Crop coefficient of pomegranate in the Comarca Lagunera

Coeficiente de cultivo de granado en la Comarca Lagunera

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Abstract

For agricultural development, water is the most important thing, so today farmers are looking for crops that have some degree of resistance to drought and high economic value such as pomegranate, however, there is poor literature on its production. The Crop Coefficient (Kc) helps us determine the water requirement during plant development, which is critical for reducing production costs and saving water. The objective of this study was to know the Kc during the phenological development of the pomegranate, in an orchard located in the municipality of Gómez Palacio, Durango, Mexico, using 8 Landsat satellite images and geographic information systems. The estimation of Kc based on the Normalized Difference Vegetation Index (NDVI), was performed as proposed by Calera (2016). The KC values obtained range from 0.33 to 0.65. Its evolution with satellite images is consistent according to the development stages of the crop. The relationship between the NDVI and KC may be a promising tool for farmers to estimate water use of pomegranate trees on a regional scale based on satellite imagery.

Crop coefficient, NDVI, Pomegranate

Resumen

Para el desarrollo agrícola el agua es lo más importante, por eso hoy en día los agricultores están en busca de cultivos que tengan algún grado de resistencia a la sequía y de alto valor económico como el granado, sin embargo, existe poca literatura sobre su producción. El coeficiente de cultivo (Kc) nos permite conocer el requerimiento hídrico durante el desarrollo de la planta, el cual es fundamental para la reducción de costos de producción y ahorro de agua. El objetivo de este estudio fue conocer el Kc durante el desarrollo fenológico del granado, en una huerta ubicada en el municipio de Gómez Palacio, Durango, México, por medio imágenes satelitales Landsat 8 y sistemas de información geográficas. La estimación del Kc en función del el Índice de Vegetación de Diferencia Normalizada (NDVI), se realizó según lo propuesto por Calera (2016). Los valores obtenidos de Kc varían desde 0.33 y 0.65. Su evolución con las imágenes de satélite es congruente de acuerdo con las fases de desarrollo del cultivo. La relación entre el NDVI y Kc, puede ser una herramienta prometedora para que los agricultores estimen uso del agua de los árboles de granado en escala regional basada en imágenes satélites.

Coeficiente de cultivo, NDVI, Granado

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Introducción

For the agricultural development of any country, water is the most important thing, that is why today research is looking for crops that have some degree of resistance to drought and of high economic value (Zang, 2017). The pomegranate can grow in different agroclimatic conditions, from temperate to tropical regions (Meshram, 2019), in addition to being able to moderately tolerate salinity (Bhantana, 2010). Its highest production is in India with 108,000 ha, 71,000 ha in China, 65,000 ha in Iran, 27,000 ha in Turkey, and 6,000 ha in Spain (Stover and Mercure, 2007), (Ayars, 2017). Production in Mexico in 2019 was 1,068 ha. (SIAP, 2020)

Today, the pomegranate is a highly lucrative agricultural business, due to the monetary return per unit of area. This has resulted in an increase in the plantation, and the export of pomegranate during the last two decades. (Meshram, 2019).

Many studies on the great benefits of using pomegranate in medicine, both the leaves, bark, roots and fruit can be used for this purpose. (Ayars, 2017).

The fruit is one of the oldest known. However, there is little literature on its production, knowing the water requirement during the development of the plant is essential to reduce production costs, especially during the dry season. (Zang, 2017).

Remote sensing is an alternative technology that has been developed in recent years, the most important characteristic is that, thanks to its radiometric calibration, it is possible to make conversions to physical values of reflectivity, giving them a homogeneity that makes them perfectly comparable with each other. in multitemporal studies, from which vegetation indices are calculated (Valdés, 2016); Thanks to the vegetation indices, we can systematically evaluate the quantity, quality and development of a crop's vegetation. (Balbontín, 2016).

Remote sensing NDVI can be a good way to monitor growth stages and water demand, due to the relationship of crop water content to near-infrared (NIR) reflectance and wave-infrared portion short (SWIR) of the specification. (Zang, 2017).

So, this is an indicator of the photosynthetic activity of the plant and from which it is possible to derive the crop coefficient. This can be used in adjusting the water needs of crops within the FAO56 model (Allen, 1998). (Valdés, 2016).

Developing a simple method for estimating Kc values would be a great benefit; remote sensors are a viable economic alternative that provide information with high spatial and temporal resolution. (Castañeda, 2015). Different experimental works have derived the Kc from vegetation indices obtained with satellite images. (Calera, 2016)

The objective of this study was to know the Kc during the phenological development period, of the pomegranate crop in La Comarca Lagunera, in the states of Coahuila and Durango, Mexico..

Methodology

Description of the study area

The study was carried out at the ranch "El Triángulo" in Gómez Palacio Durango with coordinates 25 ° 37'41 "North 103 ° 26'54" West, and 1123 meters above sea level.

The evaluated crop was the two-year-old Wonderful variety pomegranate. The study area was twenty hectares, the crop is in a planting frame of three bolillo of three by five meters and a density of 666 trees ha-1. The irrigation system was drip, one dripper per tree of four liters per hour was located.

Figure 1 Z one of study, located in the municipality of Gómez Palacio, Durango
Source: Own elaboration

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Data required

To carry out this study, images from the Landsat 8 satellite acquired by the OLI and TIR sensors were used, which were obtained from the portal of the United States Geological Survey (USGS). http://earthexplorer.usgs.gov/.

In addition, a digital elevation model at 30 m was used obtained from the portal of the National Institute of Statistics and Geography (INEGI).

Date	Path / Row
18/02/2016	30/42
05/03/2016	30/42
21/03/2016	30/42
09/06/2016	30/42
25/06/2016	30/42
11/07/2016	30/42
12/08/2016	30/42
13/09/2016	30/42
15/10/2016	30/42
31/10/2016	30/42
16/11/2016	30/42

Table 1 Landsat images used in the study
Source: Own elaboration

Image processing

The pre-processing of the images was carried out with the ArcGis 10.3 software, which allows the use of a series of tools specially designed to process satellite images.

For this, it is necessary to convert the values of digital levels (ND) of each pixel to physical parameters, to obtain the spectral radiance and reflectance, these parameters represent the physical bases for the SEBAL processing and are carried out by using software GIS, via raster calculator tool.

Transformation of ND values to radiance

For the conversion of these values to radiance levels, the "spectral radiance scaling method" is used, which is expressed with the following formula (USGS, 2016):

$$L\lambda = ML * Qcal + AL \quad (1)$$

Where:

$L\lambda$ = It is the value of spectral radiance measured in values of (Watts / m2 * srad * µm).

ML = It is the multiplicative specific scaling factor obtained from the metadata.

AL = It is the additive specific scaling factor obtained from the metadata.

Qcal = Standard product quantified and calibrated by pixel values (ND).

The data required to apply the formula is found within the image metadata, in the .MTL file.

Transformation of ND values to reflectance

For the conversion the following equation is used (USGS, 2016):

$$\rho\lambda' = M\rho * Qcal + A\rho \quad (2)$$

Where:

$\rho\lambda$ '= It is the planetary reflectance value.

$M\rho$ = It is the multiplicative factor of specific scaling obtained from the metadata.

$A\rho$ = It is the additive specific scaling factor obtained from the metadata.

Qcal = Standard product quantified and calibrated by pixel values (ND).

The data required to apply the formula is found within the image metadata, in the file. MTL.

Surface albedo (α)

The surface albedo is obtained by the linear combination of the reflectances, in the first instance the albedo is obtained in the upper part of the atmosphere (αtoa) by the following equation:

$$\alpha_{toa} = \sum_{\omega\lambda * \rho\lambda'} \quad (3)$$

Where:

$\rho\lambda$ '= It is the planetary reflectance value.

$\omega\lambda$ = It is obtained with the following equation:

$$\omega\lambda = \frac{ESUN\lambda}{\sum ESUN\lambda} \quad (4)$$

ESUN values are obtained from Table 2.

LANDSAT 8 OLI						
Band	**Low**	**High**	**Center**	**Linear**	**ESUN TOA**	**$\omega\lambda$**
2 (Blue)	0.45	0.51	0.480	1991	2067	0.3026
3 (Green)	0.53	0.59	0.560	1812	1893	0.2759
4 (Red)	0.64	0.67	0.655	1549	1549	0.2336
5 (REL)	0.85	0.88	0.865	962.6	972.6	0.1417
6 (SWIR)	1.57	1.65	1.610	251.7	245	0.0357
7 (SWIR)	2.11	2.29	2.200	86.30	79.72	0.0116

Table 2 Corresponding ESUN values for LANDSAT 8 OLI scenes. USGS

Where, ESUNλ is the mean solar exo-atmospheric irradiance for each band (W / m2 / μm).

Finally, to calculate the surface albedo, the equation described by (Allen et al., 2002) is used.

$$\alpha = \frac{\alpha\text{toa} - \alpha\text{path\_radiance}}{\tau_{sw}2} \quad (5)$$

The value of these variables oscillates between the range of 0.025 and 0.04, according to the use of SEBAL it is recommended to use the value of 0.03 (Bastiaanseen, 2000).

τ_sw = Corresponds to atmospheric transmissivity which is calculated by the following equation, (Allen et al., 2006).

$$\tau_{sw} = 0.75 + 2\;x\;10^{-5}\;x\;z \quad (6)$$

Where:

z = is the elevation above sea level (m).

Typical surface albedo values for different surfaces are presented in Table 3

Surface	Rank
Snow	0.80 – 0.85
Black soil	0.08 – 0.14
Pasture	0.15 – 0.25
Cornfield	0.14 – 0.22
Rice field	0.17 – 0.22
Forest	0.10 – 0.15
Water	0.025-0.348

Table 3 Typical albedo values according to the type of surface
Source: Allen, 2002.

Vegetation Indices

Vegetation indices are used to highlight the characteristics of healthy vegetation and developed against the ground.

Normalized Vegetation Index (NDVI)

The NDVI, according to Rouse et al., 1974, is estimated as follows:

$$NDVI = \frac{(IRC-R)}{(IRC+R)} \quad (7)$$

Where:

IRC = corresponds to the reflectivity in the near infrared band, while

R = refers to the reflectivity in the red band.

Determination of Kc with satellite images from NDVI

The estimation of the Kc based on the NDVI was according to what was proposed by Calera (2016), whose formula for its estimation, valid mainly for annual crops, is:

Kc= 1.25*NDVI+0.1

According to the author, the equation carries a series of limitations that it is important to consider when applying it to calculate evapotranspiration (ETc) and the water needs of the crops under study. Thus, in their maximum development phase they achieve complete soil coverage. In the germination phase of crops or in the case of crops such as garlic, onions, etc., where in their maximum development phase they do not reach complete soil coverage, the evaporative component of the soil can be very high, and therefore therefore, this method will tend to underestimate the value of Kc. The formula was applied for each of the phases.

Results

In Table 4, the NDVI values obtained in the different development dates of the pomegranate crop.

Date	Julian day	NDVImax	NDVImin	NDVIaverage
18/02/2016	49	0.217214	0.099375	0.187266
05/03/2016	65	0.337619	0.108201	0.245869
21/03/2016	81	0.437426	0.145578	0.336978
09/06/2016	161	0.494853	0.10572	0.358889
25/06/2016	177	0.508704	0.135227	0.366808
11/07/2016	193	0.530918	0.135735	0.386618
12/08/2016	225	0.548841	0.187262	0.443249
13/09/2016	257	0.543986	0.183996	0.414608
15/10/2016	289	0.595187	0.122032	0.427126
31/10/2016	305	0.556329	0.112361	0.417664
16/11/2016	321	0.560583	0.114595	0.416978

Table 4 NDVI values for pomegranate cultivation
Source: Own elaboration

NDVI values between 0.21-0.59 are recorded. There were no negative values, as there were no bare soil conditions.

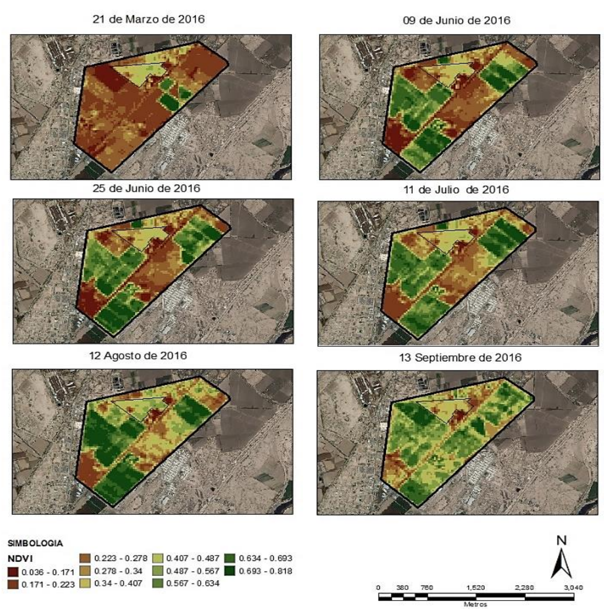


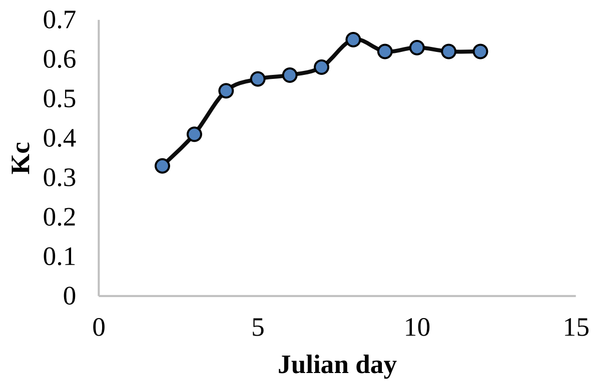
Figure 2 Variations of NDVI in the phenological period of the pomegranate, during the study time
Source: Own elaboration

Date	Julian day	KC
18/02/2016	49	0.33
05/03/2016	65	0.41
21/03/2016	81	0.52
09/06/2016	161	0.55
25/06/2016	177	0.56
11/07/2016	193	0.58
12/08/2016	225	0.65
13/09/2016	257	0.62
15/10/2016	289	0.63
31/10/2016	305	0.62
16/11/2016	321	0.62

Table 5 Kc of pomegranate variety Wonderful
Source: Own elaboration

Based on the NDVI, the Kc obtained for pomegranate in 2016 is shown in Table 5.

The Kc values obtained vary from 0.33 to 0.65. The evolution of Kc with satellite images is congruent according to the development phases of the crop, in the initial phase, when the trees are still dormant, the value is small. And the highest is in August, when the pomegranate reaches its maximum coverage. In the collection phase, the Kc values, as expected, are decreasing as observed in graphic 1.



Graphic 1 Behavior of the pomegranate cultivation coefficient during its phenological development, expressed in Julian days
Source: Own elaboration

Values like those reported by the authors Bonet and Bartual (2012) in Alicante Spain; but below those reported by Meshram and Gorantiwar (2010) in India, corresponding to the second year of life of the tree.

The current study confirmed that this method is an alternative for the determination of the KC in pomegranate, and with it to know the water needs in each phenological stage.

Annexes

Pomegranate production in Mexico

Year	Surface (ha) Sown	Harvested	Sinister	Production (ton)
2019	1,068.00	974	20	7,144.43
2018	1,206.25	1,058.00	0	8,073.88
2017	1,084.90	946.9	0	6,816.22
2016	812.9	725.9	0	5,209.59

Table 6 Production of Pomegranate in Mexico per year in tons, with cycle: Ciclicos-Perenes, modality: Irrigation + Temporary
Source: SIAP, 2020

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Conclusions

The KC was obtained based on the normalized vegetation index (NDVI) for the cultivation of the Wonderful variety pomegranate, established in the El Triángulo ranch, according to the climate and soil of that site. The relationship between NDVI and Kc that have been established may be a promising tool for farmers to estimate water use of pomegranate trees on a regional scale based on satellite imagery.

The Kc calculation methodology (Calera, 2016) yields consistent results for the analyzed crop, although it would be interesting to deepen the study by doing a more detailed analysis and repeat the experiment for at least one more year. With this cultivation coefficient they are intended to be used as reference information, in a way that allows improving water efficiency, not only in the amount of water, but also at the right time to irrigate.

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