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# Parametric calibration of the Hargreaves–Samani equation for use at new locations

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## Abstract:

The Hargreaves–Samani (HS) evapotranspiration equation is very useful for the on-site irrigation management in data-short situations such as small and midsize farms and landscaped areas. Although much work has been performed to improve the precision of the evapotranspiration ($ET_o$) estimates for use at new locations, the results have not been consistent and many have not been confirmed by other works. The purpose of this study was to review and to evaluate the seven most promising parameters used for the calibration of the HS evapotranspiration equation, using two different regions: California and Bolivia. The results of this study show that annual correlations between HS and Penman–Monteith can be misleading because the correlation is poor in the humid months and improves progressively along the dry season until the first rains. The average monthly wind speed can be used for both spatial and seasonal calibration of the HS equation, especially during the irrigation season. Elevation and precipitation can be used to calibrate the HS equation when no reference $ET_o$ values are available at nearby stations. The monthly value of $K_T$ calculated from solar radiation follows a parabolic function along the year and should not be used for improving the estimates of the HS equation because the clearness index produces better results than actual solar radiation measurements. The results also indicate that the use of distance to coast, temperature range and temperature parameter does not improve the precision of the HS equation. Copyright © 2012 John Wiley & Sons, Ltd.

KEY WORDS evapotranspiration; Hargreaves–Samani; Penman–Monteith

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## INTRODUCTION

The scarcity of water as a natural resource calls for sensible and practical decision support tools that aid decision making and enable farmers and landscape managers to determine precise crop water requirements. The daily calculation of reference evapotranspiration ($ET_o$) is one of the most important tools for assessing the water needs of crops.

Hargreaves analysed 8 years of grass evapotranspiration data from a precision lysimeter and weather data from Davis, California (latitude, 38º; elevation, 18 m) and observed through regressions that for five day time steps, 94% of the variance in measured $ET_o$ could be explained by average temperature, T, and solar radiation, $R_s$. As a result, in 1975 he published the following equation for estimating $ET_o$ based only on these two parameters (Hargreaves, 1975):

$$ET_o = 0.0135\ R_s(T + 17.8) \tag{1}$$

where $R_s$ is in equivalent units of water evaporation (mm $day^{-1}$) and $T$ is the temperature (°C). Subsequent attempts to use wind velocity ($U_2$) and relative humidity (RH) to improve the results were not encouraging; hence, these parameters were left out (Hargreaves and Allen, 2003).

The clearness index, or the fraction of the extraterrestrial radiation that actually passes through the clouds and reaches the earth's surface is the main energy source for evapotranspiration, and later studies by Hargreaves and Samani (1982) showed that it can be estimated by the difference between the maximum, $T_{max}$ and the minimum, $T_{min}$ daily temperature. Under clear skies the atmosphere is transparent to incoming solar radiation so $T_{max}$ is higher, while night temperatures are lower because of outgoing longwave radiation (Allen *et al*. 1998). On the other hand, under cloudy conditions, $T_{max}$ is lower since part of incoming solar radiation never reaches the earth, while night temperatures are relatively higher as clouds limit heat loss due to outgoing longwave radiation. Based on this principle, Hargreaves and Samani (1982) recommended a simple equation to estimate solar radiation using the temperature difference:

$$R_s/R_a = K_T(T_{max} - T_{min})^{0.5} \tag{2}$$

where $R_a$ is extraterrestrial radiation in millimetres per day and can be obtained from tables (Samani, 2000) or calculated (Allen *et al*., 1998). The empirical coefficient $K_T$ was initially fixed at 0.17 for Salt Lake City and other semiarid regions. It is understood that this equation accounts for effects of cloudiness and humidity on solar

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