# Determination of Site-Specific Crop Coefficients of Corn (*Zea mays*)

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## ABSTRACT

*Knowledge of crop water requirement is important in the operation and management of irrigation systems. Its computation requires crop coefficient (Kc) values corresponding to crop growth stages. Locally determined Kc information is very limited and not available for many important crops in the Philippines. This study was conducted to determine growth stage specific Kc for IPB Var13 corn variety. Drainage-type lysimeter was used to determine crop evapotranspiration (ETc) while local weather data were used to determine the reference crop evapotranspiration (ETo) in CROPWAT 8.0. The growth stages of the crop were assessed in terms of plant height, leaf area and leaf area index (LAI). The computed average Kc values were 0.43, 0.69, 0.92 and 0.70 during the initial, development, mid-season and late season stages, respectively. These values were different from Food and Agriculture Organization-recommended values especially during developmental and mid-season stage that could be a result of soil, climate and crop genetic differences. On the other hand, the computed Kc values were only slightly different to values from local studies with the same climate and soil type, with the discrepancy attributed to varietal difference and method of computing ETo. The generated results are more applicable to local conditions and should be used in the computation of crop water requirement of corn in the Philippines.*

*Keywords: crop coefficient, lysimeter, crop water requirement, evapotranspiration, corn*

## INTRODUCTION

Crop water requirement (CWR) is important for water resources planning and irrigation management. It is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field (Allen *et al.*, 1998). Accurate determination of CWR is helpful in developing more efficient and sustainable water management techniques and in irrigation scheduling of crops (Allen *et al.*, 1998; Attarod *et al.*, 2009), leading to optimization of crop growth and production, improvement of water use efficiency, and maximization of water uses (Fisher, 2012; El-Shirbeny *et al.*, 2013). It also helps increase crop yield and quality, hence, increasing profitability (Evett *et al.*, 2006). The accurate estimation of irrigation requirement of different crops requires the understanding of crop specific water use as represented by the crop coefficient (Kc) (Bhandari, 2012). Doorenbos and Pruitt (1977) define Kc as the ratio of actual crop evapotranspiration (*ETc*) over reference crop evapotranspiration (*ETo*). It helps in determining water requirement of crops with respect to their growth stages and environmental factors (Shukla *et al.*, 2007).

Crop coefficient values remove the burden of setting experiments every time just to identify the right amount of water to be applied for a specific place and season and to make accurate estimation for crop evapotranspiration. There are existing crop coefficient values that are recommended in general (FAO No. 56). However, there are few recommended values of crop coefficient for a specific location. Crop coefficient is location- and season-specific (Tyagi, *et al.*, 2000, cited by Bhandari, 2012). This is due to the factors affecting crop coefficient that include the type of crop, climate, soil evaporation, and crop growth stages (Allen *et al.*, 1998). Moreover, conditions regarding the environment and culture could be different from one place to another despite having crop coefficient functions developed for certain crops around the world that are included in Food and Agriculture Organization (FAO) guidelines (Allen *et al.*, 1998; Fisher, 2012). Accurate measurement of crop water requirement and estimation of crop coefficient results in an effective irrigation management strategy. It is important for farmers and irrigators to know this information to improve water use efficiency, hence this study. The general objective of this study is to determine the crop water requirement and crop coefficients of IPB Var13 corn at every growth stage using a drainage-type lysimeter. The computed Kc values were evaluated and compared with available local literatures and FAO established Kc values for corn.

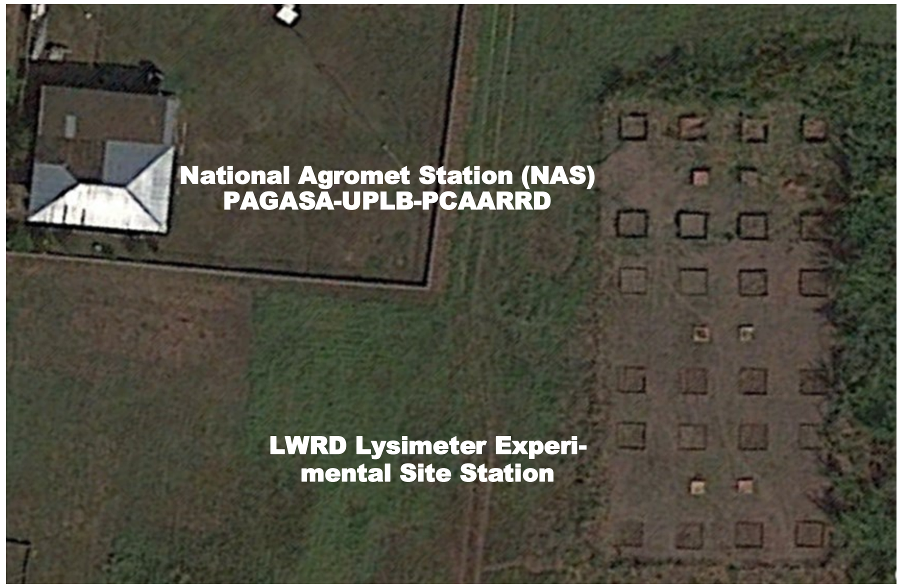

Figure 1. Location of the Experimental Site.

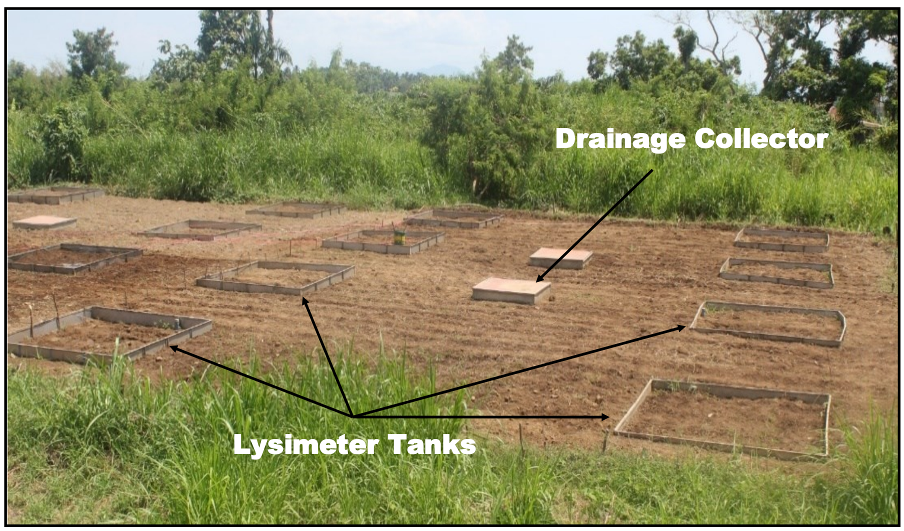

Figure 2. Lysimeter Setup.

## MATERIALS AND METHODS

### Experimental Setup

The experiment was conducted at the Land and Water Resources Division (LWRD) Lysimeter Area in UP Los Baños situated beside the National Agromet Station (NAS) PAGASA-UPLB-PCAARRD as shown in Figure 1. It is located at 14°09'N and 121°15'E with an elevation of 21.7 m above sea level. The experimental site falls under Type 1 climate based on the Modified Corona Classification, with two pronounced seasons: dry from November to April, and wet during the rest of the year. Maximum rain period is from June to

September. Mean annual rainfall and mean temperature is about 1,942 mm and 26.71°C, respectively. The soil type in the experimental site was found to range from sandy loam to sandy clay loam.

Four sets of drainage-type lysimeters were used for the study. One set is composed of four 2.44 m × 2.44 m × 1.22 m (8 ft × 8 ft × 4 ft) lysimeter tanks and one 1.22 m × 1.22 m × 2.44 m (4 ft × 4 ft × 8 ft) drainage collector tank. The effective soil depth in the lysimeter tanks is 1.22 m. The lysimeter tanks were filled with the same soil in the field and with 0.1 m (4-in) sand-gravel pack at the bottom to facilitate drainage and collection of excess water from the upper soil to the drainage collector tank. Figure 2 shows the arrangement of lysimeter tanks and collector tank. The bottom of the lysimeter was slightly sloping for ease of flow to the drainage pipes connected to the drainage collector tank. The upper rims of the lysimeter protrude above the soil surface to prevent surface runoff water from entering the lysimeter but this was limited near the ground level to minimize the boundary layer effect in and around the lysimeters.

Land preparation of the field and the lysimeter was done before planting. Land soaking was done to moisten the soil and facilitate early growth and normal root growth. The field was planted with IPB VAR-13 variety of corn which is commonly planted in Luzon with an average national yield of 6.23 tons/ha. In each lysimeter tank, 24 corn plants were sown. The row and interrow spacing used were 60-cm and 30-cm, respectively. Recommended amounts of fertilizer were applied to the crop using row band placement at the time of sowing and at knee height stage. The corn plants were grown for 120-days.

**Soil Sampling and**
**Soil Moisture Content Determination**

Soil texture was determined using the standard hydrometer method. Bulk density ($\boldsymbol{\rho}$) was determined from undisturbed soil sample taken from the site using core sampler. Using the bulk density ($\boldsymbol{\rho_b}$), apparent specific gravity ($A_s$) was computed by dividing the bulk density with the density of water. The water contents by volume at field capacity ($FC_m$) and permanent wilting point ($PWP_m$) were determined using pressure plate apparatus and the total available water ($TAW$) was obtained using the following equation.

$$TAW = \left(\frac{FC_m - PWP_m}{100}\right) x\ As \times d$$

*Equation 1*

where:

$TAW$ is the Total Available Water (cm);
$FC_m$ is the moisture content by mass at Field Capacity (%);
$PWP_m$ is the moisture content by mass at Permanent Wilting Point (%);
$As$ is the apparent specific gravity; and
$d$ is the depth of root zone (cm)

Three Jet Fill tensiometers (Figure 3) were installed inside three randomly selected lysimeter tanks to measure soil moisture tension at specific depths. Readings from the tensiometers were monitored and recorded daily.

Simultaneously, soil samples were obtained from the site specifically from around each tensiometer at a depth of approximately 0.35 m at the same depth as the tensiometer. This was done to get the corresponding moisture content at the observed tensiometer reading. The moisture contents of the soil samples were determined via gravimetric method which requires the fresh weight of the soil sample and its oven-dry weight measured after 48 h of oven-drying. Soil moisture content was computed using this equation:

$$MC_m = \frac{FW - ODW}{ODW} \times 100$$

*Equation 2*

where:

$MC_m$ is the moisture content in dry mass basis (%)
$FW$ is the fresh weight of the soil sample (g)
$ODW$ is the oven-dry weight of the soil sample (g)

The tensiometer readings and the corresponding moisture contents were plotted to generate the soil moisture retention curve. The developed soil moisture retention curve was then used to convert tensiometers readings to soil moisture readings.

**Irrigation Water Application and Drainage**

Soil moisture content was monitored daily by getting the tensiometers readings and getting the equivalent moisture content using the generated soil moisture retention curve. The obtained soil moisture content was then converted to its volumetric moisture content by multiplying to the apparent specific gravity of the soil and then translated to its equivalent depth by multiplying to the depth of root zone.

Irrigation water was applied to the crop when 55% depletion of the available soil moisture occurred within the effective root zone of the crop (Doorenbos & Kassam, 1979; Allen *et al.*, 1998). Similar irrigation amount at this depletion was given to the crop inside and outside the lysimeter to ensure uniform plant growth. The volume of water needed to irrigate the field was computed using the equation:

$$V = A \times D$$

*Equation 3*

Figure 3. Tensiometer installed inside lysimeter tank.

where:

$V$ is the amount of water to be added ($m^3$)
$A$ is the surface area of lysimeter ($m^2$)
$D$ is the depth of application (m) which was computed using this formula:

$$D = (FC_m - MC_f)\ x\ As\ x\ d$$

*Equation 4*

where:

$d$ is the depth of root zone (m)
$As$ is the apparent specific gravity
$MC_f$ is the moisture content (%) at 55% allowable moisture depletion, which is computed as follows:

$$MC_f = FC_m - 0.55\,(FC_m - PWP_m)$$

*Equation 5*

Excess water was then collected from the drainage collector tanks and measured using graduated cylinders.

**Agronomic Data Collection**

Among the growth parameters, plant height was measured at each growth stage from five random plants from the plot. Leaf area index (*LAI*) was determined by capturing a bird's eye view image using digital camera and was computed as the ratio of leaf area to the area of land occupied by these plants in the given frame captured in the image.

**Determination of Crop Coefficient**

Actual Crop Evapotranspiration ($ETc$) was computed using the soil water balance equation:

$$ETc = I + R - D \pm \Delta S$$

*Equation 6*

where:

$ETc$ is the actual crop evapotranspiration (mm)
$I$ is the irrigation applied (mm)
$R$ is the rainfall received (mm)
$D$ is the drainage water (mm)
$\Delta S$ is the change in soil water (mm).

The reference crop evapotranspiration ($ETo$), on the other hand, was calculated using the FAO Penman-Monteith equation imbedded in CROPWAT 8.0, which is a program that determines the crop water requirement, irrigation scheduling, and cropping pattern of a given crop through various inputs (soil data, climate data, etc.). Climatic parameters such as rainfall, sunshine hour duration, air temperature, relative humidity and wind speed were collected daily from the NAS-PAGASA-UPLB-PCAARRD located 4 m away from the lysimeters. An automatic weather station (iMethos) was also installed near the site for verification.

The crop coefficient Kc was calculated as the ratio of $ETc$ and $ETo$ and was computed daily. The computed average crop coefficient for each growth stage was then compared to related literatures.

**Table 1. Agronomic Data for IPB Var13corn variety.**

| DAP | LEAF AREA $cm^2$ | *LAI* | PLANT HEIGHT, cm |
|---|---|---|---|
| 10 | 68.18 | 0.26 | 26.30 |
| 20 | 157.69 | 0.32 | 34.40 |
| 30 | 227.65 | 0.39 | 69.85 |
| 40 | 317.98 | 0.44 | 95.40 |
| 50 | 467.72 | 0.52 | 128.35 |
| 60 | 545.52 | 0.79 | 147.50 |
| 70 | 763.36 | 0.96 | 178.80 |
| 80 | 942.13 | 1.34 | 198.55 |
| 90 | 1137.74 | 1.58 | 210.80 |
| 100 | 1270.50 | 1.89 | 225.50 |
| 110 | 1158.20 | 2.10 | 210.50 |
| 120 | 1001.98 | 1.52 | 193.25 |

**Table 2. Initial information needed in the soil water balance.**

| PARAMETER | VALUE |
|---|---|
| Crop | Corn (IPB var13) |
| Growth Duration | 120 days |
| Lysimeter tank height | 2438.4 mm (8 ft) |
| Soil type | Sandy loam |
| Allowable Moisture Depletion (AMD) | 55% |
| Permanent Wilting Point (PWPv) | 17% |
| Field Capacity (FCv) | 38% |
| Apparent Specific Gravity (As) | 1.32 |

## RESULTS AND DISCUSSION

### Agronomic Data

The growth of IPB Var13 corn variety was also assessed based on the seasonal change of plant height, leaf area and leaf area index ($LAI$). Table 1 shows the average results of these parameters taken every 10 days for both cropping seasons.

The *LAI* understandably was lowest at initial stage for both cropping seasons but the leaf area, *LAI* and plant height increased consistently from initial to the development and mid-season stages. The maximum *LAI* was achieved when the crop reached their maximum height at mid-season stage with high crop evapotranspiration due to leaf enlargement that increases transpiration. At this stage of the crop development, leaf area and *LAI* started to decrease, whereas plant height remained relatively constant for the rest of the season. The decrease in leaf area and *LAI* was due to the maturity of the crop associated with leaf ageing, senescence and dropping of leaves.

**Soil Water Balance**

The data and assumptions in the soil and water calculations are summarized in Table 2. Values of soil properties in the lysimeters were taken from the analysis of Gonzales (2016). For the soil water balance equation, the change in soil water, **Δ*S***, or the available moisture in the soil, is equal to the difference between the inputs, such as irrigation water applied (*I*) and amount of rainfall (*R*), and output parameters such as crop evapotranspiration (*ETc*) and drainage (*D*). Surface runoff, ground-water movement, deep percolation, and spray and drift losses were not included in the original water balance equation. The upper rims of the lysimeter were designed to prevent surface runoff in or out of the lysimeter tank. Spray and drift losses from irrigation water were neglected. Groundwater movement were also neglected since the lysimeter prevents upward movement of water to reach the soil inside the lysimeter. Deep percolation is considered as the drainage since the downward movement of water through the lysimeter would be collected in the drainage collector tank.

Table 3 shows the depths of water corresponding to the initial moisture content, critical moisture content, and moisture content at field capacity. The critical moisture content and the moisture content at field capacity served as the lower and upper boundary of the soil water in the experimental site, respectively. It means that if the soil water decreases to an amount lower than 644.96 mm, irrigation shall be applied until the amount of soil water reaches the depth at field capacity equivalent

**Table 3. Depth of water translated from the given moisture content values.**

| MOISTURE CONTENT LEVEL | $MC_v$ (%) | | | DEPTH (mm) | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| Field Capacity | 38.00 | 38.00 | 38.00 | 926.59 | 926.59 | 926.59 |
| Initial | 29.04 | 28.99 | 29.11 | 708.11 | 706.82 | 709.72 |
| Critical | 26.45 | 26.45 | 26.45 | 644.96 | 644.96 | 644.96 |

**Table 4. Average decadal values of water balance components (mm) for 1st cropping.**

| DAP | R | I | D | ΔS | ETc | ETo |
|---|---|---|---|---|---|---|
| 10 | 29.00 | 0.00 | 0.00 | 7.72 | 2.13 | 4.99 |
| 20 | 13.10 | 0.00 | 0.00 | -2.15 | 1.99 | 4.89 |
| 30 | 32.20 | 0.00 | 0.00 | 3.00 | 2.92 | 5.05 |
| 40 | 63.80 | 0.00 | 0.00 | -3.00 | 3.22 | 4.51 |
| 50 | 63.20 | 0.00 | 0.00 | 29.05 | 3.42 | 4.48 |
| 60 | 75.60 | 0.00 | 0.00 | -3.39 | 3.44 | 3.82 |
| 70 | 7.80 | 0.00 | 0.00 | -32.06 | 3.99 | 4.46 |
| 80 | 174.20 | 0.00 | 2.75 | -1.72 | 2.82 | 3.03 |
| 90 | 34.30 | 0.00 | 0.24 | -1.82 | 3.61 | 3.84 |
| 100 | 24.70 | 0.00 | 8.42 | -0.75 | 3.39 | 4.28 |
| 110 | 119.60 | 0.00 | 76.15 | 16.99 | 2.70 | 3.96 |
| 120 | 38.50 | 0.00 | 21.49 | -0.32 | 1.73 | 3.06 |
| Total | 676.00 | 0.00 | 109.05 | 11.55 | - | - |

**Table 5. Average decadal values of water balance components (mm) for 2nd cropping.**

| *DAP* | *R* | *I* | *D* | *ΔS* | *ETc* | *ETo* |
|---|---|---|---|---|---|---|
| 10 | 47.80 | 0.00 | 0.00 | 33.17 | 1.46 | 3.56 |
| 20 | 42.10 | 0.00 | 0.00 | -1.01 | 1.54 | 3.52 |
| 30 | 6.20 | 0.00 | 0.00 | -12.28 | 1.85 | 3.48 |
| 40 | 56.30 | 0.00 | 0.00 | -2.31 | 1.89 | 2.74 |
| 50 | 119.20 | 0.00 | 0.00 | 97.47 | 2.17 | 3.02 |
| 60 | 184.00 | 0.00 | 142.06 | 36.42 | 2.39 | 2.79 |
| 70 | 23.30 | 0.00 | 0.00 | -2.22 | 2.55 | 3.03 |
| 80 | 0.00 | 0.00 | 0.00 | -3.54 | 3.33 | 3.38 |
| 90 | 2.00 | 0.00 | 0.00 | -29.79 | 3.18 | 3.28 |
| 100 | 6.50 | 0.00 | 0.00 | -2.38 | 2.5 | 3.04 |
| 110 | 8.80 | 0.00 | 0.00 | -12.66 | 2.15 | 3.12 |
| 120 | 1.80 | 0.00 | 0.00 | -13.84 | 2.27 | 3.96 |
| Total | 498.00 | 0.00 | 142.06 | 87.03 | - | - |

to 926.59 mm. If the soil water exceeds 926.59 mm, drainage shall occur until the soil water reached the depth at field capacity. The drained water was measured and collected from the drainage collector of each lysimeter tank.

**Crop Evapotranspiration**

Crop evapotranspiration values (*ETc*) were obtained with respect to the components of the soil water balance equation. Table 4 and 5 shows the average amounts of rainfall (*R*), irrigation applied (*I*), drainage (*D*), crop evapotranspiration (*ETc*) and change in soil water (Δ*S*) for every 10 days after planting (*DAP*) for both cropping seasons. The relative distribution of rainfall for both cropping seasons can also be observed. The total amount of rainfall measured during the experiment for the 1st and 2nd cropping season were 676.0 mm and 498.0 mm, respectively. As for the *ETc* decadal values ranged from 17.33 mm to 39.86 mm for the 1st season and 14.63 mm to 33.27 mm for the 2nd season. The highest amount of *ETc* was observed at the point of lowest rainfall. This was an expected result since *ETc* and rainfall have an inverse relationship with respect to the soil water balance equation.

Table 4 and 5 show that higher *ETc* values were generally observed between 70-100 days after planting for both seasons as compared to the values in the beginning and end of the crop life cycle. Both *ETc* and *ETo* have irregular and fluctuating trends throughout the planting season which is expected because of changes in the crop growth and daily changes in weather parameters such as radiation, humidity, wind speed and temperature. Crop evapotranspiration increases with increasing air temperature and solar radiation, the two primary drivers of evapotranspiration (Irmak, 2009). The total crop water requirement of the IPB Var13 variety based on the 1st and 2nd cropping season in the study were found to be 353.43 mm and 272.84 mm, respectively. The highest water requirements were recorded at the mid-season stage followed by the development stage while the lowest were observed in the initial growth stage for both cropping seasons. The lowest crop water requirement at the initial growth stage is mainly due to low crop leaf area development with a low transpiration capacity as can be seen by the Leaf Area Index (*LAI*) of the crop as shown in Table 1. On the other hand, the rapid reduction in *ETc* in the late season stage was due to the physiological deterioration of the leaves because of aging and senescence. The period of maturity coincides with the period of less water demand because of drying of leaves and minimum leaf area available for transpiration (Kassam, *et al.*, 1975).

It can also be observed from both tables that the field was not irrigated throughout the planting season. This was because rainfall throughout the planting season was enough to supply the amount of water needed to prevent the soil from reaching the critical moisture content of 26.45% or 644.96 mm depth. The water loss accounted for *ETc* amounted to a total of 353.42 mm throughout the 1st cropping season and 272.84 mm for the 2nd cropping season. Moreover, no drainage water was collected for the first 60-70 DAP of both cropping seasons. This can be accounted for the high water demand of the crop during vegetative and developmental stage that consumed the supplied water by the soil and rainfall (Villagra *et al.*, 1994). But after the 60-70 DAP, a total of 109.05 mm for 1st cropping season and 142.06 mm for 2nd cropping season of drainage water were collected until harvest due to the occurrence of high rainfall amounts. As mentioned before, drainage occurs when the amount of soil water exceeded the depth of water at field capacity which is 926.59 mm in this case.

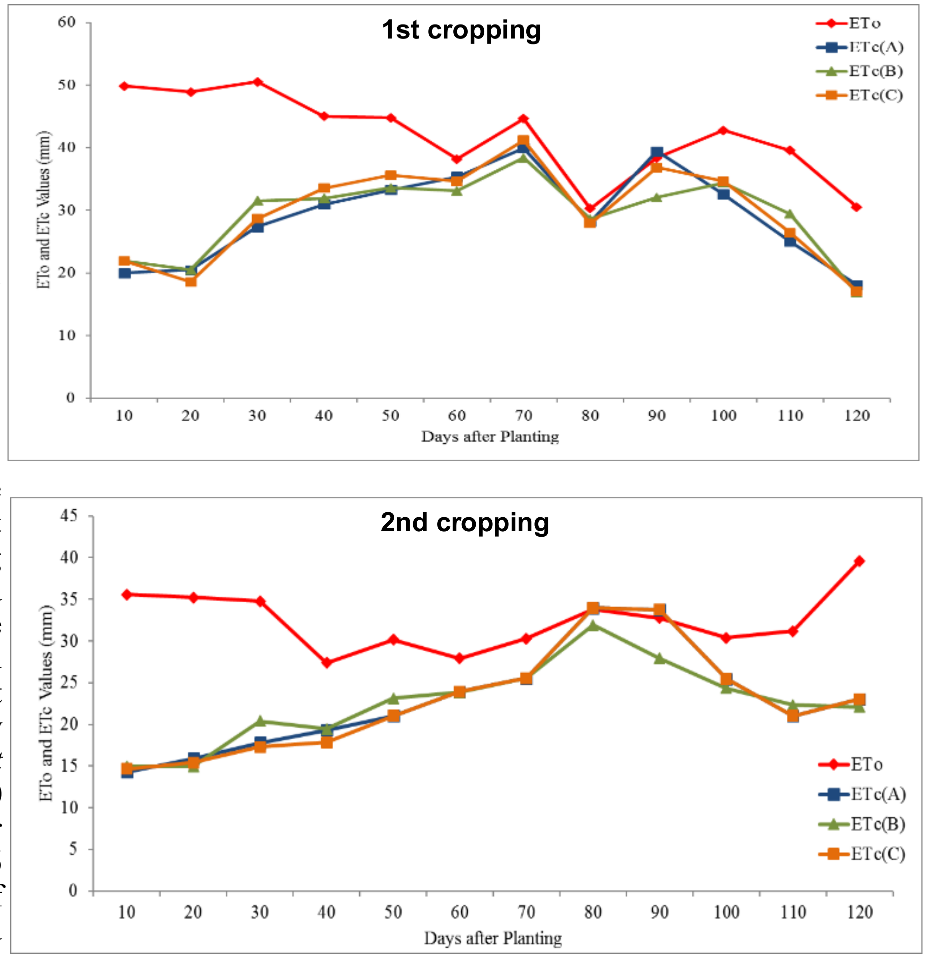


Figure 4. Actual and reference crop evapotranspiration of IPB Var13 corn variety for both cropping seasons.

**Reference Crop Evapotranspiration**

CROPWAT 8.0 was used to compute the daily reference crop evapotranspiration (*ETo*). The evapotranspiration process is determined partly by the amount of energy used to vaporize water. Air temperature or the sensible heat of the surrounding air and solar radiation directly affects the rate of evapotranspiration. Solar radiation has the following components: extraterrestrial radiation, shortwave radiation, relative solar radiation, net shortwave radiation, net longwave radiation, and net radiation. Net radiation, the difference between incoming and outgoing radiations, is one of the outputs of CROPWAT 8.0.

The other major part of evapotranspiration is the vapor removal due to turbulent transport which is dependent mainly on air humidity and wind speed. Low humidity means less moisture present in the air that would increase the vapor pressure deficit between the air and the evaporating surface and increases evapotranspiration rate. On the other hand, faster wind speed means larger quantities of air would pass through the evaporating surface carrying more vapor and increasing the vapor

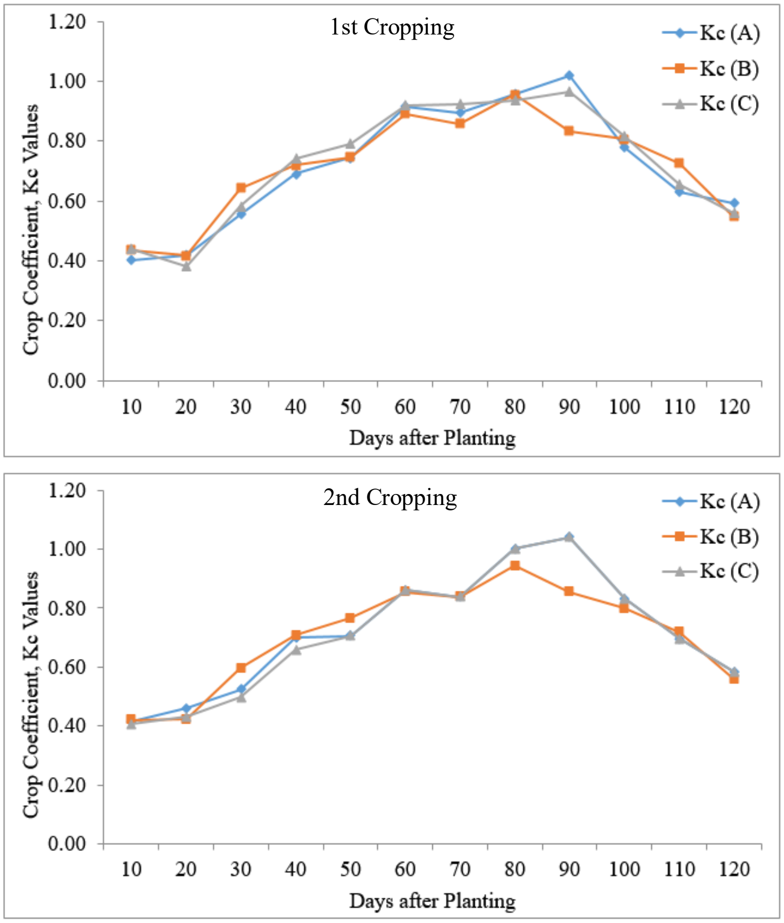


Figure 5. Decadal values of crop coefficient, Kc for both cropping seasons of IPB Var13 corn variety.

pressure deficit, thus higher rate of evapotranspiration (Allen *et. al.,* 1998).

The 10-day total *ETo* and *ETc* were plotted as a function of growth duration as shown in the Figure 4. For the first 10 days, *ETo* started at a high amount 49.85 mm and 35.58 mm for 1st and 2nd cropping, respectively. The period is characterized by long sunshine hours, high temperature, and large net radiation. Being a climatic parameter, *ETo* then fluctuated corresponding to the changes in climatic parameters such as radiation, humidity, wind speed, and temperature (Abedinpour, 2015; Shenkut *et al.*, 2013). On the other hand, *ETc* from the three lysimeter setups A, B and C started at low amounts, which means that crop water use was very low during the initial stages. This may be attributed to low crop leaf area development leading to low transpiration capacity (Shenkut *et al.*, 2013).

**Table 6. Comparison of computed crop coefficient values with FAO-recommended values.**

| STAGE | % GROWTH DURATION | DAP | 1st Cropping Kc | 2nd Cropping Kc | Average Kc | FAO Kc Values |
|---|---|---|---|---|---|---|
| Initial | 0 - 17 | 0-20 | 0.42 | 0.43 | 0.43 | 0.40 |
| Crop Developmental | 17 - 44 | 21-52 | 0.70 | 0.67 | 0.69 | 0.80 |
| Mid-Season | 44 - 76 | 53-90 | 0.93 | 0.92 | 0.92 | 1.15 |
| Late-Season | 76 - 100 | 91-120 | 0.69 | 0.70 | 0.70 | 0.70 |

**Table 7. Comparison of computed crop coefficient values with local studies.**

| % GROWTH DURATION | DAP | 1st CROPPING Kc | 2nd CROPPING Kc | AVERAGE Kc | DAVID (1983)* |
|---|---|---|---|---|---|
| 0-20% | 0-24 | 0.41 | 0.43 | 0.42 | 0.40 |
| 20-40% | 25-47 | 0.72 | 0.67 | 0.69 | 0.70 |
| 40-70% | 48-83 | 0.91 | 0.89 | 0.90 | 0.90 |
| 70-90% | 84-106 | 0.83 | 0.85 | 0.84 | 0.80 |
| HARVEST | 107-118 | 0.57 | 0.59 | 0.58 | 0.55 |

* Source: David, W.P. Lysimeter studies. 1975-1983, UPLB, College, Laguna

The *ETc* values increased in the course of the corn development period due to the high evaporative and crop water demands (Villagra *et al.*, 1994; Abedinpour, 2015) brought about by the fully developed crop canopies (Abedinpour, 2015) and its reproductive growth (Shenkut *et al.*, 2013). High water demands were also expected at tasseling and silking stages (Villagra *et al.*, 1994). It was also observed in all lysimeter setups and in both cropping seasons that the amount of *ETc* exceeded the *ETo* at 80-90 days after planting. This mid-season stage has high demand for crop water use due to flowering, grains formation and filling (Shenkut *et al.*, 2013). Afterwards, *ETo* continuously increased and fluctuated with air temperature and solar radiation (Irmak, 2009) whereas the *ETc* rates gradually decreased. This reduction was mainly due to the physiological deterioration of leaves because of aging or specifically the cessation of leaf growth (Allen *et al.*, 1998). This period of maturity indicated the period of less water demand because of drying leaves and minimum leaf area available for transpiration (Kassam *et al.*, 1975).

**Crop Coefficient**

Figure 5 shows the computed 10-day average values of Kc for the three lysimeter setups and for both cropping seasons. Generally, the Kc curve has an increasing trend from initial to the mid-season stage when vegetative growth has already ended and the crop undergoes reproductive growth, then a decreasing trend afterwards. As crop grows, Kc increases until it reaches a certain peak and decreases as the crop approach harvest (Evett *et al.*, 2006). The shape of the curve is a representation of the changes in ground cover during plant development and maturation that affect the ratio of *ETc* to *ETo* . With grass as reference crop for *ETo* , the *ETc* of corn should be different because the ground cover, canopy properties and aerodynamic resistance of corn differs from that of grass. These differences in crop-specific characteristics were integrated in the crop coefficient (Allen *et al.*, 1998).

The obtained Kc curves from the three lysimeter setups for both cropping seasons have similar trends and only minor variations, which is expected since the setups are located in the same experimental site, under the same climate and other surrounding conditions. The slight variations may be accounted for by the difference in the initial soil moisture content of each setup which cause discrepancy in the computation for *ETc* using soil water balance equation. The lowest Kc values occurred during the initial stage, 10-20 days after planting, when the difference between *ETc* and *ETo* is at its largest. Afterwards, Kc values increased from initial to development stages and reached its highest value at mid-season stage or at 90 days after planting. At this point, *ETc* exceeded *ETo* when there was low evaporative demand but high crop water use demand for reproductive growth (Shenkut *et al*., 2013). From that peak, Kc values started to decline from the mid-season to the late-season stage as the difference between the *ETc* and *ETo* again became larger. Decreased leaf surface due to aging restricts transpiration that decreases *ETc* leading to reduction value of *K* (Allen *et al*., 1998).

Table 5 show the computed Kc values as compared with the FAO recommended values (Doorenbos & Pruitt, 1977). The growth stages stated in FAO were dependent on ground cover and other plant characteristics. For comparison purposes, these growth stages were converted to percent growth duration which is divided in number of days. It can be observed that the computed Kc values were higher during the initial stage than the FAO values with a percent difference of 7.5%. This may be due to high initial evaporation from long sunshine hours and low initial rainfall in the experimentation site. The Kc values at developmental and mid-season stage, on the other hand, were slightly lower than the FAO recommended values with percent difference of 14.74% and 22.22%, respectively. The Kc values are the same during the late season stage. The discrepancy of the FAO-recommended Kc values to the computed Kc values in this study can be attributed to differences in both variety, and climate or environmental conditions, confirming the findings of Allen *et al*. (1998), Tyagi, *et al*. (2000) cited by Bhandari (2012), and Fisher (2012).

The obtained Kc values were also compared with values from studies conducted in the same experimental site compiled by David (1983) as shown in Table 6. The computed Kc values were only slightly higher than the values obtained from lysimeter studies conducted by David (1983) with a maximum percent difference of only 5.31% at the harvesting stage. The Kc values are the same during the mid-season stage. While the variety used in both studies are different, the climate and soil properties are the same. It should be noted however, that the Kc values from these previous studies were computed based on potential evapotranspiration (*ETp* or *PET*) using the original Penman method for open water surface unlike the method used in the study which is based on reference crop evapotranspiration (*ETo*).

## SUMMARY AND CONCLUSION

Crop coefficients are essential in estimating crop water requirement needed in developing an effective irrigation management scheme. In this study, drainage-type lysimeter was used to determine the actual crop evapotranspiration (*ETc*) under water balance system on a sandy loam soil while local weather data were used to determine the reference crop evapotranspiration (*ETo*) using CROPWAT 8.0. The daily crop coefficient (Kc) values were then computed by getting the ratio of *ETc* over *ETo*. The results showed the computed Kc values of 0.43, 0.69, 0.92 and 0.70 during the initial, development, mid-season and late season stages, respectively. The computed values differed from the FAO-recommended values with percent difference of 7.23%, 14.75%, 22.22% and 0% for the initial, crop development, mid-season and late stages, respectively. The variations were attributed mainly to differences in both variety (crop genetic factor), and climate or environmental conditions. On the other hand, comparing the computed Kc values with values based on available lysimeter studies in the Philippines resulted in very small differences with a maximum percent difference of only 5.31% at the harvest stage during which terminal irrigation is already in effect. The slight difference may be attributed to difference in variety and method used in computing *ETo*. The computed Kc values in the study are more applicable to local conditions than with the FAO-recommended values and can be used in the computation of crop water requirement of corn in the Philippines.

## RECOMMENDATIONS

Locally determined Kc information is very limited and not available for many important crops in the Philippines. It would be advisable to conduct same study using different crops. Moreover, it would be advisable to conduct same study at different growing season to increase the accuracy of the resulting crop coefficients. It is also recommended to use other varieties of corn in future studies for comparison purposes on the effect of crop genetic factor and phenology. Other types of soil should also be considered to determine the effect of using different soil types in determining crop coefficients.

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