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Measuring Crop Coefficient For Vineyards

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Abstract

In this paper crop coefficient for vineyard was measure from water consumption or crop evapotranspiration in afield of vineyeard located in Travers City, Michigan State/ United State of America. The objectives were to find it varaities with time as plant grew, and to compare the predicted crop coefficient with the local available values (MSU) and with the recommended values by FAO. Measurements were conducted on the basis of soil water content and weather parameters to calculate crop evapotranspiration (consumptive use) and reference evapotranspiration by means of Penman-Monteith model, respectively. The results of the statistical analysis of error showed that the predicted crop coefficients were always less than the local values (Michigan State) for all months of study period except for August (late- mid of the season) where the predicated value was more than the local one. Additionally the absolute error showed that the lowest error was in June, July, and August and the highest value was in May with an average absolute error value for all months 0.2. While, the predicated crop coefficients were almost close to FAO values for all months except for May and August with an average absolute error value for all months 0.085. Moreover, the statistical analysis by using root mean square difference (RMSD), relative error (RE), and mean bias error (MBE) to compare predicated and FAO vineyard crop coefficient were: 0.099, 18% and 0.01, respectively, while for predicated and local values were: 0.25, 35%, and – 0.17, respectively.

Key words: crop coefficient, vinyard, evapotranspiration, soil water content.

Introduction

Crop coefficient, variety, and development stage should be considered when assessing evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover, and crop rooting characteristics results in different ET levels for different types of crops under identical environmental conditions. Due to the differences in evapotranspiration during the various growth stages, crop coefficient for a given crop varies

Over the growing period. The growing period can be divided into four distinct growth stages: dormant, bloom, fruit set and development, and late season (1). Once the reference ET has been determined, a crop coefficient must be applied to adjust reference ET value to local conditions and type of crop being irrigated. Crop coefficients for Apples, Cherries, Pears, and Grapes with cover crops have been segregated into months (8). The most important use of evapotranspiration information is in the irrigation scheduling where good water management requires that the irrigator apply only enough water to meet the crop needs plus some additional amount to compensate for the inefficiencies of irrigation systems (3). Crop coefficients that are given in (FAO 1975) resulted in an updated Kc values to be applied to Penman-Monteith method and procedures to arrive to better estimates under various climatic conditions and crop height and expanding the range of crops and crop types (6). Proper irrigation is essential to maintain, healthy and productive grapes orchard. Over irrigation slows root growth, increases iron chlorosis in alkaline soils, and leaches nitrogen and sulfur out of the root zone. Drought stress will effect fruit development from pit hardening to harvest, and typically occurs concurrently with the highest temperature of the season (2). Reference and actual evapotranspiration were calculated by using the field experimental data at the experimental station via Penman-Monteith equation and derived the crop coefficient. All collected requirements input data for the CROPWAT irrigation management model were used to estimate the irrigation requirements for paddy and upland crops (9). Crop coefficient can be computed from consumptive use by different ways. Excel solver was used to estimate crop evapotranspiration. Estimated crop evapotranspiration was used to compute Kc value, and then the average Kc value in each growth stage was compared for the continuous flooding irrigation. The excel solver estimated crop evapotranspiration with R^2 values higher than 0.81.

The objectives of this paper are to predicate and evaluate the crop coefficient for vineyard by using water consumption (or cropevapotranspiration) in a field of vineyeard and to find its changes with time as plant grow. Also, comparing the predicated crop coefficient with available values used by Michagn State University and with the FAO recommended values.

Area of the Study

The study area is located North-West of Michigan State in the United State of America, called Travers City, where the research center of Michigan State University (MSU) is located. Vineyard 5 years old was used which were spaced at 2×2m. Trickle irrigation system was used and four emitters per crop of total capacity 4.77 *l/hr* were used as shown in Figure 1. The soil analysis indicated that soil texture was loamy sand with medium to small stones, and groundwater was the source for irrigation. Time Domain Reflectometer (TDR) soil moisture tools were used to measure soil water content every fifteen minutes during the day and throughout the growing season of vineyard. Determination of water content with TDR relies on the fact that the travel time of an electromagnetic pulse through stainless steel probe (the wave guided), embedded in the soil, is a function of soil's water content. A total number of twenty four TDR devices were being used to cover the studied area, where at each location two of the tools were used at depths 915*mm* and 1220*mm* land 250mm apart, 200*mm* away from center of the tree.

Figure 1: Vineyard field and location of TDR controller.

Materials and Methods

Actual Crop Evapotranspiration

Actual crop evapotranspiration (ETc) can be estimated by measuring soil moisture content, especially when the plant age is 5 years and the shaded area is large enough to reduce evaporation from the ground surface. Additional to that soil sensor were used first sensor was installed at a shallow depth below the soil surface and the second sensor was installed below the first one by about 305mm. Average values of all soil moisture measurements tools were recorded. The difference between the reading in the early time of the day and the late hour of the day is the consumptive use of the plant or is the crop evapotranspiration. The estimated crop evapotranspiration can be calculated from the following equation (FAO, 4):

$$ETc = ETo * Kc \qquad \text{….. (1)}$$

Where:
ETc = Actual or crop evapotranspiration (Mm/day),
ETo = Reference evapotranspiration (mm/day), and
Kc = crop coefficient.

Crop Coefficient (Kc).

Crop coefficient for vineyard varies over the growing season starting from April to October (growing season in Michigan State). FAO classified the growing stages for vineyard as: initial, mid-season, and late of season, while the local classification in Michigan State depends on percentage of growth as 0% in April to 100% in September to October as shown in Figure 2.

From crop evapotranspiration measurement by using the soil moisture content, the predicted or modified crop coefficient (Kc) is found by using Eq.1, assuming that there is no deep percolation (drainage water), or:

$$Kc = \frac{ETc}{ETo} \qquad \text{….. (2)}$$

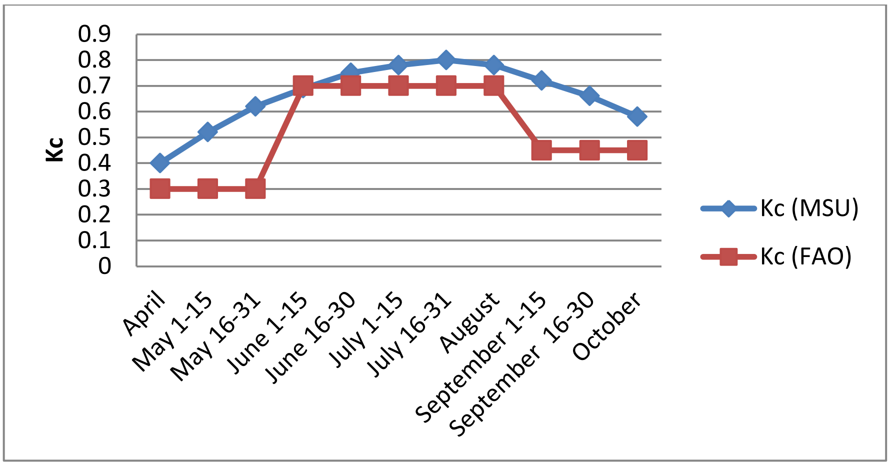

Figure 2: Comparisons of crop coefficient for vineyard recommended by MSU and FAO.

Reference evapotranspiration

Reference evapotranspiration (ETo) is calculated by using Enviro-Weather station which is located by near the area of study to measure weather parameters such as: wind speed, temperature, relative humidity, and sunshine period. FAO-56 Modified Penman-Monteith equation was used to calculate reference evapotranspiration.

Statistical Analysis Methods

Comparison between predicted Kc, local crop coefficient (MSU) and FAO values are made on daily basis, monthly, and growing stages. For error analysis the following indicators are used:

$$\mathrm{RMSD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(yi - xi)^2} \qquad \ldots.. \ (3)$$

$$\mathrm{RE} = \frac{\mathrm{RMSD}}{\mathrm{xav}} * 100 \qquad \ldots.. \ (4)$$

$$\mathrm{MAE} = \frac{\left|\sum_{i=1}^{n}(yi - xi)\right|}{n} \qquad \ldots.. \ (5)$$

Where:
RMSD = root mean square difference,
n = number of observations,
yi = predicted crop coefficient,
xi = local or FAO crop coefficient,
xav = average value of crop coefficient (from local or FAO values),
RE = relative error (%), and
MAE = mean absolute error.

Results And Discussions

In this study crop evapotranspiration values were measured during May 16-31, June 16-30, July 1-15, August, and September and predicted Kc values are calculated accordingly. Figure 3 shows the comparison of vineyard crop coefficient values as predicted and used by Michigan State University (MSU) and by FAO. Crop coefficient values used by MSU during the whole growing season are higher than the values recommended by FAO. These values are only approximates under standard climatic conditions and can be adopted for most applications related to irrigation planning, design, management, and soil wetting conditions

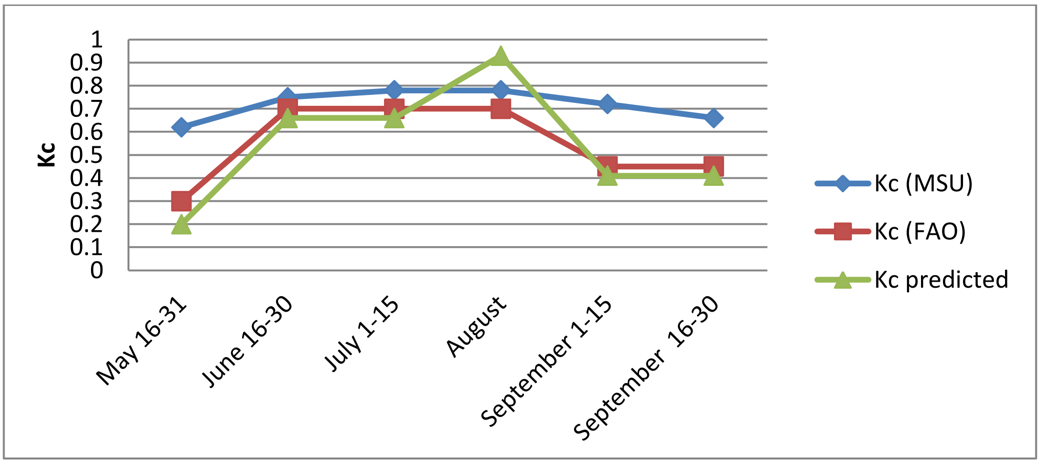

Figure 3: Comparison of vineyard crop coefficient predicted, by MSU and FAO

Table 1 shows the statistical error analysis between predicted and local crop coefficient values. The results show that predicted crop coefficients are always less than the local values for all months of the study period except in August (mid of season) where the predicted value was more than the local one. This was due to the warm conditions during the study time. Additionally the absolute error shows that the lowest error was in June, July, and August and the highest value was in May. The average absolute error value for all months was 0.22. In May when the weather conditions were still cold and the growing season was at the beginning (initial) stage, the evapotranspiration was at the minimum value. Moreover, during May and due to frozen weather time in Michigan State for some years, evapotranspiration values were not constant and during the period of this study the recorded evapotranspiration were equal to zero in the early 2 weeks of May 2011. Therefore, crop coefficients differed from FAO and even from the used values.

Table 1:.Mean absolute error analysis between predicted and MSU crop coefficient.

Month	Predicted Crop coefficient (Kc)	Local crop coefficient (MSU)	Absolute error |Predicted − MSU|
May 16-31	0.20	0.62	0.42
June 16-30	0.66	0.75	0.09
July 1-15	0.66	0.78	0.12
August	0.93	0.78	0.15
September 1-15	0.41	0.72	0.31
September 16-30	0.41	0.66	0.25
Average			0.22

Table 2 shows the statistical error analysis for the predicted and FAO crop coefficient values. The results show that the predicted crop coefficient values were almost close to FAO values for all months except for May and August. The small values of the predicted crop coefficient in May which were calculated according to low evapotranspiration depend on weather conditions in that area, where the spring season was early in some years and sometimes the snow weather was late. Moreover, the high value of the predicted crop coefficient in August was due to warm or high temperature as was mentioned before. The average absolute error value for all months is 0.085.

Table 2: Mean absolute error between predicted and FAO crop coefficient.

Month	Predicted crop coefficient (Kc)	FAO crop coefficient	Absolute error |Predicted − FAO|
May 16-31	0.20	0.3	0.12
June 16-30	0.66	0.7	0.04
July 1-15	0.66	0.7	0.04
August	0.93	0.7	0.23
September 1-15	0.41	0.45	0.04
September 16-30	0.41	0.45	0.04
Average			0.085

The statistical error analysis is essential to confirm the strength of the comparison. Figure 4 shows the comparison of absolute error between the predicted, MSU and FAO vineyard crop coefficients. The comparison was done only for the available recorded information.

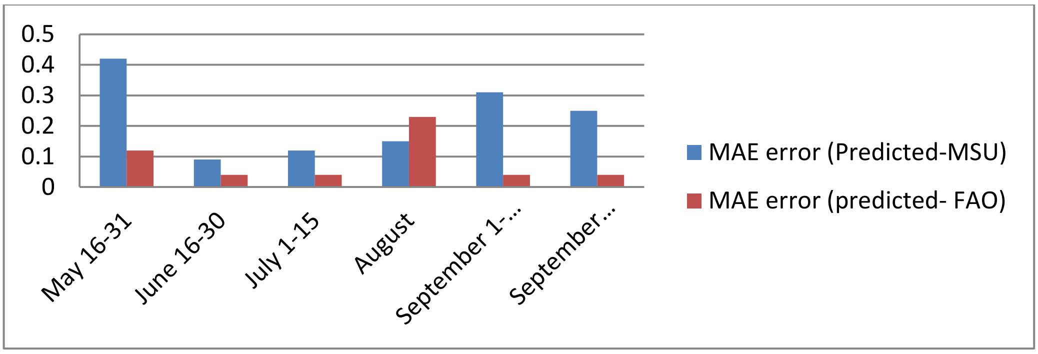

Figure 4: Mean absolute error analysis for the crop coefficients

A summary of root mean square difference, relative error and mean absolute error for the comparison between predicted and used crop coefficients and between predicted and FAO recommended values is shown in table 3.

Table 3: RMSD, RE and MBE for vineyard crop coefficient predicted, by MSU and FAO

Comparison of Kc	RMSD	RE (%)	MAE
Predicted, by MSU	0.099	18	0.01
Predicted, by FAO	0.25	35	- 0.17

From table 3, the statistical error analysis shows that the comparison between predicted and FAO vineyard crop coefficient using RMSD, RE, and MAE are: 0.099, 18%, and 0.01, respectively. While the comparison between predicted and used values in the state are: 0.25, 35%, and – 0.17, respectively.

Conclusions and Recommendations.

The conclusions from this paper are: selecting the proper crop coefficient value affects the schedule of irrigation process based on water balance approach, therefore when the Kc value is low, this will be harmful to plant growth and plant production will be under water stress. Additionally, when selecting high value of Kc, the irrigation water applied will be over the limit of field capacity and extra water will go as deep percolation. Recommendation for further research works is to predict crop coefficient for initial and development stages for different weather conditions, and to analyze the effect of water stress on crop growth and production to minimize the applied amounts of irrigation water.

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مقارنة معامل نبات الكرم

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الخلاصه:
في هذا البحث تم أستباط وتقييم معامل نبات الكرم من خلال حساب قيم الاستهلاك المائي الحقيقي للنبات في حقل مزروع بنبات الكرم في مزرعة بحثية في مدينة ترافرس - ولاية مشيكان الامريكية, لغرض تحديد متغيرات قيم معامل النبات مع مراحل نموه ومقارنة هذه القيم المستنبطة مع القيم المستعملة في الولاية ومع القيم المقترحة من قبل منظمة الاغذية والزراعة الدولية. تم أعداد القياسات على أساس تحديد المحتوى الرطوبي للتربة وقياس المتغيرات الجوية في محطات الأنواء الجوية لغرض حساب الاستهلاك المائي الحقيقي للنبات والاستهلاك المائي الكامن (بأستخدام معادلة بنمان – مونتيث المعدلة) على التوالي. أظهرت نتائج التحليل الاحصائي للخطأ بأن قيم معامل النبات المستنبطة كانت دائما أقل من القيم المستخدمة ولكافة أشهر الدراسة البحثية عدا شهر أب (مرحلة نهاية منتصف الموسم) حيث كانت قيمة معامل النبات المستنبطة أكبر من القيمة المستخدمة في ولاية مشيكان ولنفس الشهر. أضافة الى ذلك كانت القيمة المطلقة للخطأ هي الاقل في حزيران و تموز و أب, بينما كانت الاكثر في شهر أيار. كان معدل الخطأ لكافة الأشهر 0.2. من ناحية أخرى كانت قيم معامل النبات المستنبطة قريبة الى القيم المقترحة من قبل منظمة الاغذية والزراعة الدولية ولكافة الأشهر عدا شهري ايار واب, حيث كان معدل التحليل الاحصائي للخطأ يساوي 0.085. كما أظهرالتحليل الأحصائي ايضا بأستخدام معدل الجذر التربيعي للفرق, والخطأ النسبي, ومعدل انحراف الخطأ لمقارنة القيم المستنبطة مع القيم المقترحة من قبل منظمة الاغذية والزراعة الدولية هي الاقل وكما يلي: 0.099, 18%, و 0.01 على التوالي. وكذلك كانت قيم التحليل الاحصائي في مقارنة القيم المستنبطة من الدراسة مع القيم المحلية هي الاكثر وكما يلي: 0.25, 35%, و -0.17 على التوالي.

مفتاح الكلمات: معامل النبات, الكرم, الاستهلاك المائي, المحتوى الرطوبي للتربة.