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RESEARCH ARTICLE

ANALYSIS OF SOLAR RADIATION IN UGANDA (A CASE STUDY OF KASESE, JINJA AND SOROTI DISTRICTS)

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ABSTRACT

Solar energy is an alternative to fossil fuels for more sustainable and reliable energy options; with a huge potential to meet many times the present world energy demand. Readily available solar radiation data is a key to design and simulation of all solar energy applications. In this project, only sunshine hour data is considered which were obtained from the meteorological Department, Entebbe. The sunshine hour's data got were measurements from 2007 to 2012, from three stations of Jinja, Soroti and Kasese. These stations are well spread throughout the country and hence the data gives a fair over view of the level of solar radiation in the country. It was observed that Soroti had high monthly averages compared to Jinja and Kasese with three minima occurring in April, July and November. This analysis revealed that more sunshine is received in the months of December to February and June to August in all the three stations. Low sunshine hours are encountered from November to December and lowest March to May. the distribution of mean sunshine interval from the three stations indicate that more sunshine occurred in Soroti with the average value of all the data recorded between 2007 and 2012 being 8.2 followed by Jinja with a value of 7.1 and finally Kasese with the lowest value of 6.1 hours. In general, a reduction in the percentage of the number of values in the lower interval range is observed across all the months implying that overcast days were either followed by a clear or partially clear days. Therefore Uganda encounters bright sunshine days most of the time in the year.

INTRODUCTION

The resource assessment is the basic step before considering the utilization of any energy source. Solar radiation is no exception. With increased interest in solar energy conversion, the need for quantitative data has assumed prime importance. Besides, because of variability behavior of solar energy both on diurnal and seasonal scale, the accurate estimation of the resources become essential for effective utilization. High-quality information on solar resources helps to implement renewable energy projects in two ways. First, by showing the overall potential for renewable energy in a country, good resource data can help renewable energy become part of the national energy development plan in areas where it makes good technical and economic sense. Secondly, reliable site-specific information is required for analyzing the merits of individual projects. This is unlike systems based on other sources of energy (Ramachandra *et al.,* 2005; Ramachandra *et al.,* 2006). Solar radiation is the primary natural energy source of the Earth. (Other natural sources are: geothermal heat flux from the earth interior, natural terrestrial radioactivity, cosmic radiation. These are negligible!) Solar radiation mainly emanates as electromagnetic radiation from the surface of the sun (photosphere). It is originated by several nuclear fusion processes in the interior of the sun. Solar radiation incident on a collecting device is of three types, namely beam, diffuse and reflected radiation. The radiation received from the sun without being scattered by the atmosphere is known as beam radiation. The radiation received from the sun after its direction has been changed is called diffuse radiation. And the radiation reflected from the surrounding surfaces on the collecting device is called reflected radiation. The resource analysis or assessment refers to quantitative estimation of these three types of radiations (Duffie and Beckman, 2013; Falayi et al., 2011; Garg, 2000; Khan, 2006). Sunshine duration is the length of time that the ground surface is irradiated by direct solar radiation (sunlight reaching the earth's surface directly from the sun). In 2003, The World Meteorological Organization defined sunshine duration as the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter. This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions. It was determined by comparing the sunshine duration recorded using

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a Campbell-Stokes sunshine recorder with the actual direct solar irradiance (Falayi *et al.,* 2011; Garg, 2000).

Uganda lies along the equator, covering a total area of 241,038 square kilometers, hence the smallest of the East African countries (Akullo *et al.,* 2014). Uganda climatic features exhibit two main seasons, the wet and dry season. Irrespective of the seasons above, Uganda receives sunshine almost throughout the year hence she is likely to be having the potentials of producing solar energy and therefore may be capable of solving the two major problems the world faces (Beltrando, 1990; Camberlin and Philippon, 2002). One of the problems the world faces is the continued depletion of fossil fuel reserves. It has been estimated that, these reserves will meet our energy needs for only two hundred years under the most optimal scenario (Rogner, 1997). The second problem is the drastic increase in the environment global pollution which likely to leave the lives of many creatures in a mess. Amidst these problems solar would be the only suitable source of energy to uphold. Solar energy is abundant as it will be there as long as the sun exists and does not cause pollution compared to other sources of energy (Balzani *et al.,* 2008). Since Uganda is no exception, she should join the rest of the world in analyzing solar radiation and developing new technologies basing on solar energy as an alternative way of solving problems and related hazards like pollution, poverty, diseases etc.

Uganda's potential in producing solar power for large scale use and the amount of other sources of energy which can be saved due to the utilization of solar energy is not yet established. Therefore there is need for further investigation in order to analyze solar radiation in Uganda since people have limited knowledge of how much solar radiation is received in Uganda. This information could be useful to the government policy makers, business community, National Environment Management Authority, power generating and distribution companies, the rural communities etc. so that environment is conserved and profits are maximized. This study intends to analyze the country's potential in producing solar power for large scale use and compare the distribution of daily sunshine received at various stations in Uganda

MATERIALS AND METHODS

Area of study

The area of study are the three Districts of in Uganda that is Kasese, Soroti and Jinja representing Western, Eastern and Central parts of Uganda. Kasese District is located in the Western Uganda along the Equator and at the foot of Mt. Ruwenzori. It is bordered by the Democratic Republic of the Congo to the west. The coordinates of Kasese District are: 00 11N, 30 05E. Jinja District is located at the confluence of Lake Victoria and the source of River Nile. Its 80 km by road, east of Kampala, the coordinates of the Jinja District are: 00 30N, 33 12E. And Soroti District is located in the northern part of the Eastern Region of Uganda with coordinates of: 01 41N, 33 37E.

Equipment and Data Collection

The duration in hours of bright sunshine during the course of the day was recorded using Campbell stroke sunshine recorder. It essentially consists of glass sphere mounted in a section of spherical glass bowl with grooves for holding the record cards. The sphere burns a trace on the card when exposed to the sun, the length of the trace on the card is a direct measure of the duration of the bright sunshine (Duffie and Beckman, 2013). Three sets of cards were used; long curved for summer, short curved for winter and straight cards at equinoxes. The sphere acts as a lens and the focused image of the sun moves along a specially prepared paper bearing a time scale. With the sun radiation intensity of more than $200W/m^2$, a burning impression is recorded on the paper. The cards were inserted in the morning at 9: 00 am and removed the following day at the same time. The burnt cards were stored in a box and the results were recorded and kept in paper files which were then entered manually into a computer.

Statistical Analysis of Data

The total number of sunshine hours received and total number of data recorded for this period (2007 to 2012) in the three stations were; Kasese 13410.7 and 2190, Soroti 12221.4 and 1482, and Jinja 11390.4 and 1612 respectively. The data also contained many missing values for some days, and years. The reason for the missing data was due to lack of sunshine cards in those periods and stations. This is shown in Table 1. Descriptive statistics that reported the monthly average daily sunshine hours, mean sunshine intervals and statistical monthly distribution of daily sunshine were determined using Microsoft excel 2007. Data are then presented in tables and graphs.

RESULTS AND DISCUSSION

Monthly mean distribution of daily sunshine hours

In this case the monthly mean sunshine hours was got by taking the mean of all the sunshine hours recorded in a given month from 2007 – 2012 for the three stations. The results are shown in Figure 1. It was observed that Soroti has high monthly averages compared to Jinja and Kasese with three minima occurring in April, July and November. July has a pronounced with monthly average of about 6.8 hours of sunshine compared to other months, which have average of about eight hours. The stations have low sunshine interval between April to August and in November. December to February, May and September show relatively high sunshine hours.

Mean sunshine received at the three stations

The mean sunshine for all the stations were obtained by summing all the data recorded from a given station and divided by the number of observations. The results are shown in Figure 2. It was observed that the distribution of mean sunshine interval from the three stations indicate that more sunshine occurred in Soroti with the average value of all the data recorded between 2007 and 2012 being 8.2 followed by Jinja

with a value of 7.1 and finally Kasese with the lowest value of 6.1 hours.

Statistical distribution of daily sunshine hours received at the three stations

It is no doubt that more sunshine hours results in more insolation and less sunshine hours results in less insolation. Therefore the value of sunshine hours can be used as an input to predict the performance of concentrating solar energy system. The aim of this section is to show the monthly distribution of sunshine received in the three stations. This distribution is very important in predicting the performance of solar system in various months of the year. Also, the data was analyzed using the distribution of two and three moving averages of daily sunshine hours. The distributions of these moving averages of daily sunshine hours are very important in predicting the number of days with low radiation. The number of days in a row without sunshine were noted since this can be of great importance when designing a storage system and planning for a backup energy resource. The total number of days in the different months range from 62 in August to 155 in January and May.

Generally more sunshine is received at Soroti with most months having more than 50% of the days with more than eight hours of sunshine. Relatively low sunshine occurs in July compared to other months. The distribution of two and three moving averages shown in the Table 2B and 2C indicate more than 50% of these averages being greater than eight hours except July which has 34.2 % and 31.0% respectively in this range. Interesting features are observed in the distribution of low average values. January to March and May have no values in the range of less or equal to two hours seen from the distribution of two days moving averages. July has about 2% of the averages less or equal to two hours compared to 7% that occurred in the distribution of daily values. The distribution of three days moving averages indicate December to March and May with no values less or equal to three hours.

In general, a reduction in the percentage of the number of values in the lower interval range is observed across all the months implying that overcast days were either followed by a clear or partially clear days. The Kasese station had the best record of data compared to other stations. The total number of days in different months range from 169 in February to 186 for the months with three days (i.e. January, March, May, July, August, October, December) See Table 1.

Table 1. Showing the years and months without data from 2007-2012 for the three stations

Year	Stations		
	Soroti	Kasese	Jinja
2007	8		1,2,3,4,5,6,7,8,9
2008			1,2,3
2009			11
2010	2,3,8,10,11,12		4,5,8,9,12
2011	1,2,3,4,5,6,7,8,9,11		1
2012	6,7,8,9,10,11,12		11,12

Table 2. Showing the percentage distribution of daily, two, and three days moving averages of hours of sunshine experienced in different months at Soroti from 2007 to 2012

A. Distribution of daily sunshine hours received in different months from 2007 to 2012 for Soroti												
Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
>1	89.7	100.0	100.0	98.0	96.1	96.7	93.5	968.0	96.0	100.0	94.4	98.4
>2	88.4	99.1	99.3	96.0	94.8	94.2	90.3	91.9	94.4	97.6	90.0	97.6
>3	87.7	97.4	98.6	92.0	93.5	90.0	83.9	90.3	94.4	94.3	85.6	94.4
>4	85.8	96.5	95.0	90.7	91.0	833.0	80.6	90.3	90.3	91.9	83.3	94.4
>5	83.2	95.6	92.9	85.3	87.7	77.5	74.2	88.7	87.1	87.0	80.0	91.1
>6	78.1	89.5	85.8	78.0	83.2	70.0	61.3	87.1	84.7	78.9	76.7	83.9
>7	72.3	87.7	75.9	66.7	78.1	67.5	50.8	77.4	77.7	68.3	60.3	79.8
>8	67.7	82.5	63.8	54.0	70.3	60.8	34.7	67.7	70.2	60.2	56.7	73.4
>9	57.4	62.3	48.0	40.0	59.4	43.3	26.6	51.6	54.0	47.2	44.4	58.9
>10	43.2	45.6	30.5	20.7	43.2	30.3	13.7	33.9	36.3	27.6	26.7	41.1
>11	24.5	20.2	7.0	8.0	25.2	14.2	5.6	22.6	10.5	10.6	16.7	16.9
>12	0.0	0.0	0.7	1.3	0.6	0.8	0.0	1.6	0.8	0.0	1.1	0.0
Total Data	155.0	114.0	141.0	150.0	155.0	120.0	124.0	62.0	124.0	123.0	90.0	124.0
B. Distribution of two days moving averages daily sunshine hours for Soroti												
>1	100.0	100.0	100.0	99.3	100.0	99.1	99.2	98.3	100.0	100.0	97.7	100.0
>2	100.0	100.0	100.0	97.9	100.0	96.6	96.7	98.3	99.1	100.0	96.6	99.2
>3	99.2	99.1	99.3	97.2	98.0	94.8	90.0	98.3	98.3	98.3	95.4	99.2
>4	97.7	96.4	99.3	94.5	96.7	90.5	82.5	96.7	97.4	97.5	94.3	98.3
>5	92.5	95.4	97.1	90.3	90.7	83.6	71.7	91.7	94.0	90.8	87.4	95.0
>6	88.7	92.7	91.2	80.7	86.7	73.3	61.7	86.7	91.4	82.4	77.0	90.8
>7	81.2	87.2	75.7	71.7	79.7	62.9	50.0	80.0	82.8	71.4	60.9	83.0
>8	72.9	80.9	61.0	52.4	68.0	56.0	34.2	68.3	73.3	57.1	47.1	68.3
>9	62.4	69.1	45.6	31.7	54.7	43.1	20.8	46.7	56.0	42.9	34.5	55.8
>10	39.8	40.9	21.3	13.8	40.0	24.1	10.8	28.3	30.2	20.2	16.1	34.2
>11	18.0	8.2	0.0	4.1	13.3	9.5	1.7	13.3	6.9	4.2	8.0	5.8
>12	0.0	0.0	0.0	0.7	0.0	0.9	0.0	1.7	0.0	0.0	0.0	0.0
Total Data	133.0	110.0	136.0	145.0	150.0	116.0	120.0	60.0	116.0	119.0	87.0	120.0

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C. Distribution of three days moving averages daily sunshine hours for Soroti												
>1	100.0	100.0	100.0	99.3	100.0	100.0	100.0	100.0	100.0	100.0	98.8	100.0
>2	100.0	100.0	100.0	98.6	100.0	99.1	99.1	100.0	100.0	100.0	97.6	100.0
>3	100.0	100.0	100.0	97.9	100.0	94.6	92.2	98.3	98.2	99.1	97.6	100.0
>4	99.2	98.1	100.0	97.1	98.6	91.1	87.1	96.6	98.2	99.1	92.9	99.1
>5	95.3	97.2	98.5	91.4	93.8	83.0	75.0	93.1	95.5	94.8	89.3	97.4
>6	89.7	94.2	92.4	83.6	91.7	74.1	60.3	89.7	92.9	85.2	82.1	94.8
>7	83.5	88.7	79.4	67.9	79.3	67.0	49.1	79.3	84.8	73.0	65.5	88.8
>8	76.4	79.2	59.5	54.3	68.3	50.0	31.0	69.0	73.2	59.1	46.4	72.4
>9	65.6	67.9	40.5	26.4	51.7	42.0	18.1	46.6	55.4	38.3	31.0	51.7
>10	37.8	41.2	16.0	10.7	32.4	23.2	6.9	24.1	22.3	14.8	14.3	30.2
>11	0.0	4.7	3.7	2.9	11.7	5.4	0.0	12.1	5.4	1.7	3.6	0.9
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total data	127.0	106.0	131.0	140.0	145.0	112.0	116.0	58.0	112.0	115.0	84.0	116.0

Table 3. Showing the percentage distribution of daily, two, and three days running averages of hours of sunshine experienced in different months at Kasese from 2007 to 2012

2A. Distribution of daily sunshine hours received in different months from 2007 to 2012 for Kasese												
Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
>1	94.6	94.7	91.4	93.3	93.0	93.9	92.5	91.4	97.2	93.5	91.1	96.2
>2	91.9	92.9	86.0	91.7	85.0	86.7	86.0	87.6	95	90.9	84.4	91.9
>3	85.5	90.5	78.5	83.3	79.0	83.3	78.5	80.1	86.1	83.3	75.4	84.9
>4	81.2	83.4	68.3	76.7	71.0	78.9	68.3	68.8	79.1	71.5	65.4	77.1
>5	71.5	78.7	60.6	66.1	62.9	67.8	59.7	58.6	67.2	60.2	57.0	65.6
>6	64.0	69.2	50.0	52.8	53.8	58.9	51.1	47.8	57.2	48.4	49.7	55.4
>7	52.2	53.3	37.1	41.1	46.8	45.0	39.2	32.8	46.1	36.0	36.9	45.7
>8	40.3	42.6	29.6	27.8	36.6	33.4	24.7	24.2	30.6	23.7	26.3	34.9
>9	24.7	30.2	16.1	16.1	24.4	21.3	15.1	15.6	14.4	9.7	12.3	22.6
>10	16.7	8.9	2.7	6.7	12.4	9.4	2.7	6.5	7.8	2.2	5.0	9.7
>11	1.1	0.0	0.0	0.6	2.7	1.1	0.0	0.5	0.6	0.5	1.1	1.1
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Data	186.0	169.0	186.0	180.0	186.0	180.0	186.0	186.0	180.0	186.0	179.0	186.0
2B. Distribution of two days moving averages daily sunshine hours for Kasese												
>1	98.3	98.8	97.8	99.4	97.8	96.0	97.2	96.7	99.4	100.0	98.3	99.4
>2	96.7	97.5	93.3	97.4	93.3	94.8	93.3	93.3	98.9	96.1	93.6	98.3
>3	93.3	94.5	85.6	88.5	86.1	87.4	83.3	86.7	94.3	94.4	84.4	93.9
>4	86.7	89.0	74.4	78.7	75.0	78.7	71.1	77.8	85.6	82.8	72.8	82.8
>5	76.1	84.7	59.4	70.1	66.1	69.0	57.2	57.2	72.4	60.6	58.4	70.6
>6	61.7	71.2	46.7	54.0	53.9	59.8	46.7	43.9	59.8	43.9	41.6	55.6
>7	46.1	54.0	32.2	36.8	40.0	43.1	33.9	31.7	36.8	28.9	30.1	40.0
>8	31.7	35.6	18.3	18.4	29.4	28.2	18.3	21.1	19.4	12.8	18.5	27.2
>9	19.4	22.1	6.7	9.2	16.7	14.9	8.3	10.0	9.2	5.0	7.5	15.6
>10	11.1	3.7	0.5	1.7	6.7	5.2	0.5	3.9	2.9	0.6	1.7	3.9
>11	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Data	180.0	163.0	180.0	174.0	180.0	174.0	180.0	180.0	174.0	180.0	173.0	180.0
2C. Distribution of three days moving averages daily sunshine hours for Kasese												
>1	100.0	99.4	99.3	100.0	98.9	98.2	98.9	98.3	99.4	100.0	100.0	100.0
>2	99.4	98.1	95.9	99.4	96.0	95.8	93.7	96.0	99.4	99.4	98.2	99.4
>3	94.8	96.2	91.0	94.0	90.2	88.7	86.8	88.0	97.0	96.0	89.8	96.6
>4	89.1	92.3	80.0	84.5	79.3	81.5	73.6	77.0	91.7	87.9	76.0	90.2
>5	78.7	86.6	64.8	71.4	69.0	68.4	61.5	60.9	80.4	67.2	54.5	75.9
>6	61.5	72.6	50.3	51.2	51.7	55.4	44.3	44.3	57.1	42.5	42.5	54.0
>7	43.7	51.6	30.4	32.7	39.1	42.3	32.2	29.3	34.5	24.1	26.3	40.2
>8	27.0	36.3	9.0	15.4	27.0	28.6	15.5	19.0	13.5	11.5	13.2	24.7
>9	16.1	17.2	5.5	6.0	13.8	12.5	5.2	58.6	3.6	2.3	6.6	8.6
>10	6.3	1.9	0.7	0.6	6.9	2.4	0.6	1.1	0.0	0.0	0.0	1.1
>11	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total data	174.0	157.0	145.0	168.0	174.0	168.0	174.0	174.0	168.0	174.0	167.0	174.0

Table 4. Showing the percentage distribution of daily, two and three days running averages of hours of sunshine experienced in different months at Jinja from 2007 to 2012

3A. Distribution of daily sunshine hours received in different months from 2007 to 2012 for Jinja												
Interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
>1	97.6	100.0	99.2	96.6	95.2	97.3	94.2	94.4	98.3	96.8	96.7	99.2
>2	92.7	97.2	96.8	92.4	93.5	94.7	90.3	93.5	96.7	91.4	95.8	96.0
>3	88.7	95.1	93.5	84.9	88.7	90.7	88.4	91.9	95.0	84.9	85.0	93.0
>4	84.7	92.3	83.9	79.8	82.3	82.7	81.9	83.9	89.2	78.0	77.5	91.9

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>5	81.5	84.5	77.4	73.1	71.8	76.0	71.0	71.0	82.5	68.8	69.2	83.9
>6	76.6	81.0	65.3	63.9	63.7	65.3	56.1	59.7	75.0	53.8	58.3	71.0
>7	67.7	75.4	55.6	55.5	47.6	52.0	46.5	41.7	60.0	38.2	45.8	60.5
>8	58.1	68.3	45.2	42.9	35.5	36.0	34.2	29.0	45.0	30.1	32.5	46.8
>9	46.8	57.0	35.5	25.2	39.8	24.0	19.4	23.4	29.2	21.5	22.5	34.7
>10	32.3	35.9	18.5	11.8	15.3	10.7	7.7	6.5	11.7	10.6	10.0	21.0
>11	13.7	8.5	2.4	0.8	3.2	1.3	0.6	1.6	0.8	1.6	4.2	5.6
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Data	124.0	142.0	124.0	119.0	124.0	150.0	156.0	124.0	120.0	186.0	120.0	124.0
3B. Distribution of two days moving averages daily sunshine hours for Jinja												
>1	99.2	100.0	99.2	100.0	98.3	98.6	99.3	100.0	100.0	100.0	99.1	100.0
>2	95.8	100.0	98.3	97.4	97.5	98.6	98.0	100.0	99.1	98.9	97.4	99.2
>3	94.2	97.8	95.8	94.8	91.7	96.6	90.7	93.3	99.1	96.1	93.1	98.3
>4	88.3	96.4	86.7	85.3	88.3	88.3	86.0	87.5	95.7	85.0	83.6	95.8
>5	83.3	91.2	80.8	75.9	80.0	76.6	74.7	75.0	94.0	68.9	70.6	91.7
>6	79.2	83.9	65.8	65.5	62.5	64.8	60.7	55.8	81.0	533.0	54.3	81.7
>7	69.2	75.9	54.2	51.7	49.2	49.7	41.3	38.3	64.7	37.8	44.8	62.5
>8	55.8	65.7	46.7	35.3	31.7	34.5	26.7	25.8	38.8	21.1	30.2	39.2
>9	39.2	54.0	30.8	22.4	20.0	17.9	10.0	14.2	15.5	12.2	13.8	28.3
>10	25.8	30.7	10.8	6.9	8.3	6.2	1.3	5.8	1.7	3.3	3.4	11.7
>11	10.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.7
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Data	120.0	137.0	120.0	116.0	120.0	145.0	150.0	120.0	116.0	180.0	116.0	120.0
3C. Distribution of three days moving averages daily sunshine hours for Jinja												
>1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
>2	99.1	100.0	99.1	100.0	96.9	100.0	98.6	99.1	100.0	100.0	100.0	100.0
>3	95.7	100.0	96.6	96.4	92.2	97.1	94.5	95.7	100.0	97.7	94.6	100.0
>4	92.2	96.2	91.4	91.1	90.5	94.3	88.3	89.7	99.1	93.1	89.3	100.0
>5	88.8	93.2	81.9	79.5	81.9	80.0	73.8	80.2	93.8	76.4	75.9	93.1
>6	79.3	87.1	68.1	67.9	67.2	62.1	58.6	60.3	88.4	56.3	57.1	82.7
>7	68.1	78.8	60.3	55.4	47.4	49.3	42.8	32.8	72.3	31.0	39.3	64.7
>8	51.7	16.7	41.4	34.8	27.6	34.3	23.4	21.6	33.0	17.2	21.4	38.8
>9	33.6	47.7	24.1	17.0	16.4	15.0	6.2	12.1	8.0	6.3	12.5	19.8
>10	21.6	26.5	6.9	4.5	5.2	1.4	1.4	5.2	0.0	2.3	2.7	6.0
>11	6.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Data	116.0	132.0	116.0	112.0	116.0	140.0	145.0	116.0	112.0	174.0	112.0	116.0

Monthly averages daily sunshine hours received at the three stations in Uganda

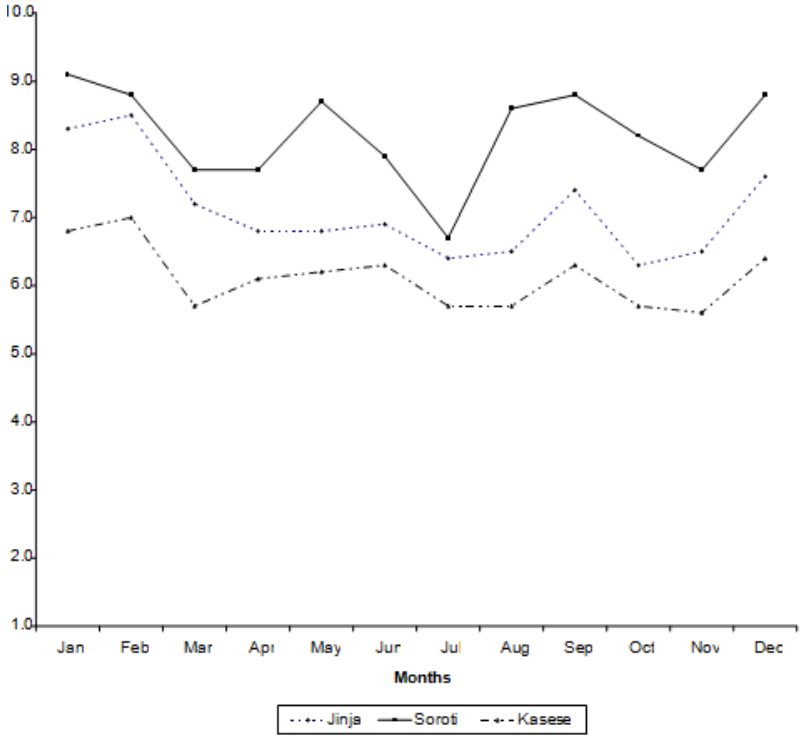

Figure 1. Monthly averages daily sunshine hours received at the three stations in Uganda

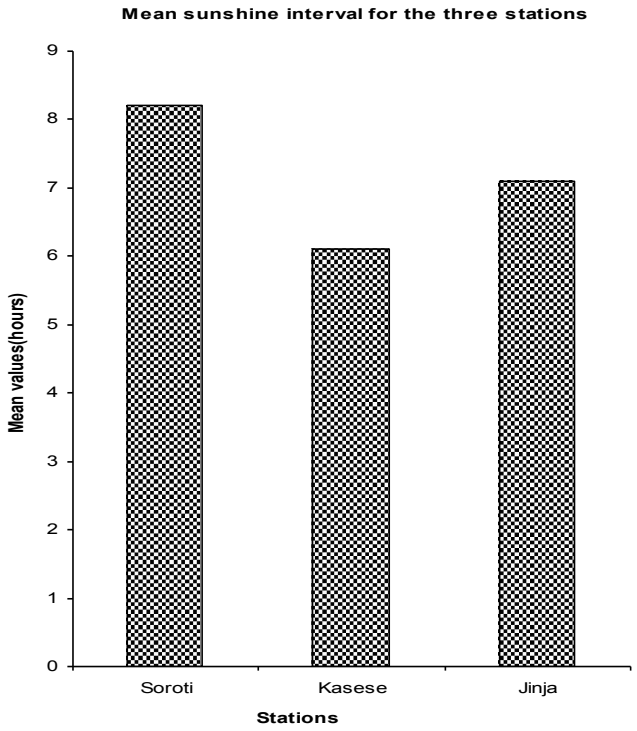

Figure 2. Mean Sunshine Intervals for Soroti, Kasese and Jinja

Relatively low sunshine is observed in Kasese compared to Soroti. The distribution of two and three days moving averages indicate little reduction in the number of lower intervals. This indicates the existence of more than three days in a row with sunshine duration as observed in Table 3.

For the Jinja station the total months' data considered ranges from 119 in April to 186 in October. December to April received high radiation with more than 50% of the days getting above seven hours as illustrated by Table 4. Low radiation is observed between May to November with a marked minimum in August. About 14% of the days in august have values less than 2 hours of sunshine.

Conclusion

In conclusion, therefore, this analysis revealed that more sunshine is received in the months of December to February and June to August in all the three stations. Low sunshine hours are encountered from November to December and lowest March to May. Therefore Uganda encounters bright sunshine days most of the time in the year. Hence Uganda has a potential for using solar energy as an alternative energy source.

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