Data Article

Dataset of solar energy potential assessment for Adama city (Ethiopia)

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ABSTRACT

This paper focuses on estimation of available solar radiation from sunshine hour duration. Sunshine hour duration data from 2013 to 2017 G.C recording from Adama metrology agency, average daily global radiation in horizontal and tilt surface for global, diffuse and beam radiation are calculated also hourly global radiation and diffuse radiation data are calculated in tilt surface reach. Finally global and diffuse radiation data for January 5, 2017 and July 5, 2017 are calculated.

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1. Data

Sunshine hours is a climatological indicator, measuring duration of sunshine in given period (usually, a day or a year) for a given location on earth, typically expressed as an averaged value over several years. It is a general indicator of cloudiness of a location, and thus differs from insolation, which measures the total energy delivered by sunlight over a given period [6]. Table 1 shows Sunshine hour duration for five years and Table 2 and Fig. 1 shows five years average Sunshine hour duration from

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nearby metrology agency. The monthly average daily global radiation, diffuse radiation and beam radiation in horizontal surface are tabulated in Table 3, Table 4 and Table 5 respectively and compared in Fig. 2. The sunset hour angle 1 and 2 are listed in Tables 6 and 7 and the minimum values are given in Table 8. In Table 9 & Fig. 3, the maximum possible solar energy harvesting potential of total solar radiation reach on tilt surface is given. The hourly global radiation and diffuse radiation reach on tilt surface are shown in Figs. 4 and 5. The global radiation and diffuse radiation for the particular day 5th of January and 5th of July 2017 are given in Figs. 6 and 7. Adama Station - Latitude (\(\phi\)) = 8 33' 23.8" N = 8.558°, Longitude = 39 17' 2.5" E = 39.28°, Altitude = 1648 m above sea level, Dominating climate of the city is hot/arid climate type [1].
2. Experimental design, material, and methods

Estimation of available solar radiation on horizontal and tilt surface from five (5) years average sunshine hour duration seen in Table 1 by using Modified angstrom-type regression equation for surface with surface azimuth angle \( y = 0^\circ \) and Collector tilt (\( \beta \)) the yearly optimum slope angle of solar collector as \( \beta_{\text{opt}} = \phi + 15^\circ \) at a location with latitude. The ground reflectance is 0.2 for all months except December and March (\( p = 0.4 \)) and January and February (\( p = 0.7 \)) using the isotropic diffuse assumption. Fig. 1 shows Sunshine hour duration for Adama city in five years (2013–2017) averages.

2.1. Modified angstrom-type regression equation [7]

\[
H_0 = 24 \times 3600 \times \frac{I_{sc}}{\pi} \left( 1 + 0.033 \cos \left( \frac{360^\circ n}{365} \right) \right)^2 \left( \cos \phi \cos \delta \sin \omega S + \pi \times (\sin \phi \times \sin \delta) \right) \tag{1}
\]

\(H_0\) = Monthly average radiation at extra-terrestrial region for the same location

Solar constant \( I_{sc} = 1367\ \text{W m}^{-2} \)

Declination angle (\( \delta \)) = \(23.45\times \sin \left( \frac{360^\circ (284 + n)}{365} \right) \) \tag{2}

Sunset hour angle (\( \omega S \)) = \( \cos^{-1} \left( -\tan \phi \tan \delta \right) \) \tag{3}

\[
a = -0.110 + 0.235 \cos \phi + 0.323 \left( \frac{n_s}{N_s} \right) \tag{4}
\]
Table 3
Monthly Average daily global radiation (MJ/m²/day) in horizontal surface.

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Average (2013–2017) | 21.7 | 23.6 | 24.7 | 24.6 | 23.9 | 23.2 | 21.8 | 22.5 | 23.1 | 23.6 | 22.4 | 21.5 |

Table 4
Monthly Average daily diffuse radiation (MJ/m²/day) on horizontal surface.

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Average (2013–2017) | 6.9 | 6.8 | 7.9 | 9.1 | 9.3 | 9.5 | 10.6 | 10.7 | 10.1 | 7.5 | 6.1 | 5.8 |

Table 5
Monthly Average daily beam radiation (MJ/m²/day) on horizontal surface.

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Average (2013–2017) | 14.9 | 16.8 | 16.8 | 15.5 | 14.6 | 13.6 | 11.2 | 11.8 | 13.1 | 16.2 | 16.3 | 15.7 |

Fig. 2. Daily solar radiation Vs months of the year.

Table 6
Sunset hour angle 1.

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Sunset hour angle | 86.7 | 88.0 | 89.63 | 91.43 | 92.93 | 93.67 | 93.3 | 92.0 | 90.3 | 88.5 | 87.0 | 86.3 |
From above equations, monthly Average daily global radiations on horizontal surface are listed on Table 3.

From above equation and Table 3, monthly Average daily diffuse radiations on horizontal surface are listed on Table 4.

Beam radiation \( (H_b) \) radiation directly come to the object without scattered obtained by subtract diffuse radiation from global radiation as follows. Monthly Average daily beam radiation on horizontal surface are listed on Table 5. Fig. 2 shows beam, diffuse and global solar radiation on horizontal surface.

\[ b = 1.449 - 0.533 \cos \phi - 0.694* \left( \frac{N_s}{N_s} \right) \]  

\[ a \text{ and } b \text{ are empirical constant [8].} \]

\[ N_s = \frac{2}{15}\omega s \]  

\[ \frac{H_d}{H} = 0.931 - 0.814* \frac{N_s}{N_s} \]

2.2. Conversion factors [5]

Beam radiation factor \( (R_b) \) the ratio of the average daily beam on the tilted surface to that on a horizontal surface for the month is \( R_b \), which is equal to \( \frac{H_b}{H_0} \).

For surface that are sloped toward the equator in the northern hemisphere that is for surface with surface azimuth angle \( y = 0^\circ \).

\[ R_b = \frac{\cos(\phi - \beta) \cos \delta \sin \omega' s + (\pi/180) \omega' s \sin(\phi - \beta) \sin \delta}{\cos \phi \cos \delta \sin \omega s + (\pi/180) \omega s \sin \phi \sin \delta} \]  

where \( \omega' s \) is the sunset hour angle for the tilted surface for the mean day of the month.

\[ \omega' s = \min\left[ \cos^{-1}(- \tan \phi \tan \delta) \cos^{-1}(- \tan(\phi - \beta) \tan \delta) \right] \]  

Sunset hour angle 1 and Sunset hour angle 1 are listed in Tables 6 and 7 respectively. The minimum value from Tables 6 and 7 are listed in Table 8.

Collector tilt \( (\beta) \) the yearly optimum slope angle of solar collector as \( \beta_{opt} = \phi + (10-15)^\circ \) at a location with latitude [2].

\[ \beta = \phi + 15^\circ = 8.558 + 15 \approx 24 \]  

\[ \omega' s = \cos^{-1}(- \tan \phi \tan \delta) \]

Or \( \omega' s = \cos 1(- \tan(\phi - \beta) \tan \delta) \)
Diffuse radiation factor ($R_d$).

$$R_d = \frac{1 + \cos \beta}{2}$$ \hspace{1cm} (12)

Reflected radiation factor ($R_r$).

$$R_r = \frac{1 - \cos \beta}{2}$$ \hspace{1cm} (13)

The ground reflectance is 0.2 for all months except December and March ($p = 0.4$) and January and February ($p = 0.7$) using the isotropic diffuse assumption [3]. Global solar radiation reach on tilt surface

Table 8

Minimum value from Table 6 and Table 7 (degree).

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Minimum value | 86.7 | 88.0 | 89.6 | 87.4 | 84.6 | 83.2 | 83.8 | 86.2 | 89.6 | 88.5 | 87.0 | 86.3 |

Table 9

Total solar radiation (MJ/m²/day) reach on tilt surface.

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Global radiation on tilt surface | 36.8 | 37.9 | 33.7 | 29.4 | 27.5 | 25.3 | 25.2 | 27.7 | 29.6 | 31.1 | 31.0 | 33.1 |

Fig. 3. Daily solar radiation Vs Months of the year
are listed in Table 9. Fig. 3 shows global solar radiation on tilt surface in meter quarter Vs months of the year.

**Prediction of hourly global radiation:** the hourly global radiation can be calculated from the knowledge of the daily global radiation. Monthly Averages of daily global radiation are shown in Fig. 4.

\[
\frac{I}{H} = \frac{\pi}{24}(a + b \cos \omega) \frac{\cos \omega - \cos \omega_S}{\sin \omega_S - \frac{\pi}{180} \omega_S \cos \omega_S}
\] (14)

where

\[
a = 0.409 + 0.5016 \sin(\omega_S - 60)
\] (15)
b = 0.6609 - 0.4767\sin(\omega_S - 60) \quad (16)

\omega = 15(t - 12) \quad (17)

**Prediction of hourly diffused radiation**: the hourly diffuse radiation also can be calculated from the knowledge of the daily radiation. Monthly Averages of daily diffuse radiation are shown in Fig. 5.
\[
\frac{I_d}{H_d} = \pi \frac{\cos \omega - \cos \omega_0}{24 \sin \omega_0 - \frac{x}{100 \cos \omega_0} \cos \omega_0}
\]  

(18)

Solar intensity in particular days from Sunshine hour duration (9.3) in the day of January 5, 2017 Fig. 6 is generated to show daily radiation amount pattern within specific day. Total global radiation amount on horizontal surface 21.6 MJ/m² and tilt surface 37.9 MJ/m².

From Sunshine hour duration (6.1) in the day of July 5, 2017 Fig. 7 is generated to show daily radiation amount pattern within specific day. Total global radiation amount on horizontal surface 20.614 MJ/m² and tilt surface 23.471 MJ/m².

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Transparency document

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