per table for the month of May 2020.

Date	4/05/20	7/05/20	12/05/20	15/05/20	18/05/20	28/05/20
Julian Day	125	128	133	136	139	149
Table 1	6.07	8.66	7.92	8.13	7.82	7.02
Table 2	6.08	8.82	8.03	8.13	7.97	7.14
Table 3	6.01	8.97	8.11	8.26	7.79	7.24
Table 4	5.80	8.72	7.78	8.24	8.04	7.14
Table 5	5.85	8.54	7.97	8.28	8.03	7.08
Table 6	5.85	8.11	8.01	8.20	8.22	7.38

Table 4 ETc values in forage maize crop using the two-step methodology (KCNDVI-ETo)
Source: Own elaboration

Figure 3 shows the temporal variability of crop evapotranspiration (ETo).

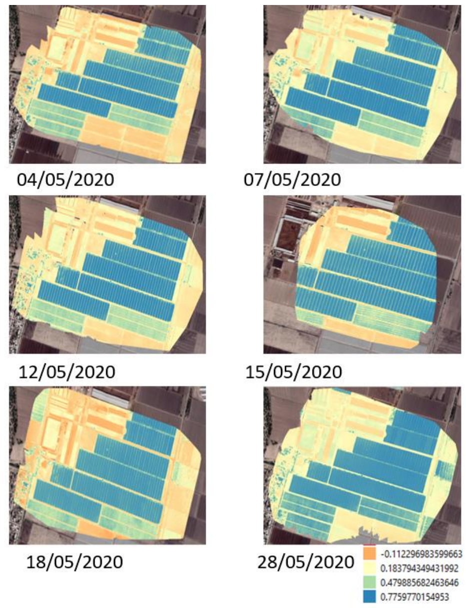

Figure 3 Temporal variability of crop evapotranspiration (ETo) using the two-step methodology (KCNDVI-ETo)
Source: Own elaboration

According to the ETc results we can observe how there is variability in the data, where despite being the same day, in each table it is different. This is in accordance with the concept of FAO (2002) where it is described "The only factors that affect ETo are the climatic parameters". In this case it is very clear that the differences between the tables are due to the fact that each had a different sowing day, therefore, their stage of development as well. Differences in transpiration resistance, crop height, crop roughness, reflexivity, soil cover and root characteristics of each plant result in different ET levels, even though they are under identical environmental conditions.

Conclusions

From the results, it is possible to use the two-step KCNDVI-ETo method with imagery obtained with UAVs as inputs in the Comarca Lagunera, under surface irrigation conditions. This methodology can be implemented to measure the complete crop cycle. In addition, it is necessary to make Et measurements in the field with a direct method to evaluate, validate and adjust the methodology. This methodology will help for the management and efficient use of water in agriculture, as well as for decision making in a timely manner thanks to the resolution of the images.

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