**TABLE 12. Single (time-averaged) crop coefficients, Kc, and mean maximum plant heights for non stressed, well-managed crops in subhumid climates (RHmin  45%, u2  2 m/s) for use with the FAO Penman-Monteith ETo.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Crop** | | https://www.fao.org/3/x0490e/x0490e2a.gif | **Kc mid** | **Kc end** | **Maximum Crop Height (h) (m)** |
| **a. Small Vegetables** | | **0.7** | **1.05** | **0.95** |  |
| Broccoli | |  | 1.05 | 0.95 | 0.3 |
| Brussel Sprouts | |  | 1.05 | 0.95 | 0.4 |
| Cabbage | |  | 1.05 | 0.95 | 0.4 |
| Carrots | |  | 1.05 | 0.95 | 0.3 |
| Cauliflower | |  | 1.05 | 0.95 | 0.4 |
| Celery | |  | 1.05 | 1.00 | 0.6 |
| Garlic | |  | 1.00 | 0.70 | 0.3 |
| Lettuce | |  | 1.00 | 0.95 | 0.3 |
| Onions | |  |  |  |  |
|  | - dry |  | 1.05 | 0.75 | 0.4 |
|  | - green |  | 1.00 | 1.00 | 0.3 |
|  | - seed |  | 1.05 | 0.80 | 0.5 |
| Spinach | |  | 1.00 | 0.95 | 0.3 |
| Radish | |  | 0.90 | 0.85 | 0.3 |
| **b. Vegetables - Solanum Family *(Solanaceae)*** | | **0.6** | **1.15** | **0.80** |  |
| Egg Plant | |  | 1.05 | 0.90 | 0.8 |
| Sweet Peppers (bell) | |  | 1.052 | 0.90 | 0.7 |
| Tomato | |  | 1.152 | 0.70-0.90 | 0.6 |
| **c. Vegetables - Cucumber Family *(Cucurbitaceae)*** | | **0.5** | **1.00** | **0.80** |  |
| Cantaloupe | | 0.5 | 0.85 | 0.60 | 0.3 |
| Cucumber | |  |  |  |  |
|  | - Fresh Market | 0.6 | 1.002 | 0.75 | 0.3 |
|  | - Machine harvest | 0.5 | 1.00 | 0.90 | 0.3 |
| Pumpkin, Winter Squash | |  | 1.00 | 0.80 | 0.4 |
| Squash, Zucchini | |  | 0.95 | 0.75 | 0.3 |
| Sweet Melons | |  | 1.05 | 0.75 | 0.4 |
| Watermelon | | 0.4 | 1.00 | 0.75 | 0.4 |
| **d. Roots and Tubers** | | **0.5** | **1.10** | **0.95** |  |
| Beets, table | |  | 1.05 | 0.95 | 0.4 |
| Cassava | |  |  |  |  |
|  | - year 1 | 0.3 | 0.803 | 0.30 | 1.0 |
|  | - year 2 | 0.3 | 1.10 | 0.50 | 1.5 |
| Parsnip | | 0.5 | 1.05 | 0.95 | 0.4 |
| Potato | |  | 1.15 | 0.754 | 0.6 |
| Sweet Potato | |  | 1.15 | 0.65 | 0.4 |
| Turnip (and Rutabaga) | |  | 1.10 | 0.95 | 0.6 |
| Sugar Beet | | 0.35 | 1.20 | 0.705 | 0.5 |
| **e. Legumes *(Leguminosae)*** | | **0.4** | **1.15** | **0.55** |  |
| Beans, green | | 0.5 | 1.052 | 0.90 | 0.4 |
| Beans, dry and Pulses | | 0.4 | 1.152 | 0.35 | 0.4 |
| Chick pea | |  | 1.00 | 0.35 | 0.4 |
| Fababean (broad bean) | |  |  |  |  |
|  | - Fresh | 0.5 | 1.152 | 1.10 | 0.8 |
|  | - Dry/Seed | 0.5 | 1.152 | 0.30 | 0.8 |
| Grabanzo | | 0.4 | 1.15 | 0.35 | 0.8 |
| Green Gram and Cowpeas | |  | 1.05 | 0.60-0.356 | 0.4 |
| Groundnut (Peanut) | |  | 1.15 | 0.60 | 0.4 |
| Lentil | |  | 1.10 | 0.30 | 0.5 |
| Peas | |  |  |  |  |
|  | - Fresh | 0.5 | 1.152 | 1.10 | 0.5 |
|  | - Dry/Seed |  | 1.15 | 0.30 | 0.5 |
| Soybeans | |  | 1.15 | 0.50 | 0.5-1.0 |
| **f. Perennial Vegetables (with winter dormancy and initially bare or mulched soil)** | | **0.5** | **1.00** | **0.80** |  |
| Artichokes | | 0.5 | 1.00 | 0.95 | 0.7 |
| Asparagus | | 0.5 | 0.957 | 0.30 | 0.2-0.8 |
| Mint | | 0.60 | 1.15 | 1.10 | 0.6-0.8 |
| Strawberries | | 0.40 | 0.85 | 0.75 | 0.2 |
| **g. Fibre Crops** | | **0.35** |  |  |  |
| Cotton | |  | 1.15-1.20 | 0.70-0.50 | 1.2-1.5 |
| Flax | |  | 1.10 | 0.25 | 1.2 |
| Sisal 8 | |  | 0.4-0.7 | 0.4-0.7 | 1.5 |
| **h. Oil Crops** | | **0.35** | **1.15** | **0.35** |  |
| Castorbean (*Ricinus*) | |  | 1.15 | 0.55 | 0.3 |
| Rapeseed, Canola | |  | 1.0-1.159 | 0.35 | 0.6 |
| Safflower | |  | 1.0-1.159 | 0.25 | 0.8 |
| Sesame | |  | 1.10 | 0.25 | 1.0 |
| Sunflower | |  | 1.0-1.159 | 0.35 | 2.0 |
| **i. Cereals** | | **0.3** | **1.15** | **0.4** |  |
| Barley | |  | 1.15 | 0.25 | 1 |
| Oats | |  | 1.15 | 0.25 | 1 |
| Spring Wheat | |  | 1.15 | 0.25-0.410 | 1 |
| Winter Wheat | |  |  |  |  |
|  | - with frozen soils | 0.4 | 1.15 | 0.25-0.410 | 1 |
|  | - with non-frozen soils | 0.7 | 1.15 | 0.25-0.410 |  |
| Maize, Field (grain) *(field corn)* | |  | 1.20 | 0.60-0.3511 | 2 |
| Maize, Sweet *(sweet corn)* | |  | 1.15 | 1.0512 | 1.5 |
| Millet | |  | 1.00 | 0.30 | 1.5 |
| Sorghum | |  |  |  |  |
|  | - grain |  | 1.00-1.10 | 0.55 | 1-2 |
|  | - sweet |  | 1.20 | 1.05 | 2-4 |
| Rice | | 1.05 | 1.20 | 0.90-0.60 | 1 |
| **j. Forages** | | | | | |
| Alfalfa Hay | |  |  |  |  |
|  | - averaged cutting effects | 0.40 | 0.9513 | 0.90 | 0.7 |
|  | - individual cutting periods | 0.4014 | 1.2014 | 1.1514 | 0.7 |
|  | - for seed | 0.40 | 0.50 | 0.50 | 0.7 |
| Bermuda hay | |  |  |  |  |
|  | - averaged cutting effects | 0.55 | 1.0013 | 0.85 | 0.35 |
|  | - Spring crop for seed | 0.35 | 0.90 | 0.65 | 0.4 |
| Clover hay, Berseem | |  |  |  |  |
|  | - averaged cutting effects | 0.40 | 0.9013 | 0.85 | 0.6 |
|  | - individual cutting periods | 0.4014 | 1.1514 | 1.1014 | 0.6 |
| Rye Grass hay | |  |  |  |  |
|  | - averaged cutting effects | 0.95 | 1.05 | 1.00 | 0.3 |
| Sudan Grass hay (annual) | |  |  |  |  |
|  | - averaged cutting effects | 0.50 | 0.9014 | 0.85 | 1.2 |
|  | - individual cutting periods | 0.5014 | 1.1514 | 1.1014 | 1.2 |
| Grazing Pasture | |  |  |  |  |
|  | - Rotated Grazing | 0.40 | 0.85-1.05 | 0.85 | 0.15-0.30 |
|  | - Extensive Grazing | 0.30 | 0.75 | 0.75 | 0.10 |
| Turf grass | |  |  |  |  |
|  | - cool season 15 | 0.90 | 0.95 | 0.95 | 0.10 |
|  | - warm season 15 | 0.80 | 0.85 | 0.85 | 0.10 |
| **k. Sugar Cane** | | **0.40** | **1.25** | **0.75** | **3** |
| **l. Tropical Fruits and Trees** | | | | | |
| Banana | |  |  |  |  |
|  | - 1st year | 0.50 | 1.10 | 1.00 | 3 |
|  | - 2nd year | 1.00 | 1.20 | 1.10 | 4 |
| Cacao | | 1.00 | 1.05 | 1.05 | 3 |
| Coffee | |  |  |  |  |
|  | - bare ground cover | 0.90 | 0.95 | 0.95 | 2-3 |
|  | - with weeds | 1.05 | 1.10 | 1.10 | 2-3 |
| Date Palms | | 0.90 | 0.95 | 0.95 | 8 |
| Palm Trees | | 0.95 | 1.00 | 1.00 | 8 |
| Pineapple 16 | |  |  |  |  |
|  | - bare soil | 0.50 | 0.30 | 0.30 | 0.6-1.2 |
|  | - with grass cover | 0.50 | 0.50 | 0.50 | 0.6-1.2 |
| Rubber Trees | | 0.95 | 1.00 | 1.00 | 10 |
| Tea | |  |  |  |  |
|  | - non-shaded | 0.95 | 1.00 | 1.00 | 1.5 |
|  | - shaded 17 | 1.10 | 1.15 | 1.15 | 2 |
| **m. Grapes and Berries** | | | | | |
| Berries (bushes) | | 0.30 | 1.05 | 0.50 | 1.5 |
| Grapes | |  |  |  |  |
|  | - Table or Raisin | 0.30 | 0.85 | 0.45 | 2 |
|  | - Wine | 0.30 | 0.70 | 0.45 | 1.5-2 |
| Hops | | 0.3 | 1.05 | 0.85 | 5 |
| **n. Fruit Trees** | | | | | |
| Almonds, no ground cover | | 0.40 | 0.90 | 0.6518 | 5 |
| Apples, Cherries, Pears 19 | |  |  |  |  |
|  | - no ground cover, killing frost | 0.45 | 0.95 | 0.7018 | 4 |
|  | - no ground cover, no frosts | 0.60 | 0.95 | 0.7518 | 4 |
|  | - active ground cover, killing frost | 0.50 | 1.20 | 0.9518 | 4 |
|  | - active ground cover, no frosts | 0.80 | 1.20 | 0.8518 | 4 |
| Apricots, Peaches, Stone Fruit 19, 20 | |  |  |  |  |
|  | - no ground cover, killing frost | 0.45 | 0.90 | 0.6518 | 3 |
|  | - no ground cover, no frosts | 0.55 | 0.90 | 0.6518 | 3 |
|  | - active ground cover, killing frost | 0.50 | 1.15 | 0.9018 | 3 |
|  | - active ground cover, no frosts | 0.80 | 1.15 | 0.8518 | 3 |
| Avocado, no ground cover | | 0.60 | 0.85 | 0.75 | 3 |
| Citrus, no ground cover 21 | |  |  |  |  |
|  | - 70% canopy | 0.70 | 0.65 | 0.70 | 4 |
|  | - 50% canopy | 0.65 | 0.60 | 0.65 | 3 |
|  | - 20% canopy | 0.50 | 0.45 | 0.55 | 2 |
| Citrus, with active ground cover or weeds 22 | |  |  |  |  |
|  | - 70% canopy | 0.75 | 0.70 | 0.75 | 4 |
|  | - 50% canopy | 0.80 | 0.80 | 0.80 | 3 |
|  | - 20% canopy | 0.85 | 0.85 | 0.85 | 2 |
| Conifer Trees 23 | | 1.00 | 1.00 | 1.00 | 10 |
| Kiwi | | 0.40 | 1.05 | 1.05 | 3 |
| Olives (40 to 60% ground coverage by canopy) 24 | | 0.65 | 0.70 | 0.70 | 3-5 |
| Pistachios, no ground cover | | 0.40 | 1.10 | 0.45 | 3-5 |
| Walnut Orchard 19 | | 0.50 | 1.10 | 0.6518 | 4-5 |
| **o. Wetlands - temperate climate** | | | | | |
| Cattails, Bulrushes, killing frost | | 0.30 | 1.20 | 0.30 | 2 |
| Cattails, Bulrushes, no frost | | 0.60 | 1.20 | 0.60 | 2 |
| Short Veg., no frost | | 1.05 | 1.10 | 1.10 | 0.3 |
| Reed Swamp, standing water | | 1.00 | 1.20 | 1.00 | 1-3 |
| Reed Swamp, moist soil | | 0.90 | 1.20 | 0.70 | 1-3 |
| **p. Special** | | | | | |
| Open Water, < 2 m depth or in subhumid climates or tropics | |  | 1.05 | 1.05 |  |
| Open Water, > 5 m depth, clear of turbidity, temperate climate | |  | 0.6525 | 1.2525 |  |

1 These are general values for Kc ini under typical irrigation management and soil wetting. For frequent wettings such as with high frequency sprinkle irrigation or daily rainfall, these values may increase substantially and may approach 1.0 to 1.2. Kc ini is a function of wetting interval and potential evaporation rate during the initial and development periods and is more accurately estimated using Figures 29 and 30, or Equation 7-3 in Annex 7, or using the dual Kcb ini + Ke.

2 Beans, Peas, Legumes, Tomatoes, Peppers and Cucumbers are sometimes grown on stalks reaching 1.5 to 2 meters in height. In such cases, increased Kc values need to be taken. For green beans, peppers and cucumbers, 1.15 can be taken, and for tomatoes, dry beans and peas, 1.20. Under these conditions h should be increased also.

3 The midseason values for cassava assume non-stressed conditions during or following the rainy season. The Kc end values account for dormancy during the dry season.

4 The Kc end value for potatoes is about 0.40 for long season potatoes with vine kill.

5 This Kc end value is for no irrigation during the last month of the growing season. The Kc end value for sugar beets is higher, up to 1.0, when irrigation or significant rain occurs during the last month.

6 The first Kc end is for harvested fresh. The second value is for harvested dry.

7 The Kc for asparagus usually remains at Kc ini during harvest of the spears, due to sparse ground cover. The Kc mid value is for following regrowth of plant vegetation following termination of harvest of spears.

8 Kc for sisal depends on the planting density and water management (e.g., intentional moisture stress).

9 The lower values are for rainfed crops having less dense plant populations.

10 The higher value is for hand-harvested crops.

11 The first Kc end value is for harvest at high grain moisture. The second Kc end value is for harvest after complete field drying of the grain (to about 18% moisture, wet mass basis).

12 If harvested fresh for human consumption. Use Kc end for field maize if the sweet maize is allowed to mature and dry in the field.

13 This Kc mid coefficient for hay crops is an overall average Kc mid coefficient that averages Kc for both before and following cuttings. It is applied to the period following the first development period until the beginning of the last late season period of the growing season.

14 These Kc coefficients for hay crops represent immediately following cutting; at full cover; and immediately before cutting, respectively. The growing season is described as a series of individual cutting periods (Figure 35).

15 Cool season grass varieties include dense stands of bluegrass, ryegrass, and fescue. Warm season varieties include bermuda grass and St. Augustine grass. The 0.95 values for cool season grass represent a 0.06 to 0.08 m mowing height under general turf conditions. Where careful water management is practiced and rapid growth is not required, Kc's for turf can be reduced by 0.10.

16 The pineapple plant has very low transpiration because it closes its stomates during the day and opens them during the night. Therefore, the majority of ETc from pineapple is evaporation from the soil. The Kc mid < Kc ini since Kc mid occurs during full ground cover so that soil evaporation is less. Values given assume that 50% of the ground surface is covered by black plastic mulch and that irrigation is by sprinkler. For drip irrigation beneath the plastic mulch, Kc's given can be reduced by 0.10.

17 Includes the water requirements of the shade trees.

18 These Kc end values represent Kc prior to leaf drop. After leaf drop, Kc end  0.20 for bare, dry soil or dead ground cover and Kc end  0.50 to 0.80 for actively growing ground cover (consult Chapter 11).

19 Refer to Eq. 94, 97 or 98 and footnotes 21 and 22 for estimating Kc for immature stands.

20 Stone fruit category applies to peaches, apricots, pears, plums and pecans.

21 These Kc values can be calculated from Eq. 98 for Kc min = 0.15 and Kc full*=* 0.75, 0.70 and 0.75 for the initial, mid season and end of season periods, and fc eff = fc where fc = fraction of ground covered by tree canopy (e.g., the sun is presumed to be directly overhead). The values listed correspond with those in Doorenbos and Pruitt (1977) and with more recent measurements. The midseason value is lower than initial and ending values due to the effects of stomatal closure during periods of peak ET. For humid and subhumid climates where there is less stomatal control by citrus, values for Kc ini, Kc mid*,* and Kc end can be increased by 0.1 - 0.2, following Rogers et al. (1983).

22 These Kc values can be calculated as Kc = fc Kc ngc + (1 - fc) Kc cover where Kc ngc is the Kc of citrus with no active ground cover (calculated as in footnote 21), Kc cover is the Kc, for the active ground cover (0.95), and fc is defined in footnote 21. The values listed correspond with those in Doorenbos and Pruitt (1977) and with more recent measurements. Alternatively, Kc for citrus with active ground cover can be estimated directly from Eq. 98 by setting Kc min = Kc cover. For humid and subhumid climates where there is less stomatal control by citrus, values for Kc ini, Kc mid, and Kc end can be increased by 0.1 - 0.2, following Rogers et al. (1983).

For non-active or only moderately active ground cover (active indicates green and growing ground cover with LAI > about 2 to 3), Kc should be weighted between Kc for no ground cover and Kc for active ground cover, with the weighting based on the "greenness" and approximate leaf area of the ground cover.

23 Confers exhibit substantial stomatal control due to reduced aerodynamic resistance. The Kc, can easily reduce below the values presented, which represent well-watered conditions for large forests.

24 These coefficients represent about 40 to 60% ground cover. Refer to Eq. 98 and footnotes 21 and 22 for estimating Kc for immature stands. In Spain, Pastor and Orgaz (1994) have found the following monthly Kc's for olive orchards having 60% ground cover: 0.50, 0.50, 0.65, 0.60, 0.55, 0.50, 0.45, 0.45, 0.55, 0.60, 0.65, 0.50 for months January through December. These coefficients can be invoked by using Kc ini = 0.65, Kc mid = 0.45, and Kc end = 0.65, with stage lengths = 30, 90, 60 and 90 days, respectively for initial, development, midseason and late season periods, and using Kc during the winter ("off season") in December to February = 0.50.

25 These Kc's are for deep water in temperate latitudes where large temperature changes in the water body occur during the year, and initial and peak period evaporation is low as radiation energy is absorbed into the deep water body. During fall and winter periods (Kc end), heat is released from the water body that increases the evaporation above that for grass. Therefore, Kc mid corresponds to the period when the water body is gaining thermal energy and Kc end when releasing thermal energy. These Kc's should be used with caution.

**Primary sources:**

**Kc ini: Doorenbos and Kassam (1979)**  
**Kc mid and Kc end: Doorenbos and Pruitt (1977); Pruitt (1986); Wright (1981, 1982). Snyder et al., (1989)**

The values for Kc mid and Kc end in Table 12 represent those for a sub-humid climate with an average daytime minimum relative humidity (RHmin) of about 45% and with calm to moderate wind speeds averaging 2 m/s. For more humid or arid conditions, or for more or less windy conditions, the Kc coefficients for the mid-season and end of late season stage should be modified as described in this chapter.

The values for Kc in Table 12 are values for non-stressed crops cultivated under excellent agronomic and water management conditions and achieving maximum crop yield (standard conditions). Where stand density, height or leaf area are less than that attained under such conditions, the value for Kc mid and, for most crops, for Kc end will need to be modified (Part C, Chapters 8, 9 and 10).