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Variability of the Ratio of Alfalfa to Grass Reference Evapotranspiration under Semiarid Climate

Koffi Djaman^{1*}, Lombard K¹, Koudahe K², Allen S¹ and O'Neill M¹

¹Department of Plant and Environmental Sciences, Agricultural Science Center, New Mexico State University, Farmington, USA ²ADA Consulting Africa, Lomé Togo

Abstract

Crop evapotranspiration estimation is critical for sustainable water management under the semiarid and arid climate in New Mexico. While irrigation scheduling is based on daily evapotranspiration through the two step approach, reference evapotranspiration and crop coefficients should be determined with accuracy. The utilization of grass reference evapotranspiration (ETo) or alfalfa reference evapotranspiration (ETr) and the conversion from one to the other calls for an understanding of the relationship between ETr and ETo. The objectives of this study were to develop the ratio of ETr to ETo values (Kr) and to determine the variability of Kr during the year for six locations across the State of New Mexico (USA). The results showed long term annual Kr values to vary from 1.28 to 1.45 and the coefficient of determination varied from 0.96 to 0.98. Kr value decreases from January to July and increases from August to December and was at its lowest Kr value at the peak daily reference evapotranspiration. Annual average Kr values were 1.31, 1.38, 1.43, 1.38, 1.38 and 1.48 at Alcalde, Fabian Garcia, Farmington, Leyendecker, Las Cruces and Tucumcari locations and the growing season average Kr values were 1.24, 1.32, 1.38, 1.31, 1.32 and 1.42 at the respective locations. The strong correlation between ETr and ETo allows the conversion of the grass reference evapotranspiration to alfalfa reference evapotranspiration and vice versa however, caution should be taken when using the crop coefficient values to convert either ETo or ETr to actual crop evapotranspiration for irrigation scheduling and water management.

Keywords: Reference evapotranspiration; Grass; Alfalfa; Ratio; New Mexico

Introduction

Crop water use is generally the main source of water losses from the hydrological cycle and is an important parameter in hydrological, agricultural and environmental studies. Accurate crop evapotranspiration estimation is therefore critical for system sustainability. While crop actual evapotranspiration could be measured via lysimeter [1], scintillometer [2,3], Bowen ratio energy balance system [4-7], or eddy covariance [6,8-11], among other methods, it is also estimated through the two step approach by multiplying crop reference evapotranspiration by the crop coefficients [12,13]. Reference evapotranspiration is the rate at which readily available soil water is vaporized from specified vegetated surfaces [12]. Reference evapotranspiration is defined as the ET rate from a uniform surface of dense, actively growing vegetation having specified height and surface resistance, not short of soil water, and representing an expanse of at least 100 m of the same or similar vegetation [14]. The reference surface has recently been expressed as a hypothetical crop (vegetative) surface with specific characteristics for convenience and reproducibility [13,15]. Grass and alfalfa are considered as reference crops grown under humid and semiarid/arid climates respectively. Under the same conditions, the ET rate for grass is usually less than for alfalfa, particularly under dry, hot and windy conditions. Part of the reason for this is that the alfalfa crop that is taken as a reference is taller (0.5 m) than a grass-reference crop (0.12 m) and also has a greater leaf area [14]. Irmak et al. [5] stated that there is no consensus on the choice of reference crop for a particular region however, they indicated that alfalfa may be preferable for semiarid or arid climates because alfalfa has a vigorous and deeper root structure and tends to transpire water at potential rates even under adventive environments, and is less likely to suffer water stress while grass has a shallow-rooted system and grass crop is subjected to suffer water stress. Therefore, the grass may be preferable under humid, subtropical climates where alfalfa is not commonly grown [5]. Wright et al. [16] reported that alfalfa has greater aerodynamic and surface conductance.

Weather variables as air temperature, relative humidity, solar radiation and wind speed are used to estimate reference evapotranspiration. Numerous reference evapotranspiration equations have been developed, tested, calibrated and validated under different climatic conditions with varying performance [13,17-30]. The Standardized Penman Monteith equation is generally regarded as the most accurate equation, used worldwide [28-34] and is recommended for reference evapotranspiration estimation under different climates [13,14].

It is critical to always relate the estimated reference evapotranspiration to either grass or alfalfa reference surface as the two step approach combines reference evapotranspiration and crop coefficients. Crop coefficients (Kc) for grass reference surface is smaller than the Kc values for alfalfa reference surface [35,36]. During crop actual evapotranspiration estimation, Kc values for grass-reference and alfalfa-reference cannot be used interchangeably with ETo and ETr without adjustment. The correction factor, the ratio of ETr to ETo (Kr), should be used to adjust ETo to ETr and vice versa when Grass Kc is available with estimated ETr or alfalfa Kc available with estimated ETo. Daily, monthly, seasonal and annual Kr values were developed for some locations. Jensen et al. [12] reported average *Kr* values range of 1.30-1.38 for the arid locations and 1.12-1.39 for humid locations. A Kr value of 1.15, for example, was suggested for dry climate under light to moderate wind [37], 1.21 for Davis California [38], and 1.20

*Corresponding author: Koffi Djaman, Department of Plant and Environmental Sciences, Agricultural Science Center, New Mexico State University, Farmington, USA, Tel: +1505 960 7757; E-mail: kdjaman@nmsu.edu

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for Kimberly, Idaho [39]. Irmak et al. [5] showed variability among developed daily, monthly seasonal Kr values for Bushland (Texas), Clay Center (Nebraska), Davis (California), Gainesville (Florida), Phoenix (Arizona) and Rockport (Missouri).

While the aforementioned Kr values were developed for some locations, very limited information exists for the semiarid and arid climate across the Southwest United States when water resource are the most limiting factor for crop and fiber production. The objectives of this study were to develop the ratio of ETr to ETo values (Kr) and to determine the variability of Kr during the year and during the crop growing season for six locations across the State of New Mexico (USA).

Materials and Methods

This study was conducted at six weather stations across New Mexico (USA) at Alcalde, Fabian-Garcia, Farmington, Las Cruces, Leyendecker and Tucumcari for the period of 2009-2017. The geographical coordinates and the long term average climatic variables are summarized in Table 1. Minimum temperature (Tmin), maximum temperature (Tmax), minimum relative humidity (RHmin), maximum relative humidity (RHmax), wind speed (u_2), and solar radiation (Rs) were collected on the daily basis from automated weather stations installed by the New Mexico Climate Center at the six sites.

Penman-Monteith reference evapotranspiration model: (ASCE-EWRI, 2005)

Daily grass-reference ET was computed using the standardized ASCE form of the Penman-Monteith (PM-ETo) equation [14]:

$$ETo = \frac{0.408\Delta(Rn-G) + (\gamma Cnu2 / (T+273))(es-ea)}{\Delta + \gamma (1+Cdu2)}$$
(1)

Where: ETo-the reference evapotranspiration (mm day⁻¹);

 Δ =slope of saturation vapor pressure versus air temperature curve (kPa°C⁻¹);

Rn-net radiation at the crop surface (MJ m⁻² d⁻¹);

G-soil heat flux density at the soil surface (MJ m⁻² d⁻¹);

T-mean daily air temperature at 1.5-2.5 m height (°C);

u2-mean daily wind speed at 2 m height (m s⁻¹);

es-saturation vapor pressure at 1.5-2.5 m height (kPa);

ea-actual vapor pressure at 1.5-2.5 m height (kPa);

es-ea-saturation vapor pressure deficit (kPa);

γ-psychometric constant (kPa°C⁻¹);

Cn and Cd=constants with values of 900°C mm s³Mg⁻¹d⁻¹ and 0.34

s m⁻¹, respectively for grass and 1600 $^{\circ}$ C mm s³ Mg⁻¹ d⁻¹ and 0.38 s m⁻¹ for alfalfa. The procedure developed by Allen et al. [13] was used to compute the needed parameters.

Estimation of Kr values

Kr values were estimated as the ratio of the alfalfa reference evapotranspiration (ETr) to the grass reference evapotranspiration (ETo) on the daily, and the average monthly, crop growing period and yearly average.

Evaluation criteria

Daily ETr was plotted against daily ETo for each location and a linear regression was forced through the origin. The regression slopes, and the coefficients of determination (R^2) were determined. Comparisons of Kr values between locations were made using the *t*-test. A paired sample *t*-test (two-sample for means) was performed to determine any significant difference between Kr values from one location to another at 5% significance level.

Results and Discussion

Climatic conditions at the study sites

The climatic conditions for the study period are summarized in Table 1. The Alcalde and Farmington stations are located at high elevation (1735 and 1720 m, respectively) and showed the greatest temperature amplitude. The highest maximum temperature (Tmax) was observed at Las Cruces and the lowest Tmax was observed at Farmington (Table 1). The lowest minimum temperature (Tmin) was observed at Alcalde and the highest Tmin was observed at Las Cruces. The lowest annual mean temperature was 11.7°C at Alcalde and highest annual mean temperature was 18.7°C observed at Las Cruces. The annual mean relative humidity was less than 55% at all stations and was at its greatest value at Alcalde with the lowest peak reference evapotranspiration value (Figure 1). Slight variation in solar radiation was observed among the stations and there was large difference between the stations in terms of annual mean wind speed that ranged 1.19 to 3.3 m/s. Wind speed on average was generally strongest at Tucumcari (3.30 m/s) and weakest at Alcalde (1.19 m/s). Wind speed is an important water evaporation driving force and the highest magnitude of the reference evapotranspiration at Tucumcari is in good alignment with the highest values of wind speed at that location as compared to other locations. With regard to the weather conditions, reference evapotranspiration was the lowest at Alcalde and the highest at Tucumcari (Figure 1). Minimum daily ETo was 7.09, 7.87, 8.25, 7.33, 7.63, and 10.25 mm/day observed in December-January at Alcalde, Fabian Garcia, Farmington, Leyendecker, Las Cruces and Tucumcari, respectively, while the maximum daily ETr was 8.45, 11.13, 12.09,

Parameters	Alcalde	Fabian Garcia.	Farmington	Leyendecker	Las Cruces	Tucumcari
Latitude (Deg. North)	36.09	32.28	36.69	32.2	32.28	35.2
Longitude (Deg. West)	-106.06	-106.77	-108.31	-106.74	-106.76	-103.69
Elevation (m)	1735	1186	1720	1176	1185.06	1246
Wind speed (m/s)	1.19	1.82	2.45	1.81	1.59	3.3
Tmax (°C)	21.09	26.5	20.94	26.12	27.14	24.07
Tmin (°C)	2.22	9.82	4.33	7.67	10.27	7.52
Tmean (°C)	11.65	18.16	12.63	16.89	18.70	15.79
Rhmax (%)	83.86	65.21	68.63	77.34	57.42	71.78
Rhmin (%)	22.88	18.6	19.7	19.09	15.53	22.29
Rhmean (%)	53.37	41.9	44.17	48.21	36.47	47.03
Rs (MJ m-2)	18.62	21.23	19.84	19.63	19.94	19.8

Table 1: Weather stations with long term average climatic condition.

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10.41, 10.81 and 14.77 mm/day at the respective locations, observed late July at all locations (Figure 1).

Variability of the ratio of Alfalfa to grass reference evapotranspiration (Kr=ETr/ETo)

The Kr values for the study period equivalent to the slopes of the simple regression relationship between the ETr and ETo varied from 1.28 to 1.45 and the coefficient of determination varied from 0.96 to 0.98 (Figure 2). The highest Kr value was obtained at Tucumcari

(Kr=1.45) while the lowest Kr value was obtained at Alcalde. There is variability in Kr values during the year and it decreases from January to July and increases thereafter (Table 2 and Figure 2). Kr values decrease with increasing daily reference evapotranspiration and increase with decreasing reference evapotranspiration. Lowest Kr values were obtained at the peak daily reference evapotranspiration. Similar trend in Kr values was observed at all six weather stations. At Alcalde, monthly Kr deceased from 1.43 in January to 1.19 in August and increased thereafter to 1.42 in December. At Fabian Garcia, Kr





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varied from 1.47 in January to 1.28 in July-August and increased from September to December. Similar trend is also observed at Farmington, Leyendecker, Las Cruces and Tucumcari with the maximum Kr values of 1.52, 1.50, 1.48 and 1.59 and the minimum Kr values of 1.32, 1.26, 1.29 and 1.38 observed in August at the respective locations (Table 2 and Figure 3). Annual average Kr values were 1.31, 1.38, 1.43, 1.38, 1.38 and 1.48 at Alcalde, Fabian Garcia, Farmington, Leyendecker, Las Cruces and Tucumcari with day to day Kr standard deviation values of 0.08, 0.07, 0.07, 0.09, 0.07 and 0.08 at the respective locations. Large Kr values observed at Tucumcari throughout the year might be due to the advective dry and high wind environment [5]. The growing season (May through October) average Kr values were 1.24, 1.32, 1.38, 1.31, 1.32 and 1.42 at Alcalde, Fabian Garcia, Farmington, Leyendecker, Las Cruces and Tucumcari, respectively, with standard deviations ranging from 0.04 to 0.05. The seasonal Kr values were significantly different from one location to another except Fabian Garcia and Las Cruces where Kr values were not significantly different (P=0.126). The Las Cruces' station and the Fabian Garcia's station are not far one from the other and are both in Las Cruces agglomeration. The Kr values could not be used interchangeably from location to location across the State of New Mexico. Similar Kr values were reported by Djaman and Irmak [35] and Payero and Irmak [40] who indicated that the minimum Kr value was obtained in the middle of summer. They found seasonal average Kr values of 1.31 with its range from 0.99 to 1.53 at Clay Center (Nebraska). Wright et al. [16] and Irmak et al. [5] also reported that Kr tends to decrease with increasing reference evapotranspiration and increases during winter time. Wright [39] indicated that the seasonal variation in Kr may reflect the relative response of the respective reference surfaces to evaporative demand and changes in general grass or alfalfa morphology during the season. As the relative humidity increases, the Kr values should decrease as stated by Jensen et al. [12]. Ji et al. [41] reported seasonal variation in the ratios of ETr to ETo with a mean value slightly lower than the generalized Kr value of 1.35 for arid conditions, due primarily to the differences in responsiveness of both standardized PM equations to the trends and interactions among input parameters. Irmak et al. [5] reported average annual Kr values of 1.46, 1.43, 1.37, 1.21, 1.33, and 1.36 for Bushland, Clay Center (Nebraska), Davis (California), Gainesville (Florida), Phoenix (Arizona), and Rockport (Missouri). Different annual Kr values were reported as 1.15 at Bushland (Texas) [42], 1.21 at Davis (California) [38], 1.20 at Kimberly (Idaho) [39], from 1.30 to 1.38 for arid areas and from 1.12 to 1.39 for humid zones [12]. The strong correlation between ETr and ETo allows the conversion of the grass reference evapotranspiration to alfalfa reference evapotranspiration and vice versa however, caution should be taken when using the crop coefficient values to convert either ETo or ETr to actual crop evapotranspiration for irrigation scheduling and water management. Ji et al. [41] reported seasonal mean Kr value slightly lower than the generalized value of 1.35 for arid conditions, due primarily to the differences in responsiveness of both standardized PM equations to the trends and interactions among input parameters. There is a need to develop local crop coefficients related to grass (Kco) or alfalfa (Kcr) reference surface [35,36,41] to avoid the

Month	Alcalde	Fabian Garcia	Farmington	Leyendecker	Las Cruces	Tucumcari
January	1.43	1.47	1.51	1.50	1.48	1.58
February	1.37	1.44	1.45	1.47	1.45	1.53
March	1.34	1.42	1.44	1.43	1.41	1.49
April	1.31	1.40	1.41	1.40	1.40	1.46
May	1.27	1.36	1.39	1.35	1.36	1.42
June	1.26	1.33	1.39	1.31	1.33	1.42
July	1.20	1.28	1.32	1.26	1.29	1.38
August	1.19	1.28	1.35	1.26	1.29	1.38
September	1.22	1.30	1.37	1.29	1.30	1.42
October	1.29	1.37	1.47	1.36	1.36	1.50
November	1.38	1.45	1.52	1.46	1.43	1.58
December	1.42	1.49	1.52	1.50	1.48	1.59

Table 2: Long term monthly average ETr to ETo ratio for the six locations.



conversion process. Failing to adjust the reference evapotranspiration to the corresponding crop coefficient values could be detrimental to crop failure and result in loss of production cost. However, Wright et al. [16] indicated that there is substantial uncertainty in the ratio of ETr to ETo (Kr) to use for conversion and how the ratio changes with location, time of year and with climate. Moreover, the Kr values computed from the standardized equations may not reproduce ratios of ETr/ETo from field measurements because of the characterization of net radiation due to impacts of daytime length, changes in albedo and low sun angle, surface resistance of living reference crops which are not kept as described as reference surface and the incorporation of the impacts of unique diurnal patterns in wind speed profile into daily step calculation [16,43].

Conclusion

The ratio of grass reference evapotranspiration (ETo) to alfalfa reference evapotranspiration (ETr) (Kr) was developed for six locations across the State of New Mexico (USA). Daily weather data for the period of 2009 - 2017 was monitored by automated weather stations. The results showed strong correlation between ETr and ETo with high coefficient of determination that varied from 0.96 to 0.98. There was variation in daily Kr with the lowest Kr values obtained late July. Annual average Kr values ranged from 1.28 to 1.45 and the growing season Kr values varied from 1.24 to 1.42. The strong correlation between ETr and ETo allows the conversion of ETo to ETr and vice versa and the use of appropriate locally developed crop coefficients could help in improving water management under the semiarid and dry climatic conditions across the State of New Mexico.

References

- Williams LE, Ayars JE (2005) Water use of Thompson seedless grapevines as affected by the application of gibberellic acid (GA3) and trunk girdling practices to increase berry size. Agric Forest Meteorol 129: 85-94.
- Hemakumara HM, Chandrapala L, Moene A (2003) Evapotranspiration fluxes over mixed vegetation areas measured from large aperture scintillometer. Agricultural Water Management 58: 109-122.
- Jerry ME, Marek GW, Colaizzi PD, Gowda PH, Evett SR, et al. (2017) Evaluation of Sensible Heat Flux and Evapotranspiration Estimates Using a Surface Layer Scintillometer and a Large Weighing Lysimeter. Sensors 17: 2350.
- 4. Bowen IS (1926) The ratio of heat losses by conduction and by evaporation from any water surface. Phys Rev 27: 779.
- Irmak S, Irmak A, Howell TA, Martin DL, Payero JO, et al. (2008) Variability analyses of alfalfa-reference to grass-reference evapotranspiration ratios in growing and dormant seasons. J Irrig Drain Eng 134: 147-159.
- Irmak S (2010) Nebraska Water and Energy Flux Measurement, Modeling, and Research Network (NEBFLUX). Transactions of the ASABE 53: 1097-1115.
- Kabenge I, Irmak S, Meyer GE, Gilley JE, Knezevic S, et al. (2013) Evapotranspiration and surface energy balance of a common reed-dominated riparian system in the Platte River Basin, central Nebraska, USA. Transactions of the ASABE 56: 135-153.
- Oncley SP, Foken T, Vogt R, Kohsiek W, DeBruin HAR, et al. (2007) The energy balance experiment EBEX-2000: I. Overview and energy balance. Boundary-Layer Meteorol 123: 1-28.
- Sun ZG, Wang QX, Matsushita B, Fukushima T, Ouyang Z, et al. (2008) A new method to define the VI-Ts diagram using subpixel information: a case study over a semiarid agricultural region in the North China Plain. Sensors 8: 6260-6279.
- Novick K, Oren R, Stoy P, Juang JY, Siqueira M, et al. (2009) The relationship between reference canopy conductance and simplified hydraulic architecture. Adv Wat Resour 32: 809-819.
- Wagle P, Gowda PH, Anapalli SS, Reddy KN, Northup BK (2017) Analysis and estimation of tall grass prairie evapotranspiration in the central United States. Agricultural and Forest Meteorology 232: 35-47.

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- Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 300.
- Irmak S, Howell TA, Allen RG, Payero JO, Martin DL (2005) Standardized ASCE Penman-Monteith: Impact of sum-of-hourly vs. 24-hour timestep computations at reference weather station sites. Transactions of the ASAE 48: 1063-1077.
- Allen RG, Smith M, Perrier A, Pereira LS (1994) An update for the definition of reference evapotranspiration. ICID Bull 43: 1-34.
- 16. Wright JL, Allen RG, Howell TA (2000) Conversion between evapotranspiration references and methods.
- Thornthwaite CW (1948) An approach toward a rational classification of climate. Geographical Review 38: 55-94.
- Turc L (1961) Estimation of irrigation water requirements, potential evapotranspiration: a simple climatic formula evolved up to date. Annals of Agronomy 12: 13-49.
- 19. Penman LH (1963) Vegetation and Hydrology. Tech Comm No 53, Commonwealth Bureau of Soils, Harpenden, England, 125.
- 20. Hargreaves GH, Samani Z (1985) Reference Crop Evapotranspiration from Temperature. Journal of Applied Engineering in Agriculture 1: 96-99.
- Abtew W (1996) Evapotranspiration measurements and modeling for three wetland systems in South Florida. Journal of the American Water Resources Association 32: 465-473.
- Irmak S, Irmak A, Allen R, Jones J (2003) Solar and net radiation-based equations to estimate reference evapotranspiration in humid climates. J Irrig Drain Eng 129: 336-347.
- 23. Trajkovic S (2007) Hargreaves versus Penman-Monteith under humid conditions. J Irrig Drain Eng 133: 38-42.
- Valiantzas JD (2013) Simplified reference evapotranspiration formula using an empirical impact factor for penman's aerodynamic term. J Irrig Drain Eng 18: 108-114.
- 25. Djaman K, Balde AB, Sow A, Muller B, Irmak S, et al. (2015) Evaluation of sixteen reference evapotranspiration methods under sahelian conditions in the Senegal River Valley. Journal of Hydrology: Regional Studies 3: 139-159.
- 26. Djaman K, Tabari H, Balde AB, Diop L, Futakuchi K, et al. (2016a) Analyses, calibration and validation of evapotranspiration models to predict grass reference evapotranspiration in the Senegal River Delta. Journal of Hydrology: Regional Studies 8: 82-94.
- 27. Djaman K, Irmak S, Kabenge I, Futakuchi K (2016b) Evaluation of the FAO-56 Penman-Monteith model with limited data and the Valiantzas models for estimating reference evapotranspiration in the Sahelian conditions. J Irrig Drain Eng 142.
- Djaman K, Irmak S, Futakuchi K (2017a) Daily reference evapotranspiration estimation under limited data in Eastern Africa. J Irrig Drain Eng 143.
- Djaman k,rudnick D, Mel Vc, Muttiibwa D, Diop L, et al. (2017b) Evaluation of the Valiantzas' simplified forms of the FAO-56 Penman-Monteith Reference Evapotranspiration model under humid climate. J Irrig Drain Eng 133.
- Djaman K, Koudahe K, Allen S, O'Neill M, Irmak S (2017c) Validation of Valiantzas' reference evapotranspiration equation under different climatic conditions. Irrig Drain Syst Eng 6: 3.
- Jabloun M, Sahli A (2008) Evaluation of FAO-56 methodology for estimating reference evapotranspiration using limited climatic data: Application to Tunisia. Agric Water Manage 95: 707-715.
- 32. Tomas-Burguera M, Vicente-Serrano SM, Grimalt M, Beguería S (2017) Accuracy of reference evapotranspiration (ETo) estimates under data scarcity scenarios in the Iberian Peninsula. Agricultural Water Management 182: 103-116.
- 33. Sentelhas P, Gillespie T, Santos E (2010) Evaluation of FAO Penman-Monteith and alternative methods for estimating reference evapotranspiration with missing data in Southern Ontario, Canada. Agricultural Water Management 97: 635-644.

Citation: Djaman K, Lombard K, Koudahe K, Allen S, O'Neill M (2018) Variability of the Ratio of Alfalfa to Grass Reference Evapotranspiration under Semiarid Climate. Irrigat Drainage Sys Eng 7: 204. doi: 10.4172/2168-9768.1000204

34. Yeh HF (2017) Comparison of Evapotranspiration Methods under Limited Data. In Current Perspective to Predict Actual Evapotranspiration. InTech.

35. Djaman K, Irmak S (2013) Actual crop evapotranspiration and alfalfa- and grass- reference crop coefficients of maize under full and limited irrigation and rain fed conditions. Journal of Irrigation and Drainage Engineering 139: 433-446.

36. Irmak S, Odhiambo LO, Specht JE, Djaman K (2013) Hourly and daily single and basal evapotranspiration crop coefficients as a function of growing degree days, days after emergence, leaf area index, fractional green canopy cover, and plant phenology for soybean. Transactions of the ASABE 56:1785-1803.

37. Doorenbos J, Pruitt WO (1977) Guidelines for predicting crop water requirements, FAO Irrigation and Drainage Paper.

 Erpenbeck JM (1981) A methodology to estimate crop water requirements in Washington State. MS thesis, Washington State Univ, Pullman, Wash. 39. Wright JL (1996) Derivation of alfalfa and grass reference evapotranspiration.

- 40. Payero JO, Irmak S (2011) Daily Crop Evapotranspiration, Crop Coefficient and Energy Balance Components of a Surface-Irrigated Maize Field. In Evapotranspiration-From Measurements to Agricultural and Environmental Applications. InTech.
- 41. Ji XB, Chen JM, Zhao WZ, Kang ES, Jin BW, et al. (2017) Comparison of hourly and daily Penman-Monteith grass- and alfalfa-reference evapotranspiration equations and crop coefficients for maize under arid climatic conditions. Agricultural Water Management 192: 1-11.
- 42. Evett SR, Howell TA, Todd RW, Schneider AD, Tolk JA (2000) Alfalfa reference ET measurement and prediction. In Proceedings of the 4th Decennial National Irrigation Symposium, pp: 14-16.
- 43. Allen RG, Walter IA, Elliott R, Mecham B, Jensen ME, et al. (2000) Issues, requirements and challenges in selecting and specifying a standardized ET equation. In Proc 4th National Irrigation Symp, pp: 201-208.

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