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Short communication

Development of Hargreaves and Samani shortwave radiation coefficient (Kr) for India

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Solar radiation plays an important role as regulator and controller of crop growth and development. Crop growth is primarily determined by the amount of sunlight (solar radiation) that the crop can intercept and use during its life. Crop growth rate increases linearly with absorbed sunlight. It is required for proper assimilation of nutrients, flowering and many other biochemical processes of crop. About 5,000 trillion kWh of solar energy with about 300 sunny days is received over India's geographical area annually (Krishna *et al*2011). There are many agro meteorological observatories collecting weather data throughout the country but very few of these are regularly recording actual sunshine data. An empirical coefficient (Kr) for the places where sunshine data are not available, a procedure to calculate the same was suggested for North American and Europian condition (Hargreaves and Samani, 1982). This was easy to calculate estimate short wave solar radiation (Rs) using the difference of maximum and minimum air temperatures only. They generalized two values of Kr. They suggested 0.16 for inland regions and 0.19 for coastal regions. Such information is not yet generated for India. Therefore, the objective of this study was to develop Kr values for the entire country so that actual sunshine based calculations agricultural and resource management planning process could be undertaken without any problem.

Normal monthly average weather data (Tmax (°C), Tmin (°C) and actual sunshine hrs (n)) from 167 different stations of India (Fig 1) was taken from CLIMWAT 2.0 database. This is a joint publication of the Water Development and Management Unit and the Climate Change and Bioenergy Unit of FAO. CLIMWAT is a climatic database developed in order to calculate crop water requirements, irrigation supply and irrigation scheduling etc., for various using CROPWAT software. CLIMWAT 2.0 offers normal data for about 5000 stations across the world. This was used to calculate Hargreaves and Samani short wave radiation coefficient (Kr) for all the 167 weather stations of India.

Hargreaves and Samani shortwave radiation coefficient (Kr)

Hargreaves and Samani (1982) recommended a simple equation to estimate shortwave solar radiation (Rs) as a function of air temperatures:

$$Rs = Kr\ (\sqrt{TD})\, Rs \qquad (1)$$

Where,

Rs = shortwave solar radiation reaching the earth surface ($MJ\ m^{-2} day^{-1}\cdot mm\ day^{-1}$; $Cal\ m^{-2}\ day^{-1}$)

TD = difference of maximum (Tmax) and minimum (Tmin) air temperature (°C)

Ra = extraterrestrial radiation ($MJ\ m^{-2} day^{-1}$); and

Kr = empirical coefficient also known as Hargreaves & Samani coefficient.

Short wave solar radiation is also estimated using Angstrom formula given in FAO 56 (Allen *et al* 1998). Where,

$$Rs = \left(as + bs\left(\frac{n}{N}\right)\right) * Ra \qquad (2)$$

n = actual duration of sunshine [hrs],

N = maximum possible duration of sunshine or daylight hours [hrs],

Ra = extraterrestrial radiation ($MJ\ m^{-2} day^{-1}$)

as = regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0),

bs = slope, fraction of extraterrestrial radiation reaching the earth on clear days (n = N).

The regression constant (*as*) and slope (*bs*) are also calibrated and reported for Indian conditions by Bandyopadhyay *et al* (2008) for better estimation of solar radiation. In this study these corrected *as* and *bs* were used to generate a near true value of Kr. Their study revealed that

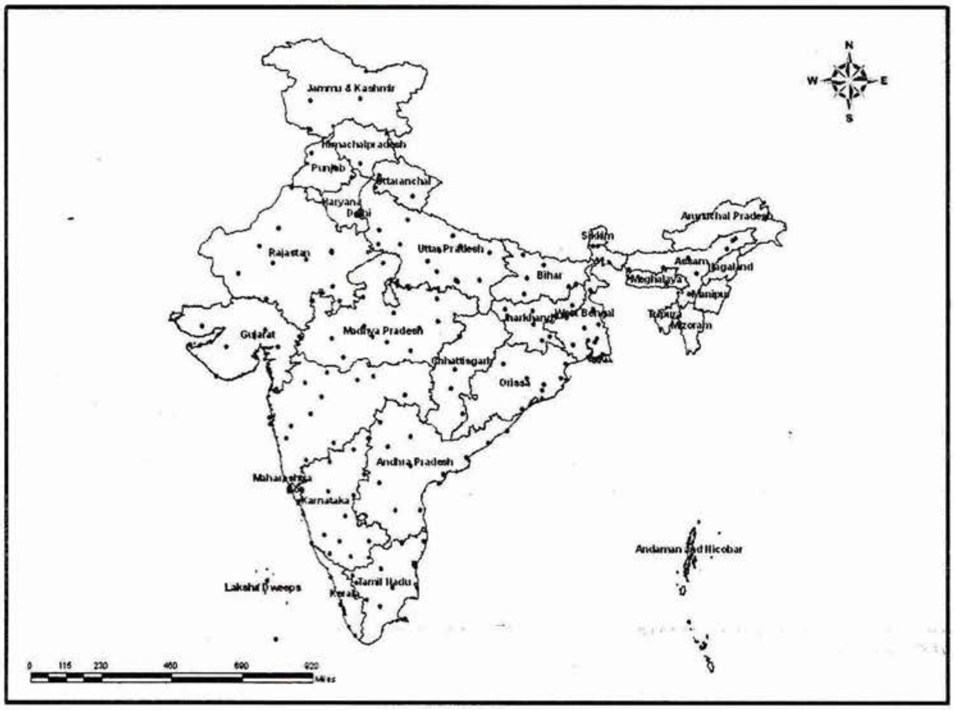

Fig. 1: CLIMWAT 2.0 reported weather stations of India

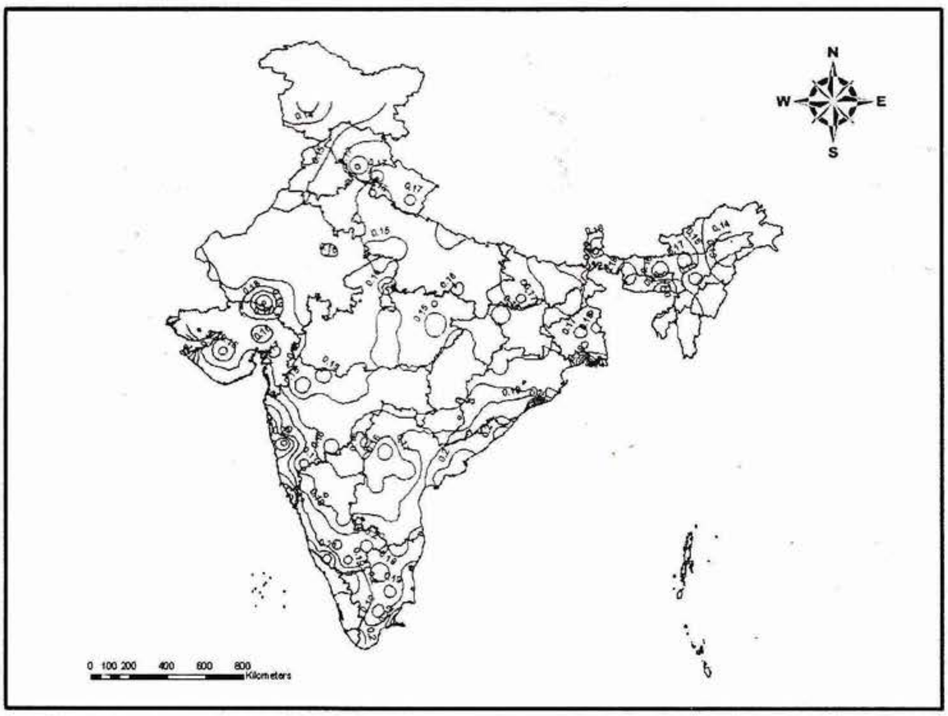

Fig. 2: Isolines of Hargreaves and Samani short wave radiation coefficient (Kr) for India.

they are influenced by the latitude (L) and altitude (Z) of the given location. The equation for their calibration is given as:

$$as = 3.517 * 10^{-3} L - 1.492 * 10^{-6} Z + 0.3263$$

$$bs = 5.042 * 10^{-4} L + 4.845 * 10^{-5} Z + 0.4644$$

combining the equations (1) & (2) it can be written as

$$Kr = \frac{as + bs\left(\frac{n}{N}\right) * Ra}{\left(\sqrt{TD}\right) * Ra}$$

Now, cancelling Ra, the equation can be rewritten as:

$$Kr = \frac{as + bs\left(\frac{n}{N}\right)}{\left(\sqrt{TD}\right)} \qquad (3)$$

Using the equation no. 3, Hargreaves & Samani coefficient (Kr) was calculated. The Kr was calculated developing a computer program on Microsoft Excel. Average annual weather data of Tmax, Tmin, actual sunshine hrs of 167 stations of India (Fig 1) given in CLIMWAT 2.0 was used to calculate the value of Kr. Latitude, Longitude and Altitude of the weather station site as given in CLIMWAT 2.0 was also collected to calculate *as* (regression constant) and *bs* (slope) as per the procedure suggested by Bandyopadhyay (2008). Contours of Kr were developed and plotted on the map of India (SOI) using Arc GIS software.

Values of Kr plotted over the map of India (Fig. 2) shows that there are islands of high Kr values in coast of the country. Strangely it is highly variable in space and site. Coastal areas on an average had Kr value of 0.2 Based on these findings it can be broadly generalize as 0.17 Kr for inland condition and 0.2 Kr for coastline of India. Although there are some exceptions in the occurrence of Kr with location but they are not of very significant nature. The Hargreeves and Samani coefficient (Kr) developed for the country will prove to be a very good tool to calculate short wave radiation (Rs) even in the absence of the values of actual sunshine hours.

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