

CROP COEFFICIENT (K_c): A water conservation tool for achieving Per Drop More Crop

Manju P S¹, Dhanalakshmi V², Chandru R³ and Manikandan N⁴

^{1,2} PGRResearch Scholar, Department of Agricultural Meteorology, College of Agriculture, Padannakkad, Kasaragod, Kerala -671314, India.

³ PG Research Scholar, Department of Plant Physiology, College of Agriculture, Padannakkad, Kasaragod, Kerala.

⁴ Assistant Professor, Department of Agricultural Meteorology, College of Agriculture, Padannakkad, Kasaragod, Kerala.

Corresponding Author Email ID: manju-2024-11-154@student.kau.in

Manuscript No: KN-V3-12/009

Abstract

Water is the lifeline of farming, yet it is becoming increasingly scarce. Farmers today are under pressure to grow more food using less water, making smart water management essential. The crop coefficient (K_c) is a simple but powerful tool that helps determine how much water a crop actually needs at different stages of its growth. By comparing the water use of a crop to that of a standard reference grass, K_c helps farmers understand when a crop is “thirsty” and when it needs less water. Factors such as crop type, height, growth stage, weather and soil moisture influence K_c . With approaches like the single and dual crop coefficient methods, farmers and researchers can estimate crop evapotranspiration more accurately. Understanding and applying K_c not only helps avoid over-irrigation and reduce costs, but also plays an important role in conserving water for the future. As water scarcity rises, K_c becomes an essential guide for sustainable and efficient agriculture.

Keywords: Crop coefficient, single and dual crop coefficient, crop evapotranspiration

Introduction

Water is the lifeline of agriculture. Around 72% of global freshwater is used by the agriculture sector. Farmers are trying to grow more food with less water but in real life farmers across the world face the challenge of conserving water. We have different methods of water conservation such as rainwater harvesting, drip irrigation, sprinkler irrigation, mulching, contour farming, soil moisture conservation practices etc. These conservation practices are important because each drop of water valuable. Yet we have to know that, crops don't need the same amount of water every day. Just as we drink more water when we work hard and less water when we relax, crops also have changing water needs throughout their growth. To understand these needs, scientists use a simple but powerful tool called the Crop Coefficient (K_c). It is a simple number that helps farmers know how thirsty a crop is at any stage. By using K_c farmers can avoid over irrigation, save water, reduce cost and also can achieve good yield.

What is crop coefficient?

Crop coefficient (K_c) concept was first introduced by Jensen in 1968. It is a simple value that represents how factors like crop characteristics, plant height, leaf area, canopy cover, irrigation method, management practices, canopy resistance affect the water use compared to reference crop.

It is the ratio between actual crop evapotranspiration (ET_c) and reference evapotranspiration (ET_0) at specific time. Here, the evapotranspiration from a crop under a disease-free, well-managed crop, grown in large fields under optimum soil water and fertility conditions and achieving full production potential is called

crop evapotranspiration (ET_c). Evapotranspiration from a reference surface representing a hypothetical grass surface with well-watered, actively growing green grass of uniform height 0.12 m, completely shading the ground, with a fixed surface resistance of 70 s/m and albedo 0.23 is called Reference evapotranspiration (ET_0).

The relationship between crop evapotranspiration, reference evapotranspiration and crop coefficient can be represented by using the formula,

$$K_c = ET_c / ET_0$$

$$ET_c = K_c \times ET_0$$

Where, ET_c = Crop evapotranspiration, ET_0 = Reference evapotranspiration and K_c = Crop coefficient

Here, ET_0 can be calculated either by using Penman Monteith formula or by pan evaporation method.

Single and Dual Crop Coefficient

In single crop coefficient approach (K_c), both crop transpiration and soil evaporation effects are combined into a single value. Single K_c is used for irrigation planning and design, irrigation management and irrigation scheduling. It is used to compute ET_c for daily, 10-day intervals or monthly.

In the dual crop coefficients ($K_{cb} + K_e$), the crop transpiration and soil evaporation effects are treated separately. They are basal crop coefficient (K_{cb}) which describe transpiration and evaporation coefficient (K_e) which describes soil evaporation. Dual crop coefficient is more accurate than single crop coefficient. This approach is best for real time irrigation scheduling, research studies, supplemental irrigation and detailed soil and hydrologic water balance studies. It can be used to compute ET_c for daily.

Single crop coefficient can be expressed as: $K_c = ET_c / ET_0$

Dual crop coefficient can be expressed as: $K_{cb} + K_e = ET_c / ET_0$

Where, K_c -Crop Coefficient, ET_c -Daily Crop Evapotranspiration [mm/day, ET_0 -Daily Reference Evapotranspiration [mm/day], K_{cb} - Basal Crop Coefficient, K_e - Soil Evaporation Coefficient, $K_{cb} + K_e = K_c$ in dual crop coefficient

Factors determining the crop coefficient

Crop type: Different crops need different amount of water at different growth stage and condition. This is because each crop has different features like height, leaf area etc. As plants grows, they use more water than reference grass, so their K_c value also increases.

Crop type	Water use behaviour	Effect on K_c	Example crops
Tall, dense, full-grown crops	Lose more water because of height + roughness	$K_c > 1$	Maize, Sorghum, Sugar-cane
Crops with day-time stomatal closure	Very low water loss	K_c very low (< 1)	Pineapple

Crop Height: Tall crops have higher aerodynamic roughness so higher K_c whereas, short crops have smaller change in K_c .

Weather:

1. Wind- As wind speed increases K_c value also increases, especially for tall crops. Wind reduces resistance to vapor movement, so crops lose more water.
2. Relative Humidity (RH)- Low relative humidity (dry air) results in higher K_c and high relative humidity (humid air) results in lower K_c .

Humid & Calm Weather	Arid & Windy Weather
<ul style="list-style-type: none"> • Differences between crops and reference grass are small. • K_c values usually do not exceed 1.05. • Both grass and crops absorb similar solar energy. • Small vapor pressure deficit = small ET difference. 	<ul style="list-style-type: none"> • K_c increases significantly, especially for tall crops. • Larger vapor pressure deficit makes crops lose more water. • Tall crops (2–3 m) may have K_c up to 30% higher under arid, windy climates.

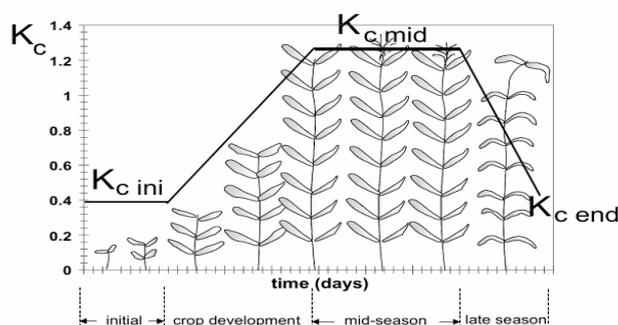
Soil evaporation: The crop coefficient (K_c) includes both soil evaporation and crop transpiration. In full-cover crops, most water loss comes from transpiration, so soil evaporation is small. When the crop is young and small, the soil is exposed and soil evaporation becomes the main component. After rain or irrigation, soil evaporation increases sharply, especially when the ground is not shaded.

- If the soil is wet frequently, evaporation is high → K_c may exceed 1.0.
- If the soil surface stays dry, evaporation reduces → K_c can be very low (as low as 0.1).

Crop growth stages: The growing season of most annual crops can be divided into four growth stages. They are,

Initial stage	From planting to stage when the crop cover 10 percent of ground surface. Evaporation is the main component of ET_c
Crop development stage	From 10 percent ground cover to effective full coverage
Mid-season stage	From effective full cover to the start of maturity Indicate aging or senescence of leaves
Late season stage	From start of maturity to harvest or full senescence

Figure 1. Crop coefficient curve curve



Source: Crop evapotranspiration: Guidelines for computing crop water requirements (Irrigation and Drainage Paper No. 56)

Determination of K_c

1. Determine total growing period
2. Identify major growth stages of the crop such as initial, crop development, mid- season and late season
3. Fix appropriate duration of each stage either by using available local field data or by using FAO guidelines
4. Determine crop evapotranspiration for each stage (most accurate method is lysimeter)
5. Determine reference crop evapotranspiration (most accurate method is Penman-Monteith equation)
6. Calculate K_c for each stage: $K_c = ET_c / ET_0$

Single crop coefficient of some important crops in sub- humid climate

Crops	K_c (initial)	K_c (mid)	K_c (end)
Rice	1.05	1.20	0.69-0.90
Wheat		1.15	0.25-0.40
Maize		1.20	0.35-0.60
Cassava	0.30	0.80	0.30
Sugarcane	0.40	1.25	0.75
Cucumber	0.60	1.00	0.75
Tomato		1.15	0.70-0.90
Banana	0.50	1.10	1.00
Pineapple (bare soil)	0.50	0.30	0.30
Pineapple (grass cover)	0.50	0.50	0.50
Rubber	0.95	1.0	1.0

Conclusion

The crop coefficient (K_c) may appear to be a small number, but it plays a significant role in helping farmers use water efficiently. With water scarcity becoming a global challenge, tools like K_c ensure that every drop counts. By understanding how crops utilize water at various growth stages, farmers can enhance efficiency, conserve resources, and foster a more sustainable future for agriculture. Since K_c changes with crop type, growth stage, weather and soil wetness, adjusting it correctly helps estimate crop water use more accurately.

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