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EVAPOTRANSPIRATION AS A FUNCTION OF LEAF AREA INDEX AND CLASS A PAN EVAPORATION[1]

EVAPOTRANSPIRAÇÃO COMO UMA FUNÇÃO DO ÍNDICE DE ÁREA FOLIAR E DA EVAPORAÇÃO DE TANQUE CLASSE A

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SUMMARY

Crop evapotranspiration (ETc) is determined by many biological and environmental factors. Leaf area index (L) is the single most important biological factor affecting ETc for it represents the size of the transpiring plant. Class A pan evaporation (E) was used as an indicator of the atmospheric demand for water. Using a multiple linear regression analysis it was found that ETc = **a** + **b** L + **c** E represents adequately the measured values. Data from three different crops (sugarcane, maize, lettuce) indicate that the values for the regression coefficients are crop specific. Larger the value of **b** more exposed are the leaves to the atmosphere. Lettuce had the highest L but the smaller **b**, because all the leaves are tied up forming a head, being consequently less exposed to the atmosphere. In regard to coefficient **c**, the results are less conclusive since the experiments were performed under different atmospheric demand, but not simultaneously. The approach here proposed is intended to eliminate, after a local calibration, the need for the use of a crop coefficient (Kc) to convert E into ETc.

Key words: atmospheric demand, irrigation requirements, water consumption.

RESUMO

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A evapotranspiração de uma cultura (ETc) é determinada por muitos fatores biológicos e ambientais. O índice de área foliar (L) é o fator biológico mais importante nesse processo pois representa o tamanho da superfície transpirante. Evaporação do tanque Classe A foi utilizada como indicador da demanda atmosférica por água. Usando análise de regressão linear múltipla, encontrou-se que $ETc = \mathbf{a} + \mathbf{b}\,L + \mathbf{c}\,E$ descreve convenientemente os valores medidos. Dados obtidos com três culturas diferentes (cana-de-açúcar, milho, alface) indicam que os valores dos coeficientes são específicos. Quanto maior o valor de **b** mais expostas estão as folhas. A alface teve o maior L, mas o menor valor para **b** visto que suas folhas formam uma cabeça fechada, sendo por isto menos expostas à atmosfera. Com respeito ao coeficiente **c**, os resultados são menos conclusivos pois os experimentos foram realizados em condições distintas, mas não simultâneas, de demanda atmosférica. Espera-se que a metodologia aqui apresentada, após uma calibragem local, seja suficiente para se eliminar a necessidade de utilização do coeficiente de cultura (Kc) para converter E em ETc.

Palavras-chave: demanda atmosférica, necessidades de irrigação, consumo de água.

INTRODUCTION

Crop evapotranspiration (ETc) can be evaluated from the reference evapotranspiration (ETo) and a correction known as crop coefficient (Kc). Such concept was defined by JENSEN (1968) and recommended by the Food and Agriculture Organization (FAO) as a standard method (DOORENBOS & PRUITT, 1975). ETo can be estimated by many meteorological methods or by a Class A pan.

Crop coefficient varies with the stage of development and, in general, it is assumed constant during a stage (DOORENBOS & KASSAM, 1979). Spacing of row crops affects Kc during early stages of leaf development (JENSEN, 1968), and RITCHIE & BURNETT (1971) have found Kc to vary in a curvilinear manner with the leaf area index (L) for cotton and grain sorghum crops. For an irrigated upland rice crop, STONE & PEREIRA (1994) found Kc to vary linearly with L.

For an irrigated maize crop grown in a semi-arid environment, OLIVEIRA et alii (1993) found that ETc was well described by a second degree polynomial function of L only. However, it is postulated here that such relationship is plausible only under the conditions of continuous high atmospheric demand as is the case in a semi-arid climate, when L is the determining factor of the water use. When the atmospheric demand for water is variable throughout the growing season, the ETc is no longer solely a funciton of L and such relationship deteriorates substantially. To prove this point, we will use a

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sugarcane crop whose growing season spans over 17 months from planting to harvest. A new function incorporating the atmospheric demand, represented by the Class A evaporation, will be shown to be a better descriptor of ETc.

MATERIAL AND METHODS

Daily sugarcane (*Saccharum sp.*, cv. NA56-79) evapotranspiration was measured from planting to harvest in a lysimeter with the following dimensions: 4.5 m wide, 6.7m long; 1.5 m deep (VILLA NOVA & REICHARDT, 1989). Water use was continuously monitored by keeping the water level inside the lysimeter at the 1.3 m depth with a continuous recharge system. The rate of recharge was determined by the rate of evapotranspiration being continuously recorded on a diagram. Due to the inertia of the system caused by the large volume of soil, only weekly averages were used to avoid daily measurements distortions. Periods with rainfall were discarded from the analysis because, in such conditions, the lysimeter was always covered by a shelter reducing ETc. The lysimeter sampled three 6.7m rows of sugarcane, with 1.5 m between rows. Planting was done in December 1979 and the harvest was in April 1981 (17 months of growing season). Leaf area index was determined weekly, until the crop covered completely the ground, and monthly afterwards. Leaf area was determined through the relationship length x width x **f**, being the coefficient **f** = 0.70 determined for the cultivar used (MACHADO et alli, 1982). Class A pan evaporation was measured on a nearby weather station about 200 m away from the experimental area. The experiment was conducted at the Sugarcane Experimental Station, of the Sugar and Alcohol Institute (now School of Agriculture, of the Universidade Federal de São Carlos), in Araras, SP, Brazil (22° 18' S; 47° 23' W; 620 m). There was a fetch border larger than 20 km in any direction.

Multiple linear regression according to the model ETc = **a** +**b** L + **c** E, using the least square method of fitting available in a commercial software, was performed for the three data sets.

RESULTS AND DISCUSSION

Multiple linear regression analysis between sugarcane evapotranspiration (ETc) and leaf area index (L), as suggested by OLIVEIRA et alii (1993), resulted in the second degree polynomial function ETc = 1.414 - 1.26 L + 0.55 L^2 (R^2 = 0.5274). Figure 1 shows that such function described well the evapotranspiration during the early period when both ETc and L increased rapidly. Such period corresponded to the warm and wet months (January - April) with large atmospheric demand for water. Afterwards, during the fall and winter (cool and dry) months, when the crop growth was minimum, if there was any growth at all, L stayed almost constant but ETc decreased; under such conditions of reduced atmospheric demand, the second degree function gave a poor fit overestimating ETc. With the onset of the spring, the crop growth increased substantially but L remained constant and about its maximum value of 3.7 m^2/m^2 (MACHADO et alii, 1982). Again, the above function did not work well, now underestimating ETc. Such poor fitting remained throughout the summer season. It can be concluded that a polynomial function with L as the only independent variable adjusted well the crop evapotranspiration only up to the point when both L and ETc were increasing and the atmospheric demand was high.

In order to correct the above poor estimation of ETc, the Class A pan evaporation (E) was used as a second independent variable representing the atmospheric demand. Now, the function integrates a biological (L) and an environmental factor (E), and it was found that ETc = -4.41 + 1.465 L + 0.66 E (R^2 = 0.9262). Figure 1 shows that this function gives a much better fit throughout the sugarcane cycle. There was a slight tendency to overpredict during the initial stage of growth, but such discrepancy disappeared afterwards. The goodness of this second approach is that E takes care of the atmospheric demand and allows the predicted ETc to fluctuate as the weather varies from day to day, a situation which is impossible if L is the only independent variable. Another important aspect of this second approach is that one no longer needs to worry about the crop coefficient (Kc).

Taking data from OLIVEIRA et alii (1993), for a maize crop, and from BASTOS (1994), for a lettuce field, and performing the same kind of analysis, the following relationships were found:

MAIZE, **ETc = -3.49 + 1.012 L + 1.23 E**; (R^2 = 0.9965).

LETTUCE, **ETc = -0.675 + 0.258 L + 0.413 E**, (R^2 = 0.9642).

The maximum L for the maize was about 2.5 m^2/m^2, and 7.5 m^2/m^2, for the lettuce. However, lettuce has all the leaves tied up forming a head, being less exposed to the atmosphere than the sugarcane and maize crops. This effect can be seen on the value of the regression coefficient for L. Lettuce had the lowest coefficient (**b** = 0.258), followed by the maize (**b** = 1.012) and sugarcane (**b** = 1.465). In regard to coefficient **c**, the results are less conclusive since the experiments were conducted under different atmospheric demand, but not simultaneously.

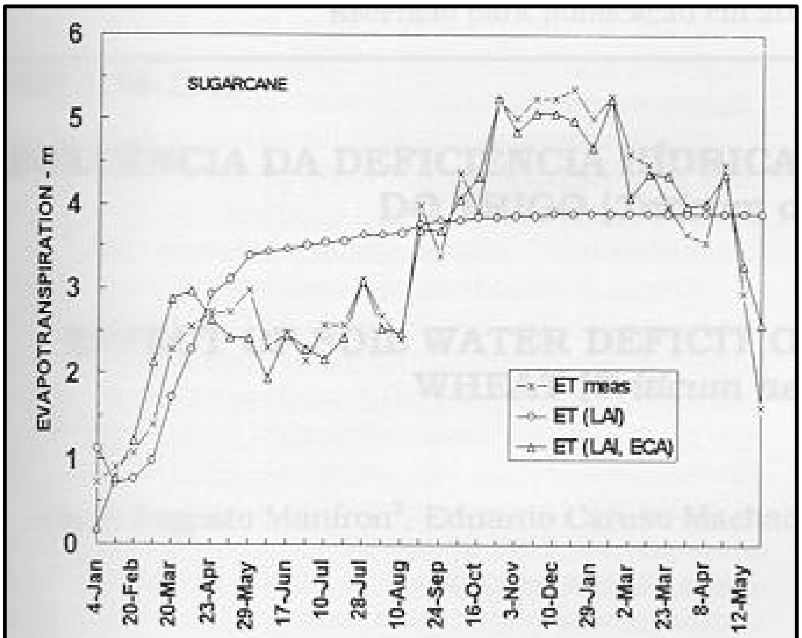

Figure 1. Seasonal variation of sugarcane evapotranspiration measured and estimated by two regression models being one based on L only, and the other on both L and E.

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