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DETERMINATION OF SOLAR INSOLATION IN MICHAEL OKPARA UNIVERSITY OF AGRICULTURE UMUDIKE USING A PHOTORESISTOR

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ABSTRACT

The average daily insolation in Umudike has been determined at a figure of $7KWhm^{-2}$ per day using the correlation between solar insolation and the solar resistance of a cadmium sulphide photoresistor cell. With this figure of insolation, Umudike falls within the high insolation zones of the globe. This is in accordance with NASA (2002) report. The community therefore has enough radiation to support not only agriculture but also high level solar projects.

KEYWORDS: Solar radiation, daily insolation, photoresistance, insolation figure, solar project.

INTRODUCTION

The sun's radiations reach us in two major components as diffused and direct radiations. According to Green (1982), the diffused radiation is richer in shorter wavelength than the direct radiation. Dickson and Cheremisinoff (1982) noted that the amount of atmospheric absorption and scattering of solar radiation is a function of the effective distance (depending on the atmospheric thickness and content) through which radiaition travels. Green (1982) also observed that the amount of sunlight that reaches any particular point on the earth's surface depends on the time of the day, month of the year, amount of cloud cover and the latitude of the place.

According to Holladay (2002), the earth receives an average intensity of solar radiation at right angles to the direction of the radiation within the earth's atmosphere, amounting to a solar constant of $1.366KWm^{-2}$. Of this 8% is in the ultraviolet wavelengths, 47% in the visible spectrum and 45% in the infrared region. Martin (1997) argued that the solar constant is not actually constant due to the orbital shape of the earth, but is subject to a small continous variation amounting to −3.3% from average about July 5 when the earth is at its greatest distance from the sun and +3.4% about January 3 when the earth is closest to the sun.

Willson (2003) reported that solar activity records show that solar radiation received on earth has been increasing since the late 19th century.

Presently ,the world is fighting a battle to reduce global emission of CO_2 as specified by the Kyoto protocol. If implemented the Kyoto protocol require that a country like the United States of America reduce its CO_2 emissions to about 7% below its 1990 levels between 2008 and 2012 (Lenuis *et al.*, 2005). The only way to achieve this global objective is to shift emphasis from fossil fuels to renewable sources such as solar energy. This has become the concern of many countries.

Solar insolation is a useful figure of merit for harnessing solar energy effectively. It is the amount of solar energy that is incident on the earth's surface per unit area per day. It is usually expressed in $KWhm^{-2}$ per day or MJ/M^2/day. Its value gives the idea of how much solar radiation is available in a location. Therefore before solar projects are mounted in a place the insolation value of the site should be known. According to the American National Aeronautics and space Administration (NASA, 2002) report, the basic scale for global insolation level recognizes three different insolation zones of the world. Those areas having insolation figure of $4KWhm^{-2}$ per day and below belonging to low insolation zone, those having 4 to 5 $KWhm^{-2}$ per day belong to the moderate insolation zone while areas with $5KWhm^{-2}$ per day and above are classified as high insolation zone.

THEORETICAL BACKGROUND

Photoresistors are light-dependent resistors sometimes called photoconductors. Their resistances change with incident light intensity. The negative coefficient type decreases in resistance with light intensity while the positive coefficient type increases in resistance with intensity.

According to photoelectric theory, as incident light falls on a photoresistor, it creates free electrons or holes which are drawn to their proper electrodes. At each instant, the number of free electrons in the crystal is determined by the stationary negative space changes of electrons that are held in so called trapping states. Also immediately one electron leaves the crystal at the anode, another one enters the crystal at the cathode so that the number of the electrons always remain constant when electromagnetic radiation energy quanta are moved into the conduction band. When this happens the empty spaces or holes created by these electrons are then filled by another electrons thus constituting an electric current.

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Photoresistance and solar insolation are related by logarithmic expression as:

$$\ln I = 6.32 - 0.98\ln R \quad \text{(1)}$$

where I = insolation and R = solar resistance.
But natural logarithm ln = 2.303log$_{10}$

Therefore applying this in equation (1) we have:

$$2.303\log_{10} I = 6.32 - 0\ 0.98 \times 2.303\log_{10} R$$

Hence,

$$\log_{10} I = \frac{6.32}{2.303} - 0.98\log_{10} R$$

and

$$\log_{10} I + \log_{10} R^{0.98} = 2.7442$$

$$\log_{10} IR^{0.98} = 2.7442 \quad \text{(2)}$$

Thus, $IR^{0.98} = 10^{2.7442}$

And

$$I = \frac{10^{2.7442}}{R^{0.98}} \quad \text{(3)}$$

For a given area of surface, equation (3) is divided by the surface area of the photoresistor A, to give;

$$I = \frac{\left(\dfrac{10^{2.7442}}{R^{0.98}}\right)}{A} \ \text{KWhm}^{-2} \quad \text{(4)}$$

The photoresistor used for this work has a radius of 0.0135m and surface area of $5.7279 \times 10^{-4}m^2$.

MATERIALS AND METHODS

For this work cadmium sulphide (cds) photoresistor of negative coefficient was used. It has a radius of 0.0135m and surface area of $5.7279 \times 10^{-4}m^2$ Digital ohm-meter and solar stand were also used in the experiment.

According to Ojosu (2001) solar panels are mounted at a tilt angle corresponding to the latitude of the site for effective results. Umudike lies within latitudes $5^0 26'$ and $5^0 43'$N and within longitudes $7^0 21'$ and $7^0 35'$E, (Abia State Ministry of lands and survey Umuahia, 1999).
Therefore the photoresistor was mounted on a solar stand at a tilt angle of 5^0 for effective results.

Photoresistance values were measured using the digital ohm-meter at hourly intervals on daily basis from 7am to 6pm local time. This continued for many days. From the solar resistance values the solar insolation for each hour was determined using equations (3) and (4). Table 1 shows the measured data comprising of solar resistance for each hour and the corresponding solar insolation for different days.

RESULTS AND DISCUSSION

This investigation was done within the premises of the Michael Okpara University of Agriculture Campus in 2003

From the data obtained solar resistance decreased with solar intensity. This is due to the negative coefficient nature of the photoresistor as stated earlier. The data are as shown in table 1. However insolation values increased with solar intensity, increasing from the hours of the morning and peaking at about the hours of mid day and decreasing again towards the eventide. This trend is shown in the insolation – time (I-t) curves of figs 1 to 5.

From the I-t curve of Umudike we see that sunlight increases from about 7 am and peaks between 12noon and 2pm and then decreases towards evening. The average insolation value obtained for each day ranges from 5KWhm^{-2} and above while the overall average daily insolation obtained within the period was 7.11KWhm^{-2} per day. Therefore judging from NASA (2002) publication as stated earlier Umudike falls within the high insolation zone of the globe and can support any solar project.

CONCLUSION

The average daily insolation in Umudike has been determined at a figure of 7KWhm^{-2} per day, using the correlation between solar insolation and the solar resistance of a cadmium sulphide photoresistor cell.

Table 1

	DATE	TIME	7am	8am	9am	10am	11am	12noon	1pm	2pm	3pm	4pm	5pm	6pm	AVG (KWH/M2/DAY
SAT	01-Nov-03	PR (Ω)	350	220	120	130	90	80	90	90	100	140	280	1090	
		INSOLATION (KWh/M²)	3.1118	49049	8.8839	8.2137	11.777	13.218	11.777	11.777	10.622	7.6383	3.8725	1.022	8.088191667
SUN	02-Nov	PR (Ω)	350	230	120	110	170	140	140	90	170	140	280	890	
		INSOLATION (KWh/M²)	3.1118	4.5968	8.8839	9.6747	6.3149	7.6383	7.6383	11.777	6.3149	7.6383	3.8725	1.247	8.58735
MON	03-Nov-03	PR (Ω)	220	190	150	120	120	110	90	140	130	180	320	1400	
		INSOLATION (KWh/M²)	4.9049	5.6628	7.1389	8.8839	8.8839	9.6747	11.777	7.6383	8.2137	5.9709	3.3975	0.8	6.912194167
TUES	04-Nov-03	PR (Ω)	500	260	190	140	120	120	110	110	110	140	200	1050	
		INSOLATION (KWh/M²)	2.1939	-4.1542	5.6628	7.6383	8.8839	8.8839	9.6747	9.6747	9.6747	7.6383	5.3851	1.05	6.711233333
WED	05-Nov-03	PR (Ω)	380	140	100	110	90	90	170	110	120	120	220	140	
		INSOLATION (KWh/M²)	2.87097	7.6383	10.622	9.6747	11.777	11.777	6.3149	9.6747	10.622	8.8839	4.9049	0.978	7.978121417
THURS	06-Nov-03	PR (Ω)	260	200	130	130	110	110	130	120	160	200	210	850	
		INSOLATION (KWh/M²)	4.1642	5.3851	8.2137	8.2137	9.6747	9.6747	8.2137	8.8839	6.7014	5.3851	5.1337	1.394	6.745583333
FRI	07-Nov-03	PR (Ω)	310	140	150	130	90	90	100	160	560	550	540	1890	
		INSOLATION (KWh/M²)	3.5049	7.5383	7.1389	8.2137	11.777	11.777	10.522	6.7014	1.9633	1.9982	2.0345	0.595	6.183708167
SAT	08-Nov-03	PR (Ω)	340	230	170	140	100	80	80	90	100	120	190	850	
		INSOLATION (KWh/M²)	3.2015	4.5958	6.3149	7.6383	10.622	13.218	13.218	11.77	10.622	8.8839	5.6628	1.304	8.098541667
SUN	09-Nov-03	PR (Ω)	260	130	170	100	150	110	220	150	330	430	310	3190	
		INSOLATION (KWh/M²)	4.1642	8.2137	6.3149	10.622	7.1389	9.6747	4.9049	7.1389	3.2966	2.5433	3.5049	0.357	5.658154167
MON	10-Nov-03	PR (Ω)	330	180	140	100	130	100	110	90	120	120	190	690	
		INSOLATION (KWh/M²)	3.2966	5.9709	7.6383	10.622	8.2137	10.622	9.5747	11.777	8.8839	8.8839	5.6628	1.5	7.75715
TUES	11-Nov-03	PR (Ω)	280	150	110	100	120	110	90	90	100	200	380	1310	
		INSOLATION (KWh/M²)	3.8725	7.1389	9.6747	10.622	8.8839	9.6747	11.777	11.777	10.622	5.3851	2.8709	0.854	7.782268167
WED	12-Nov-03	PR (Ω)	310	250	110	140	120	140	90	120	140	160	330	1420	
		INSOLATION (KWh/M²)	3.5049	3.8725	9.6747	7.6383	8.8839	7.6383	11.777	8.8839	7.6383	6.7014	3.2966	0.789	6.881549167
THURS	13-Nov-03	PR (Ω)	300	200	150	120	130	120	180	160	210	300	390	2040	
		INSOLATION (KWh/M²)	3.6193	5.3851	7.1389	8.8839	8.2137	8.8839	5.9709	6.7014	5.1337	3.6193	2.7987	0.553	5.578154167
FRI	14-Nov-03	PR (Ω)	290	220	130	150	90	130	120	110	130	190	200	910	
		INSOLATION (KWh/M²)	2.1431	4.9049	8.2137	7.1389	11.777	8.2137	8.8839	9.6747	8.2137	5.6628	5.3851	1.27	6.780125
SAT	15-Nov-03	PR (Ω)	310	170	110	190	140	90	90	90	100	120	180	890	

Table 1: Contd

		INSOLATION (kWh/M²)	3.5049	6.3149	9.6747	5.6628	7.6383	11.777	11.777	11.777	10.622	8.8839	5.9709	1.2468	7.904183333
SUN	16-Nov-03	PR (Ω)	360	190	170	210	160	140	130	120	130	150	190	770	
		INSOLATION (kWh/M²)	3.0271	5.5628	6.3149	5.1337	6.7014	7.6383	8.2137	8.8839	8.2137	7.1389	5.6628	1.437	6.168018667
MON	17-Nov-03	PR (Ω)	340	200	130	210	140	150	90	200	140	170	330	1110	
		INSOLATION (kWh/M²)	3.3975	4.9049	8.2137	5.1337	7.6383	7.1389	11.777	5.3851	7.6383	6.3149	3.2966	1.0041	5.98691667
TUES	18-Nov-03	PR (Ω)	340	200	130	190	190	90	90	130	140	160	260	850	
		INSOLATION (kWh/M²)	3.2015	5.3851	8.2137	5.6628	5.6628	11.777	11.777	8.2137	7.6383	6.7014	4.1642	1.3043	6.641818667
WED	19-Nov-03	PR (Ω)	550	250	150	120	140	130	60	150	120	140	210	920	
		INSOLATION (kWh/M²)	1.9982	4.3274	7.1389	8.8839	7.6383	8.2137	11.777	10.622	8.8839	7.6383	5.1337	1.207	6.955191667
THURS	20-Nov-03	PR (Ω)	360	150	150	100	90	90	100	130	140	130	230	970	
		INSOLATION (kWh/M²)	3.0271	5.5628	7.1389	10.622	11.777	11.777	10.622	8.2137	7.6383	8.2137	4.6958	1.146	7.544525
FRI	21-Nov-03	PR (Ω)	330	180	130	100	100	100	90	100	110	140	260	960	
		INSOLATION (kWh/M²)	3.2966	5.9709	8.2137	10.622	10.622	10.622	11.777	10.622	9.6747	7.6383	4.1642	1.1577	7.885091667
SAT	22-Nov-03	PR (Ω)	330	160	120	100	90	90	90	100	110	130	190	690	
		INSOLATION (kWh/M²)	3.2966	6.7014	8.8839	10.622	11.777	11.777	11.777	10.622	9.6747	8.2137	5.6628	1.6	8.384008333
SUN	23-Nov-03	PR (Ω)	410	210	160	140	100	110	100	110	150	120	410	1360	
		INSOLATION (kWh/M²)	2.6636	5.1337	6.7014	7.6383	10.622	9.6747	10.622	9.5747	7.1389	8.8839	2.6636	0.69693	6.842810833
MON	24-Nov-03	PR (Ω)	350	170	120	100	110	100	100	150	120	170	200	850	
		INSOLATION (kWh/M²)	3.1118	5.3149	8.8839	10.622	9.6747	10.622	10.622	7.1389	8.8839	6.3149	5.3851	1.3043	7.406533333
TUES	25-Nov-03	PR (Ω)	400	150	120	180	90	90	140	100	160	130	200	580	
		INSOLATION (kWh/M²)	2.7301	7.1389	8.8839	5.9709	11.777	11.777	7.6383	10.622	6.7014	8.2137	5.3851	1.6231	7.371783333
WED	26-Nov-03	PR (Ω)	380	220	110	100	160	90	90	100	110	120	210	910	
		INSOLATION (kWh/M²)	2.8709	4.9049	9.6747	10.622	6.7014	11.777	11.777	10.622	9.6747	8.8839	5.1337	1.22	7.82185
THURS	27-Nov-03	PR (Ω)	300	180	190	140	90	150	90	150	110	170	390	2190	
		INSOLATION (kWh/M²)	3.6193	5.9709	5.6628	7.6383	11.777	7.1389	11.777	7.1389	9.6747	6.3149	2.7988	0.5159	6.86895
FRI	28-Nov-03	PR (Ω)	320	190	160	210	100	130	100	100	120	120	210	960	
		INSOLATION (kWh/M²)	3.3975	5.6628	6.7014	5.1337	10.622	8.2137	10.622	10.622	8.8839	8.8839	5.1337	1.1577	7.008191667
SAT	29-Nov-03	PR (Ω)	310	170	140	110	150	120	90	100	110	130	200	810	
		INSOLATION (kWh/M²)	3.5049	6.3149	7.6383	9.6747	7.1389	8.8839	11.777	10.622	9.6747	8.2137	5.3851	1.3874	7.516281667
SUN	30-Nov-03	PR (Ω)	340	190	170	100	90	160	100	100	110	120	210	870	
		INSOLATION (kWh/M²)	3.2015	5.6628	6.3149	10.622	11.777	6.7014	10.622	10.622	9.6747	8.8839	5.1337	1.2749	7.5409

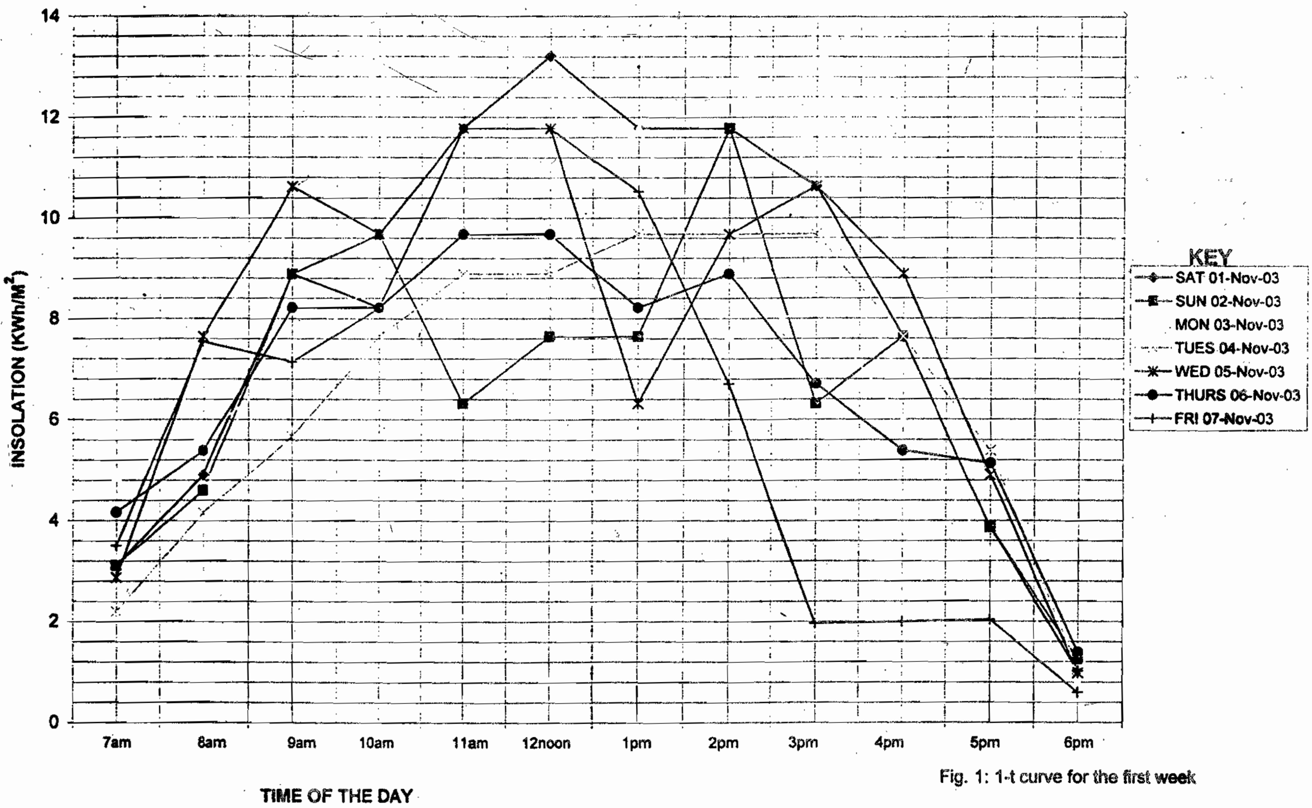

Fig. 1: 1-t curve for the first week

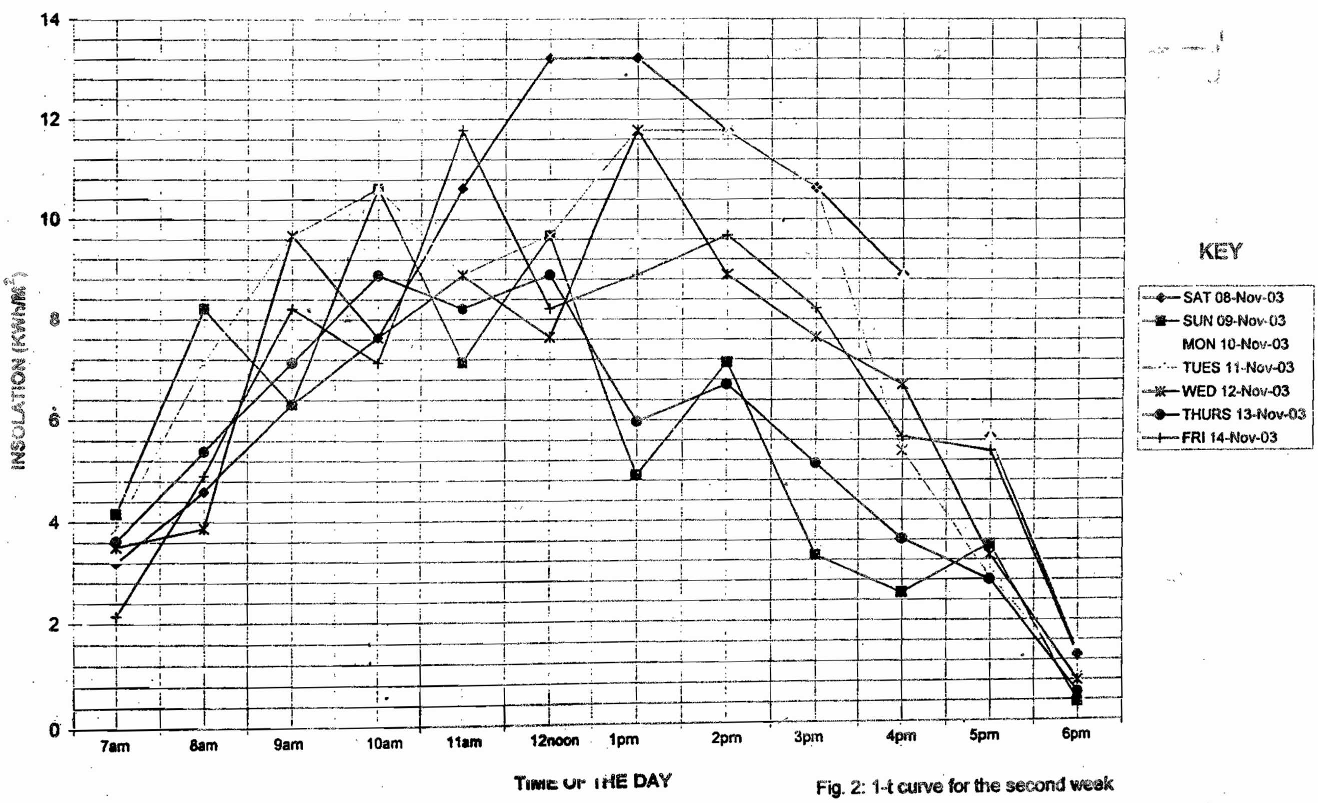

Fig. 2: 1-t curve for the second week

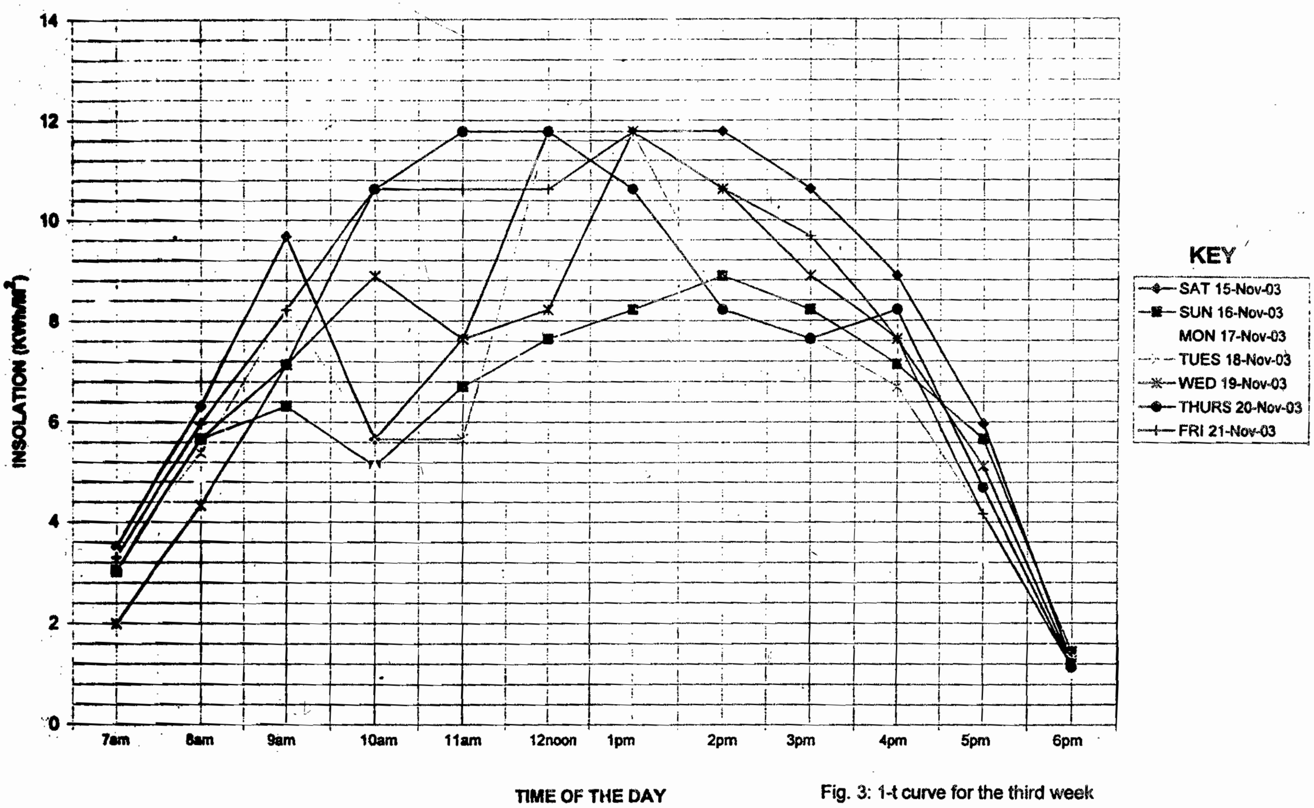

Fig. 3: 1-t curve for the third week

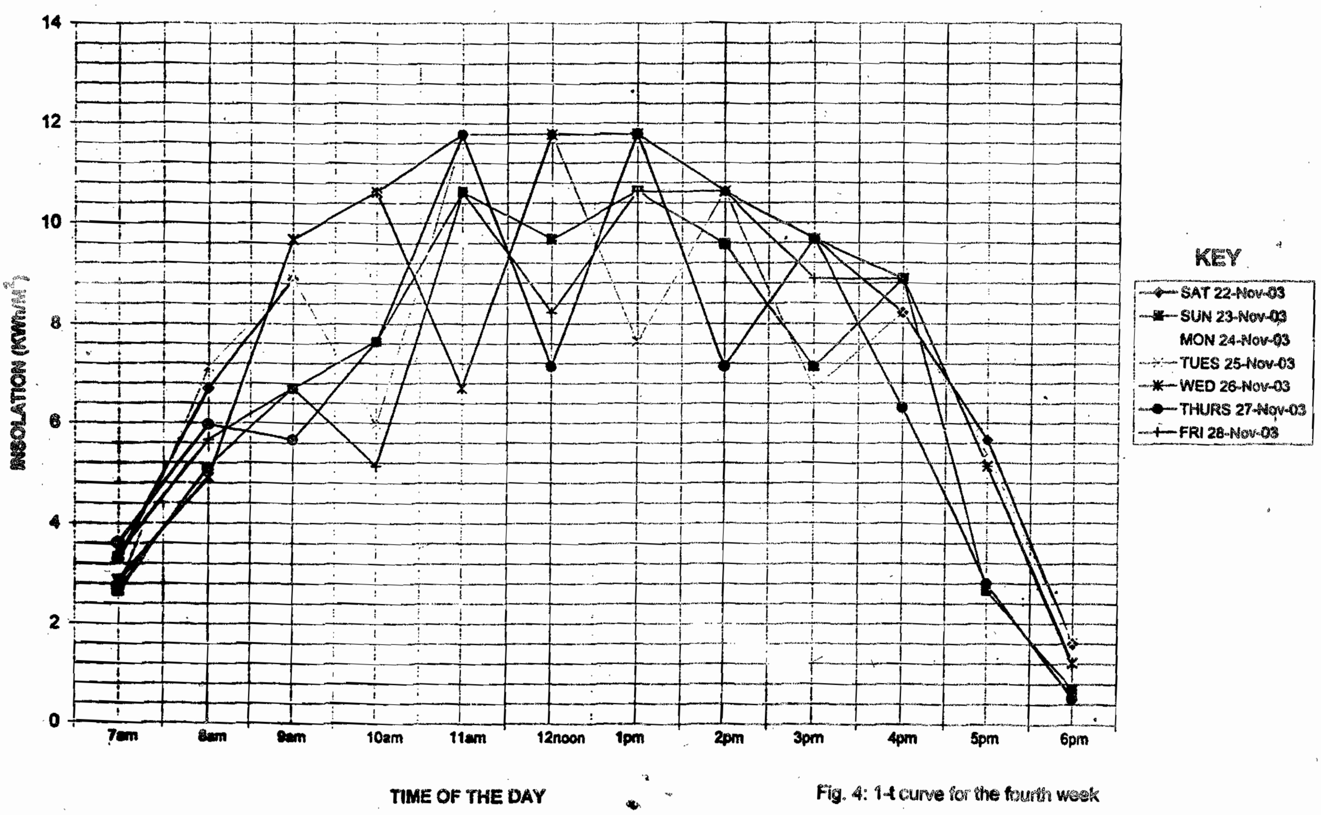

Fig. 4: 1-t curve for the fourth week

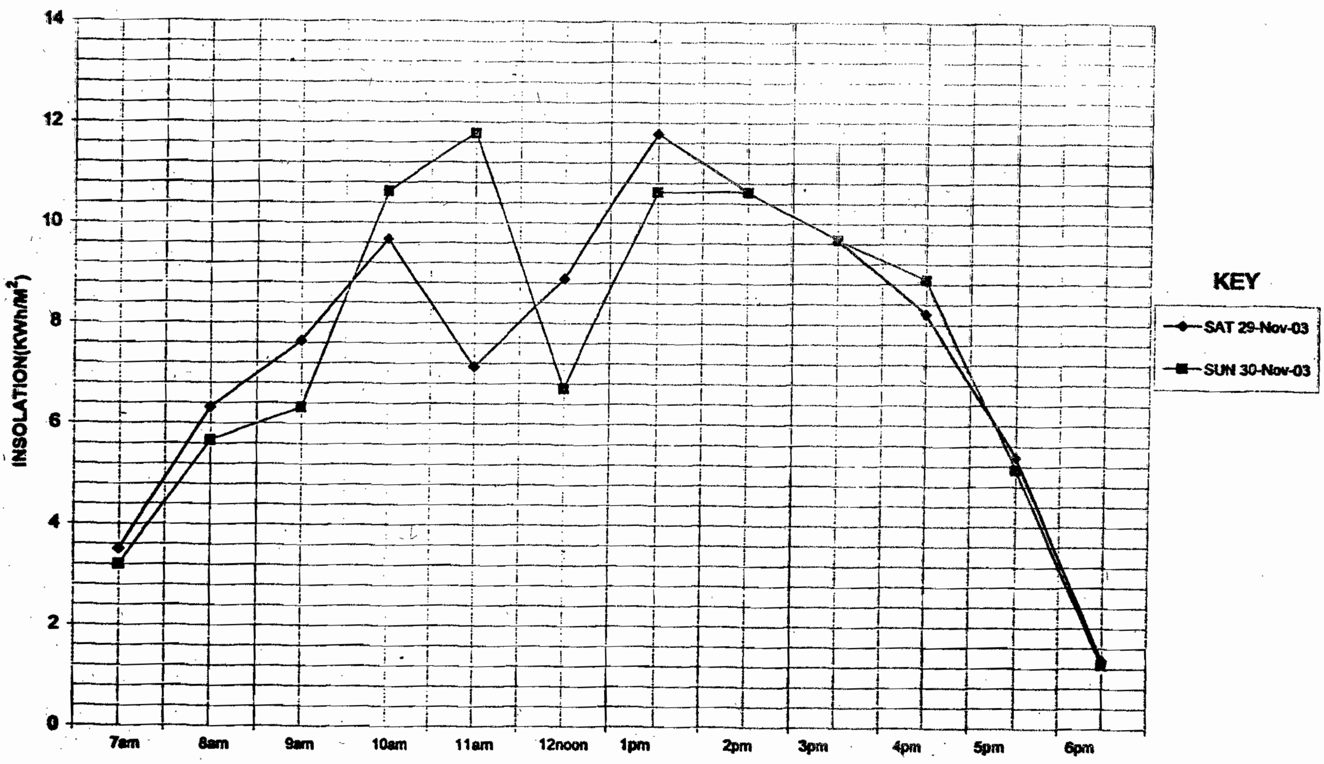

Fig. 5: I-t curve for the fifth week

With this figure of solar insolation, Umudike falls within the high insolation zones of the globe. This is true judging from the basic scale for global insolation level as reported by NASA (2002). From this scale areas with insolation figure of 5KWhm^{-2} and above, belong to the high insolation and thus high radiation zone.

Therefore the Umudike Community has enough solar radiation to support not only agriculture but also high level solar projects.

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