Comparison of Reference Evapotranspiration from the American Society of Civil Engineers (ASCE) Standardized Penman-Monteith and Kimberly-Penman Equations in Northeast Colorado

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Introduction

The standardized American Society of Civil Engineers Penman-Monteith (ASCE P-M) and Penman-Kimberly equations are sufficiently accurate to recommend their use for the calculation of reference evapotranspiration. This study compared ETr reference values which were calculated using the ASCE standardized Penman-Monteith and Penman-Kimberly equations with the local weather conditions in northeast Colorado, as reported by Colorado Agricultural Meteorological network (CoAgMet), known to provide accurate local weather data (Gent and Schwartz, 2003). The system provides internet access to hourly and daily climate data and calculated reference ET rates using both equations (Gillespie, et al., 2008).

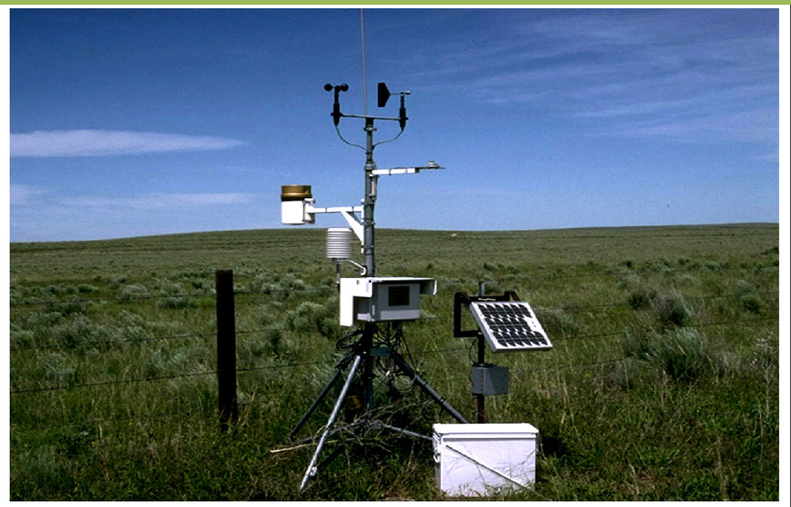
The ASCE standardized Penman-Monteith and Penman-Kimberly equations are both included in the Ref-ET program. The weather data were used to calculate the reference ET rates. The results of the equations can be compared with lysimeter measurements to determine which approach is more accurate for the semi-arid conditions in northeast Colorado. There are differences in the results due to the way the equations were developed. The objectives of this paper include the following:

1-To compare the ETr values calculated with the standardized ASCE Penman-Monteith ET equation and the Penman-Kimberly ET equation using CoAgMet's data for three locations in Colorado - ARDEC, Greeley4 and Iliff for the years 2008 – 2011.

2-To evaluate and determine the effect of climatic factors on the reference evapotranspiration for the three locations in northeast Colorado.

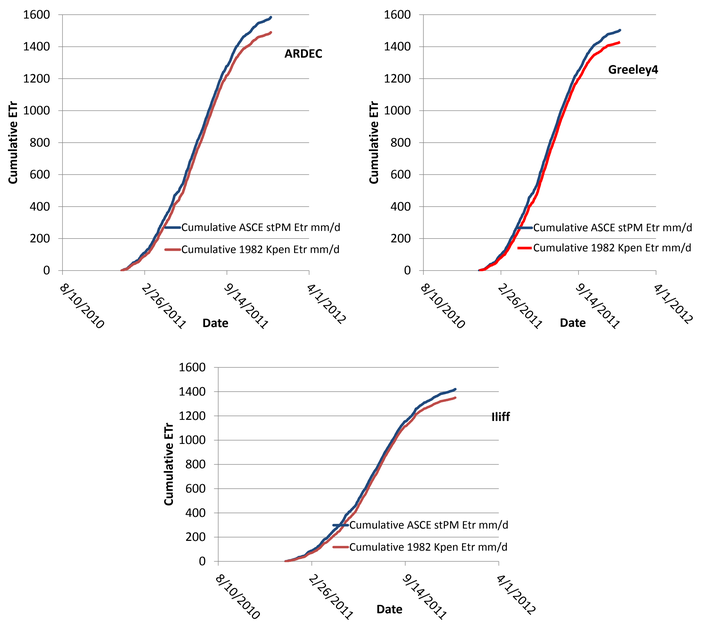
Materials and Methods

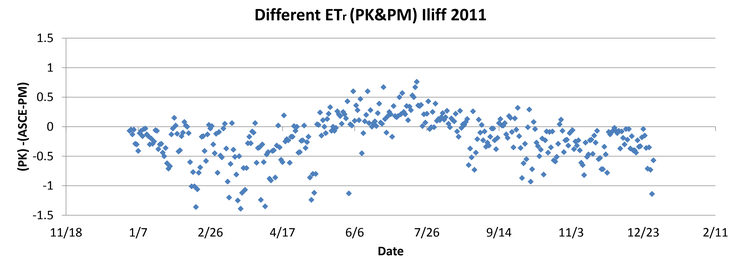
The Colorado Agriculture Meteorological Network (CoAgMet) weather stations used in the study include the Greeley4, ARDEC, and Iliff stations. The locations of these sites provide a west to east climosequence with ARDEC to the west and Iliff to the east. The Colorado State University Agricultural Research Development and Education Center (CSU – ARDEC) is located 6 miles northeast of Fort Collins (Longitude: 105° West, Latitude: 40.6525° North). The Greeley 4 station is located 1.5 miles North of the Greeley Airport (Longitude: 104.638° West, Latitude: 40.4487° North). The Iliff station is located 1.5 miles East of the town of Iliff (Longitude: 103.045° West Latitude: 40.7678° North). The daily ASCE standardized Penman-Monteith ET and the Kimberly-Penman ET were provided by CoAgMet.



Complete automatic weather stations were installed at the three sites to measure the factors needed in the ET equations. ASCE Penman-Monteith ET and Penman-Kimberly ET have been selected for this study. The REF-ET program also calculates reference evapotranspiration for a short crop (similar to grass) that has a height of 12 cm and a tall crop (similar to alfalfa) that has a height of 50 cm. The calculations were based on the climate data provided by CoAgMet. The comparisons between the two equations were based on daily reference ET which was calculated in a two step process. This two-step process is to use hourly weather data to calculate hourly ETr and then convert the hourly ETr into daily ETr. The collected weather data and ET values from the 2 equations for the three stations for the years 2008 – 2011, were analyzed using Microsoft Office Excel. The performance of the reference ET based on the standardized ASCE Penman-Monteith ET and the Penman-Kimberly equations were examined using Root-Mean-Square Error (RMSE), Relative Error (RE), index of agreement (d), Sum, Average, Min, Max, STDEV, and R^2.

Results and Discussion





The difference in daily reference ET mm d^{-1} between the Penman-Kimberly and ASCE standardized equations from the Iliff station for the year 2011.

Conclusion

This study concludes that there is a clear difference between the two equations, when comparing the cumulative daily reference ET mm d^{-1} for the two equations. These cumulative values show the Penman-Kimberly equation values to be lower than the standardized ASCE-PM. Also, the highest averages of daily ETr were recorded in the east (Iliff), and the lowest values were recorded at the west location (ARDEC), with the middle values recorded at the middle location (Greeley-4). Likewise, the recorded temperature, solar radiation and wind speed followed the same pattern, highest at the east location and lowest at the west location. As a result of high precipitation, which increased the amount of soil water content, and higher temperatures, solar radiation, wind speed, and low relative humidity, there was greater evapotranspiration in the East. As a result of the difference between the two equations, this study recommends that the standardized ASCE Penman-Monteith and Penman-Kimberly equations are compared to lysimeter measurements to determine which equation is the most accurate for calculating daily ETr.

Year	Relative Error of Mean (%)	RMSE mm/d	Index of Agreement (d) between Penman-Monteith and Penman-Kimberly	Location
2008	-4.96	0.75	0.98	ARDEC
2009	-5.92	0.49	0.99	
2010	-8.12	0.43	0.99	
2011	-5.99	0.47	0.99	
2008	-0.76	0.34	0.99	Greeley
2009	-1.03	0.33	0.99	
2010	-3.27	0.36	0.99	
2011	-4.94	0.44	0.99	
2008	-3.58	0.52	0.99	Iliff
2009	-0.59	0.29	0.99	
2010	-3.93	0.38	0.99	
2011	-4.93	0.43	0.99	

Refrences

Gent, D. H. and H. F. Schwartz (2003). "Validation of potato early blight disease forecast models for Colorado using various sources of meteorological data." Plant Disease 87(1): 78-84.

Gillespie, M., D. M. Hultstrand, et al., 2008. "14 Snow Hydrology at the Niwot Ridge LTER by Mark W. Williams Cloud Seeding to Enhance Snowfall by Daniel Breed Effects of Ski Slope Development on Stream Channel Morphology in Colorado."