ASSESSING THE POTENTIAL OF SOLAR ENERGY UTILIZATION IN CENTRAL TANZANIA

By

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Project submitted in partial fulfillment for the award of Postgraduate Diploma in Meteorology in the Department of Meteorology, University of Nairobi.

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Declaration

This project is my original work and has not been presented for a degree in any other University.

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This proposal has been submitted with our approval as University Supervisor

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I also wish to extend and express my sincere thanks my supervisor Dr. C.Oludhe for their counsel and advice in the development and preparation of this project and other colleagues for their ideas in fruitful this work.

I express my sincere thanks to my family, especial to my husband L.Ndumbaro, my daughter Jessica L. and my son Jonathan L. for being their patience during the entire period of my absence, keeping me harmonious and for their kind cooperation and constant encouragement which has helped me in the completion of this study. I will be grateful forever for their love.

I also wish to acknowledge with thanks the Tanzania Meteorological Agency (TMA) for providing me with this golden opportunity to do this wonderful course of Meteorology; I really appreciate for the financial support and the data they provided me with.

ABSTRACT

Solar energy is the energy direct from the sun. Central Tanzania is a very vulnerable area in the face of climate change, already seeing great droughts leading to recurrent hydro-power crisis and agricultural problems. So through different technologies solar energy can therefore be harnessed for thermal use and for electrical generation purposes. This technology can be harnessed through Active_solar techniques_using photovoltaic panels, pumps, and fans to convert sunlight into useful energy as well as Passive solar techniques which_include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the sun.

Solar radiation data, sunshine hour's data and cloud amount data for both Dodoma and Tabora was obtained from Tanzania Meteorological Agency (TMA) and was from 2002 to 2012.

The methodology used in this study included the calculation of missing data by arithmetical mean method, homogeneity by single mass curve and trend by time series.

The study indicated that solar energy viability is more efficiency from May to Nov, at this period cloud amount are few, solar radiation is low and sunshine hours are high. During this period sunshine rays are in high amount and almost found throughout .Residence can turn up on using this energy since is highly reliable and requires little maintenance.

Table of contents

LIST OF ABBREVIATIONS

NREL = National Renewable Energy Labour.

MW = Mega watts.

j.s = Joules second.

ev.s = electron volts seconds.

CO_2 = Carbon dioxide.

WHO = World Health Organization.

WMO = World Meteorological Organization.

GMT = Greenwich Mean Time

LIST OF FIGURES

CHAPTER ONE

1.0 Introduction

1.1 Renewable Energy

Renewable energy sources derive their energy from existing flows of energy, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. A renewable resource is natural resources which can replenish with the passage of time, either through biological reproduction or other naturally recurring processes. Renewable resources are a part of Earth's natural environment and the largest components of its ecosphere. A positive life cycle assessment is a key indicator of a resource's sustainability. Renewable resources may be the source of power for renewable energy. However, if the rate at which the renewable resource is consumed exceeds its renewal rate, renewal and sustainability will not be ensured.

The term renewable resource also describes systems like sustainable agriculture and water resources. Sustainable harvesting of renewable resources (i.e., maintaining a positive renewal rate) can reduce air pollution, soil contamination, habitat destruction and land degradation. One major advantage with the use of renewable energy is that as it is renewable it is therefore sustainable and so will never run out. Renewable energy facilities generally require less maintenance than traditional generators. Their fuel being derived from natural and available resources reduces the costs of operation. Even more importantly, renewable energy produces little or no waste products such as carbon dioxide or other chemical pollutants, so has minimal impact on the environment.

Renewable energy projects can also bring economic benefits to many regional areas, as most projects are located away from large urban centers and suburbs of the capital cities. These economic benefits may be from the increased use of local services as well as tourism.

Renewable featured in both Agenda 21 and the Climate Change Convention (United Nations, 1992). Because of the important role of fossil fuels in the build-up of greenhouse gases in the atmosphere (it is estimated that the energy sector accounts for about half the global emissions of green-house gases) and concomitant climate change concerns, renewable are perceived to constitute an important option for mitigating and abating the emissions of greenhouse gases (Karekezi,1992).

1.2 Solar Energy

The sun is 93 million miles away and yet, this ball of hot gases is the primary source of all energy on earth. In the inner core of the sun, small atoms of hydrogen are fused, that is, the centers of the two atoms are combined. Fusion releases far greater energy than splitting the atom (fission, see below). Without sunlight, fossil fuels could never have existed. The sun is the supplier of energy which runs the water cycle. The uneven heating of the earth produces wind energy. Solar energy can be used to cook food, heat water and generate electricity. It remains the cleanest energy source and it is renewable. It is the hope for the energy source of the future and scientists at NREL are actively working on ways for solar energy to supply more our energy needs!(Renewable energy activities journal)

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately $1.8*10^{11}$MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy source.(Sukhatme,1996)

Solar energy can therefore be harnessed for thermal use and for electrical generation purposes. This technology is Active_solar techniques_use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. And Passive solar techniques_include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the sun.

1.3 Solar energy in Central Tanzania

Tanzania is located near the equator this means that it receives an average 325 days of radiant energy thus endowed with abundant sun. The main sources of electricity in Tanzania are hydro power, gas and Diesel. These contributed to the recent large price increases of electricity. Increased deforestation has lead to the reduced availability of water in catchment areas. As a result a few dams have been closed. This has lead to the surge interest in the use of solar energy.

Access to regular electricity in Tanzania has increased from in currently. However many rural communities may never get access to it as it is very expensive and requires heavy government subsidies. Currently only few Tanzanians in rural areas are served by the national grid and many may never get access to it as this is very expensive and requires heavy government subsidies. The government of Tanzania is planning on expansion of the energy system in order to supply all parts of the country with electricity and to support rural development. As the country increases its electric power capacity, there are many decisions to make regarding the different options of power generation. Presently the electric power sector in Tanzania is dominated by hydropower but to meet the growing demand, thermal power capacity is being increased. In such a situation, solar energy can be of great help. Sunlight can be converted into electricity by use of solid state photovoltaic cells. It is environmentally friendly, silent, needs no fuel, there are no emissions , there are no moving parts which often lead to wear and tear and there is little or no maintenance required.

1.4. Theory on photovoltaic (solar) cells: converting photons to electrons.

Michael (2007) state that photovoltaic is the direct conversion of light energy into electricity at the atomic level. Some materials exhibit a property known as photo-electric effect which enables them to absorb photons of light and release electrons. When these free e electrons are captured, electric current results and can be used as electricity. Photovoltaic cells are made of special materials known as semi-conductors such as silicon, which is currently the most commonly used. Basically when light strikes the cell, a certain portion of it is absorbed. Within the semi-conductor material, only 20% of the electromagnetic spectrum is absorbed (Smith and Rouse Robert, 1975). The spectrums energy has to be above the band gap i.e. from the energy equation**,** $\mathbf{hv \geq E_g}$ where;

$\mathbf{E_g}$ is the energy gap.

h is the Planck's constant given by $\mathbf{6.63 \times 10^{-34}}$ **j.s or** $\mathbf{4.14 \times 10^{-15}}$ **ev.s** and

v is the frequency of a quantum of light or photon wave.

This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose allowing them to flow freely. Photovoltaic cells also have one or more electric fields that act to force electrons freed by light absorption to flow in certain direction. This flow of electrons is current and by placing metal contacts on the top and bottom of the photovoltaic cell, we can draw that current off to use externally. This current together with the cells voltage (which is as a result of its build in electric field or fields) defines the power that the solar cell needs.

1.5 Statement of the problem

Tanzania is a very vulnerable country in the face of climate change, already seeing great droughts leading to recurrent hydro-power crisis and agricultural problems. Energy supply insecurity crisis arising from high oil prices, inability to provide adequate access to modern services for Tanzanian's poor and adverse local, regional and global environmental impacts of excessive reliance on conventional energy systems are some of the challenges that are been faced. Large scale hydropower is being relied on. On the other hand, the impact of high oil prices is being felt in all sectors of the economy although the poor are the worst affected .There is therefore a need to switch to another sustainable renewable energy source.

1.6 Hypotheses

If there is enough amount of solar radiation in a study area and people be aware with technology will reduce cost of electricity and improve their life.

1.7 Justification of the study

Due higher need of energy consumptions in Tanzania ,scarcity of precipitation which lead to low hydroelectric production, so to assess the energy viability by evaluating the amount of sunshine hour, cloud amount and solar radiation data. This will turn people to utilize it

1.8 Area of study

The study will be conducted over Central Tanzania. The Regions are Dodoma and Tabora which lies within the geographical coordinates - and - as shown in figure. It's surrounded by Kigoma region to the North West, Mwanza, Shinyanga and Singida to the North and Tanga and Morogoro to the North East, Iringa and Njombe to the South East, Mbeya and Rukwa to the South West. It has a land mass area of 945203 Km^2. As mentioned earlier. The research will limit itself to the analysis of solar insolation data from Dodoma and Tabora as recorded in the year 2002-2012. Data will be obtained from the Tanzania meteorological agency. Data will also be collected from Dodoma. Time and finances available limit the research

Figure 1.Map of Tanzania (www.maps,1997)

1.9 Objective of the study

The overall objective of this study is to assess the potential of solar energy utilization in central Tanzania. This will help the locals in weighing their options between the various energy sources with regard to their usage.

1.10. Specific Objective

The specific objectives are to;

(i).Determine the temporal viability of solar radiation, sunshine hours and cloud amount at the area of study

(ii).Determine the spatial distribution of solar radiation, sunshine hours and cloud amount at Dodoma and Tabora.

(iii). Assess the viability of solar energy at the Dodoma and Tabora.

CHAPTER TWO

2.0. Literature Review

The sun is the source of virtually all the energy that we use every day. The energy we derive from wood fuel, paraffin, hydroelectricity and even our food originates indirectly from the sun (HANKINS, 1991). Solar energy can also be collected from the sun directly for heating water, producing steam and generating electricity. However the use of sun directly in Africa has not been successful. Part of the problem is that rural people are unaware of the technologies and do not have the materials or information resources to attempt projects no matter how technically environmentally viable they may be.

The important development that has increased interest in renewable in the region is the recurrent crises faced by most power utilities in the region. For example, in year 2000 alone, Ethiopia Kenya, Malawi, Nigeria and Tanzania faced unprecedented power rationing which adverse0ly affected their economies. The rapid development of renewable is often mentioned as an important response option for addressing the power problems faced by the region.(Karekezi 1992)

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8*1011MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one of the most promising of the unconventional energy source. In addition to its size, solar energy has two other factors in its favour. Firstly, unlike fossil fuels and nuclear power, it is an environmental clean source of energy. Secondly, it is free and available in adequate quantities in almost all parts of the world where people live (Sukhatme,*et al*,1996).

According to Ndaba(2009) African countries are also facing tradeoffs between hydro-power and solar power. The massive hydro-power projects are stripping off an already dry region of water. A recent investigation in Kenya and Tanzania showed that the majority of their electricity supply is generated from hydro-power. This is highly vulnerable to drought which is occurring more frequent with climate change.

This position was supported by energy expert Mark Hankins, A Nairobi consultant for international rivers and Mozambique Justical Ambient, who acknowledges the attraction of hydro in a region dominated by coal, noting that South Africa is “one of the top CO_2 emitters in the world.” Hankins believes that cheap electricity is dirty electricity. He says that in Kenya, electricity cost 3 times what it does in South Africa. “Eskom is the fifth largest power company in the world and South Africa has been very successful in giving people access to electricity.” Green energies tend to be more expensive but they create jobs and do not damage the environment. Hankins notes that there is huge potential for cost effective efficiency measures in Africa that could greatly reduce the need for dams in Africa.

In Africa there are no efficient cheap subsidized and easy to find fossil fuels therefore solar energy would not face stiff competition. In the developing world, clean energy would cost less over the long term compared to energy generated by burning extremely inefficient expensive and difficult to find fuels. For rural people solar energy would cost less over the long term than what is spent now collecting or buying firewood, kerosene, candles and dry batteries. Villagers spend countless hours carrying firewood from their increasingly remote forest, notes Vikram Widge, an energy expert .in the long term solar energy is cheaper and healthier too. The World Health Organization, WHO estimates that 2.5 million people die prematurely each year in the developing world from inhaling biomass burnt indoors-deaths that could be averted in many cases through the use of cleaner energy sources.

Electricity has a profound impact on local demographics. One of the greatest problems in Africa is the mass migration of young men and women from their farming villages towards cities in such of excitement and employment. They find no jobs and are wretched in poverty. Research shows that this has also contributed o the spread of HIV/AIDS. Having electricity would not stop migration completely but it would make a difference. “If they just had a T.V or Radio here, they might stay and they would not be just old men and women.” argues **Budu** a chief of timber in Ghana. According to Nicholas *et a*l (2002), if Africa expands its energy consumption via fossil fuel based energy path, it will quickly become among the leading emitters of greenhouse gases frustrating any hope of preventing the predicted climatic upheaval(prolonged storm drought and calamities).

Lack of electricity has contributed to the lack of internet facilities in rural areas. Mobile phone service providers hesitate to build capacity in rural areas. “Under utilization of solar energy is depriving rural areas of an opportunity to access information through ICT. Social and economic development is inseparable from scientific and technological advances. Africa has lagged behind in technology and harvesting solar energy to use development programs,” **Geoffrey Munyeme** said, the Head of Physics Department at the University of Zambia (2007).

CHAPTER THREE

3.0 DATA AND METHODOLOGY

This sections elucidates the data and the methods used to address the objectives of the study

3.1 Data

Solar radiation data and the sun shine hours data from selected stations within Tanzania will be retrieved from the Tanzania Meteorological Agency. The data will span the period 2002 to 2012 and will be archive. The solar data are reported daily at the stations used in this study. The sunshine hours, cloud amount and solar radiation data are normally observations.

3.2. Methodology

Several methods will be undertaken to pursue the objectives of the study. They include the

3.2.1 Data quality control

The quality of meteorological data is critical in any type of research. The quality of data rests on the accuracy of measurements and completeness. Quality control will ensure that meteorological data acquired meets certain standards. It will involve estimating missing data, looking for errors in the acquired data and possibly removing mistakes from it, and testing for data in homogeneity or inconsistency.

3.2.2 Estimating missing data.

If the data to be used will have any missing gaps, then the gaps will be filled using the arithmetic mean method to ensure that data analysis is up to date.

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where;

$\bar{X}$ Is the long term mean

n Is the number of years**.**

3.2.3 Data homogeneity

Data in homogeneity can arise due to changes in observational schedules and methods, instrumental changes, changes of exposure conditions, shifting of station sites, and other human processes (WMO, 1996). The test that I will use to check for data consistency is the single mass curve. This is a plot of cumulative data for a given location against time. The data is accumulated backwards in time. The single mass curve detects data inconsistency and provides a corrective measure for these inconsistencies.

3.2.4 Time Series

Trend is the long term movement in a time series. Examination of the trend component in any time series analysis is significant since it will show whether the time series is stationary or non stationary. Trend can be linear or non linear, and the objective approach to examine this is through graphical and statistical approach (WMO,1996). The graph of the time series will indicate whether or not a linear relationship will provide good approximation to the long term movement, regression analysis may give the curve of the best fit. Graphical and statistical method will be applied to examine trend.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter contains discussion of the results obtained from the analysis.

4.1 Testing of Data Homogeneity

Before data was used for analysis, it was subjected to data quality control. Single mass curves were used for testing the homogeneity of data. The plots of cumulative was found to be the straight line as shown below in single mass curves for Dodoma and Tabora stations. The Result shows that data are homogeneity.

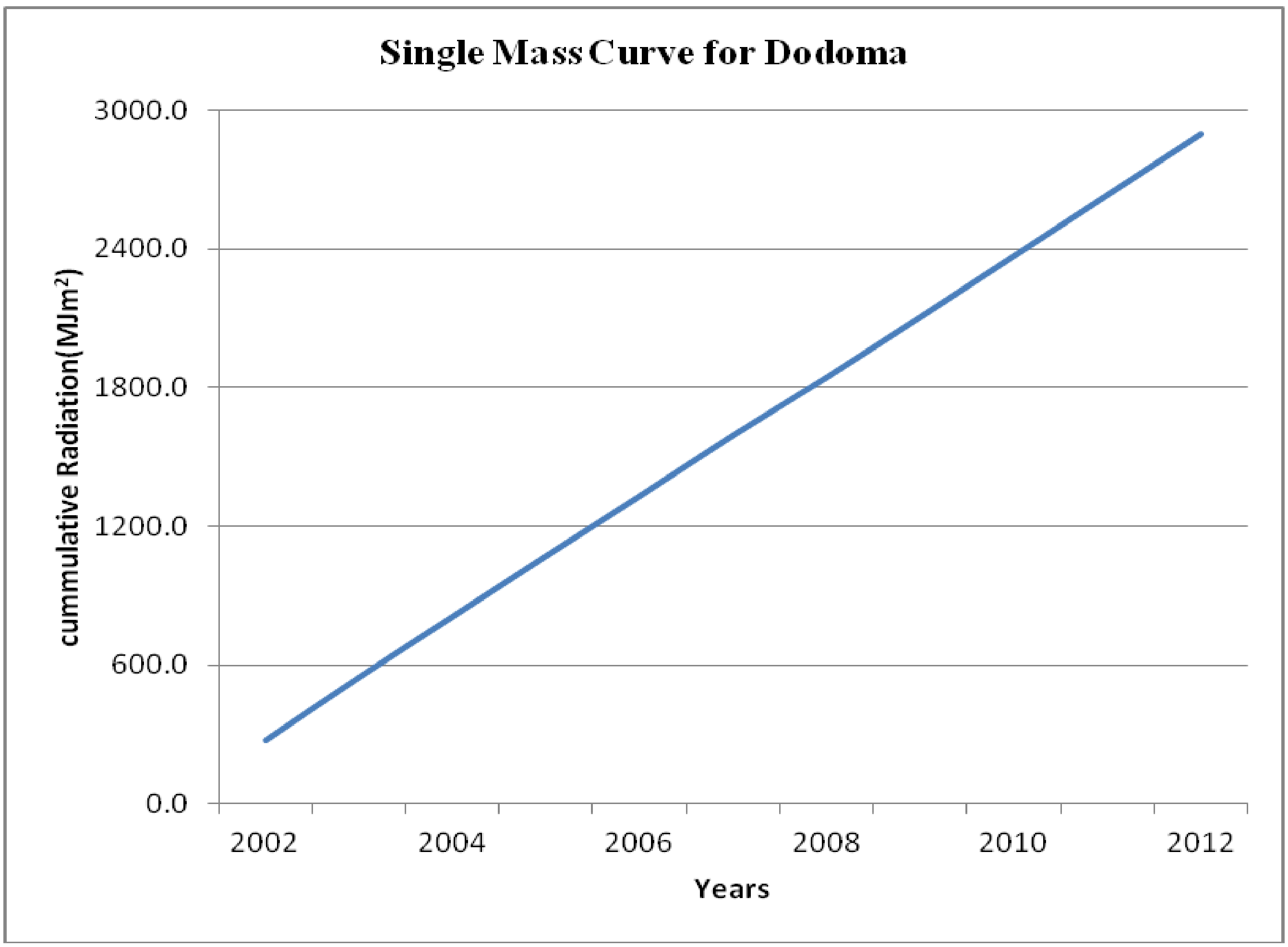

Figure 2(a). Single mass curve for Dodoma Radiation.

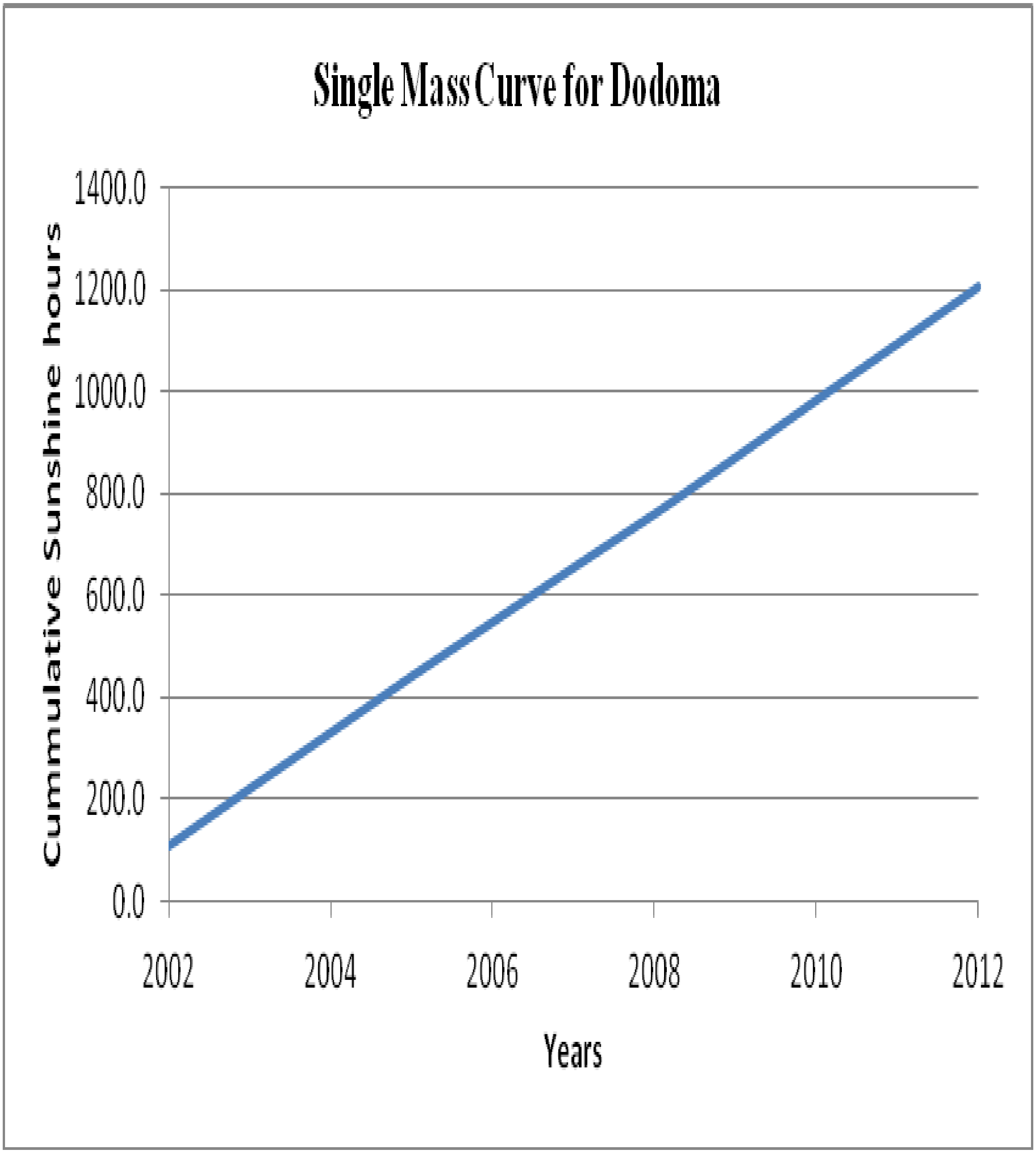

Figure 2(b). Single mass curve for Dodoma sunshine hours.

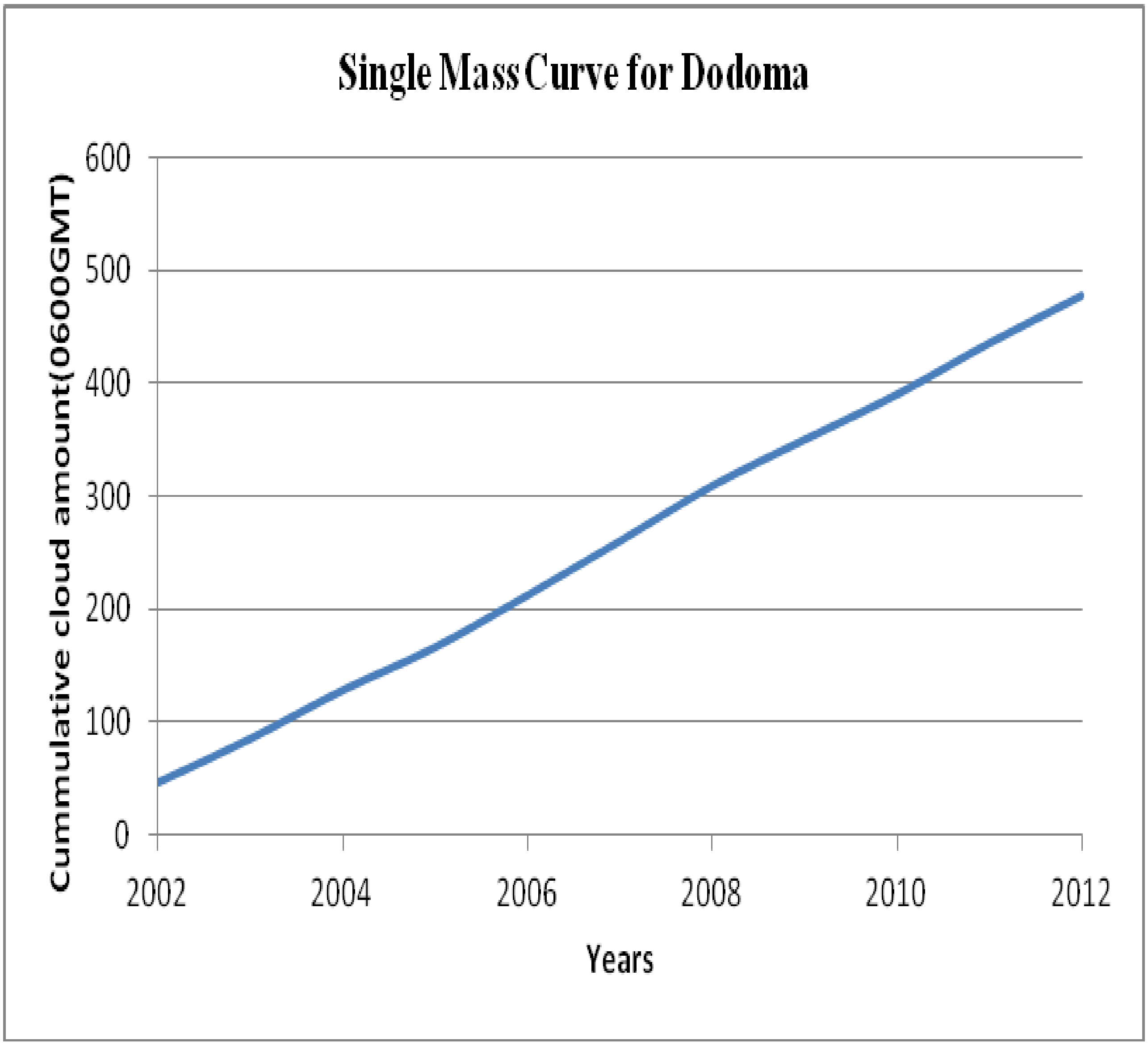

Figure 2(c). Single mass curve for Dodoma cloud amount (0600GMT)

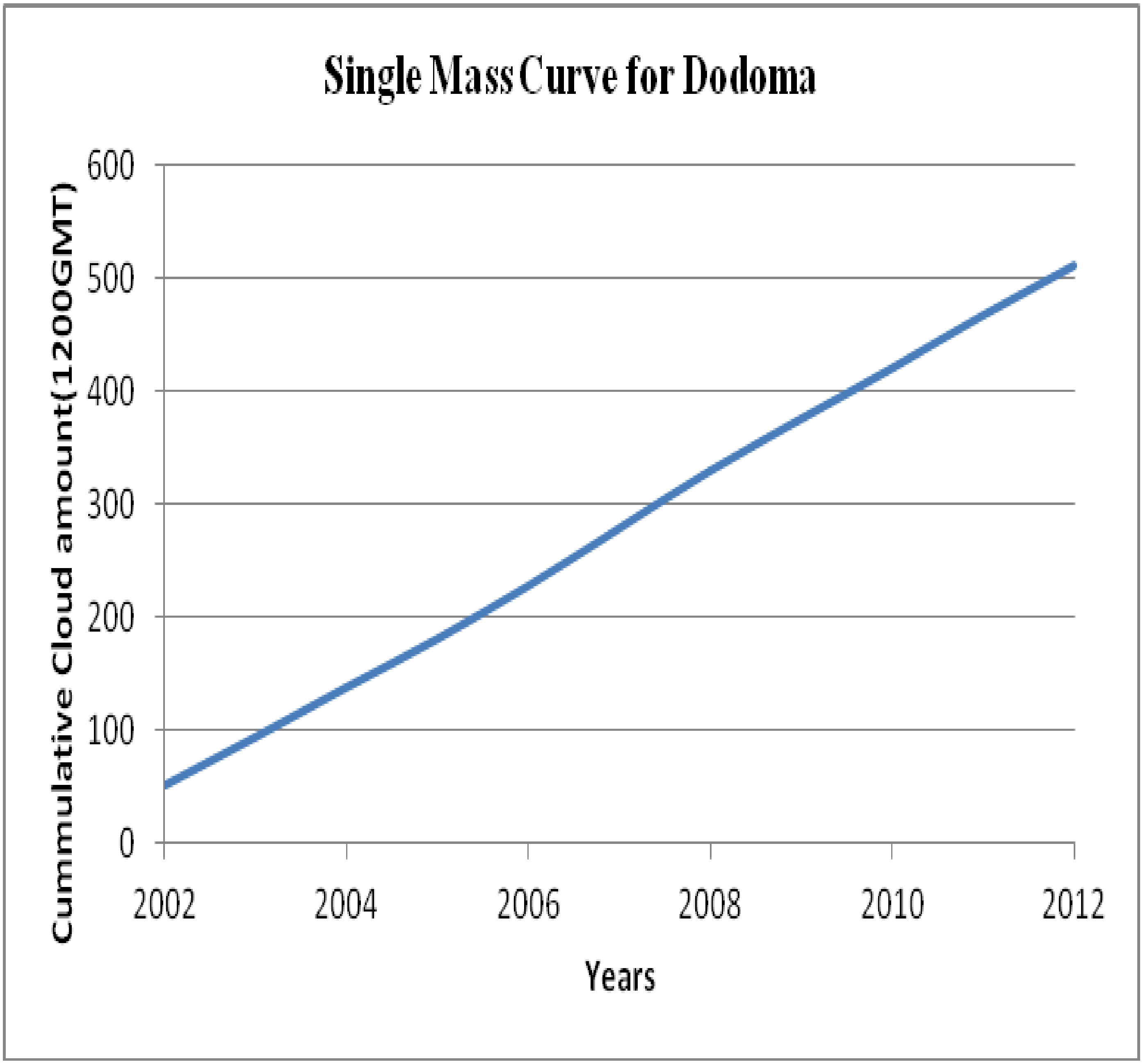

Figure 2(d). Single mass curve for Dodoma cloud amount (1200GMT)

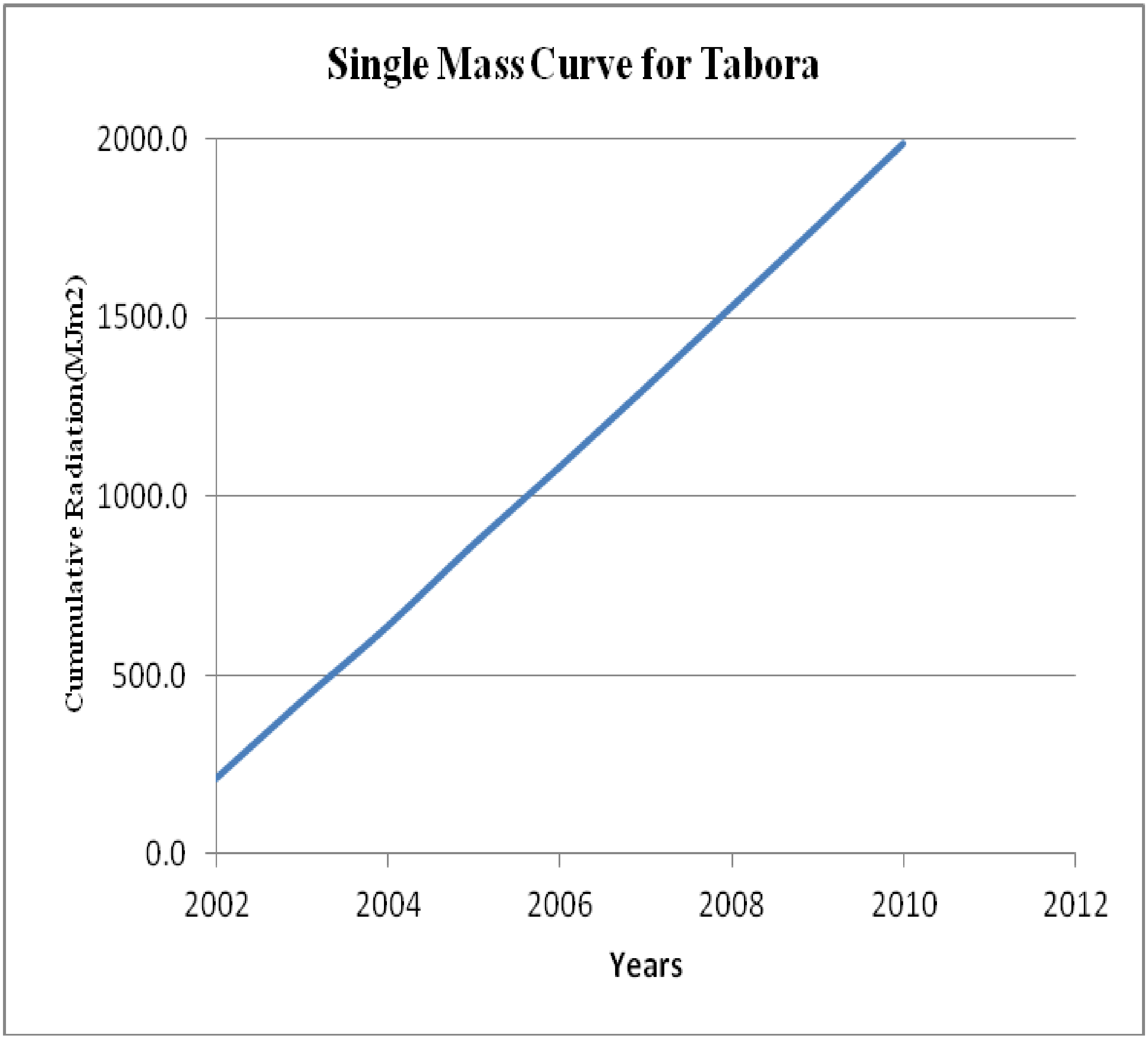
Single Mass Curve for Tabora
Cummulative Radiation(MJm2)
2000.0
1500.0
1000.0
500.0
0.0
2002
2004
2006
2008
2010
2012
Years

Figure 3(a) Single mass curve for Tabora Radiation

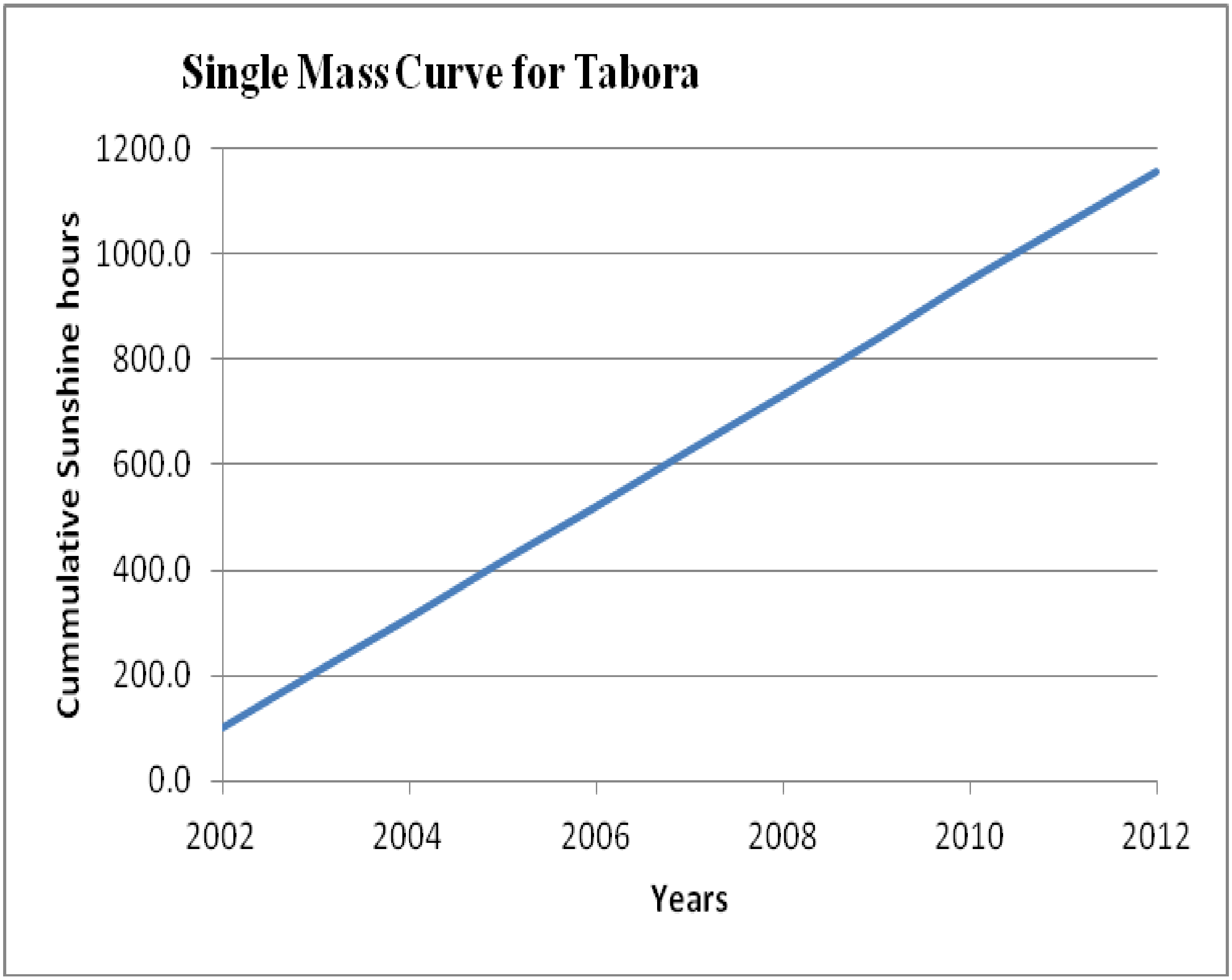

Figure 3(b). Single mass curve for Tabora sunshine hours.

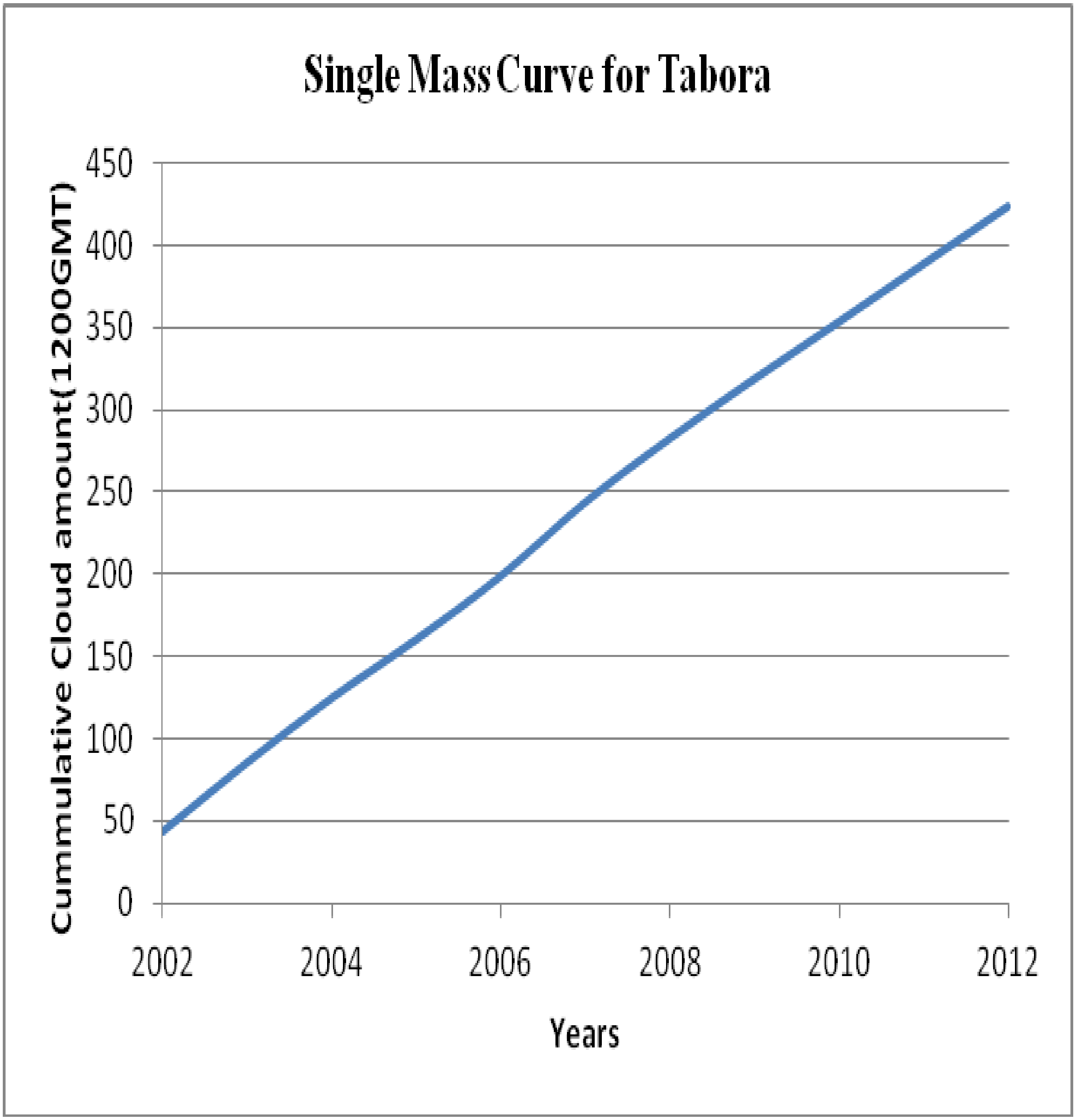

Figure 3(c). Single Mass curve for Tabora cloud amount (1200GMT)

4.2 Trends in Radiation, Sunshine hours and Cloud amount

This section examines the trends of solar radiation, Sunshine hours and Cloud amount as shown below.

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4.2.1 DODOMA

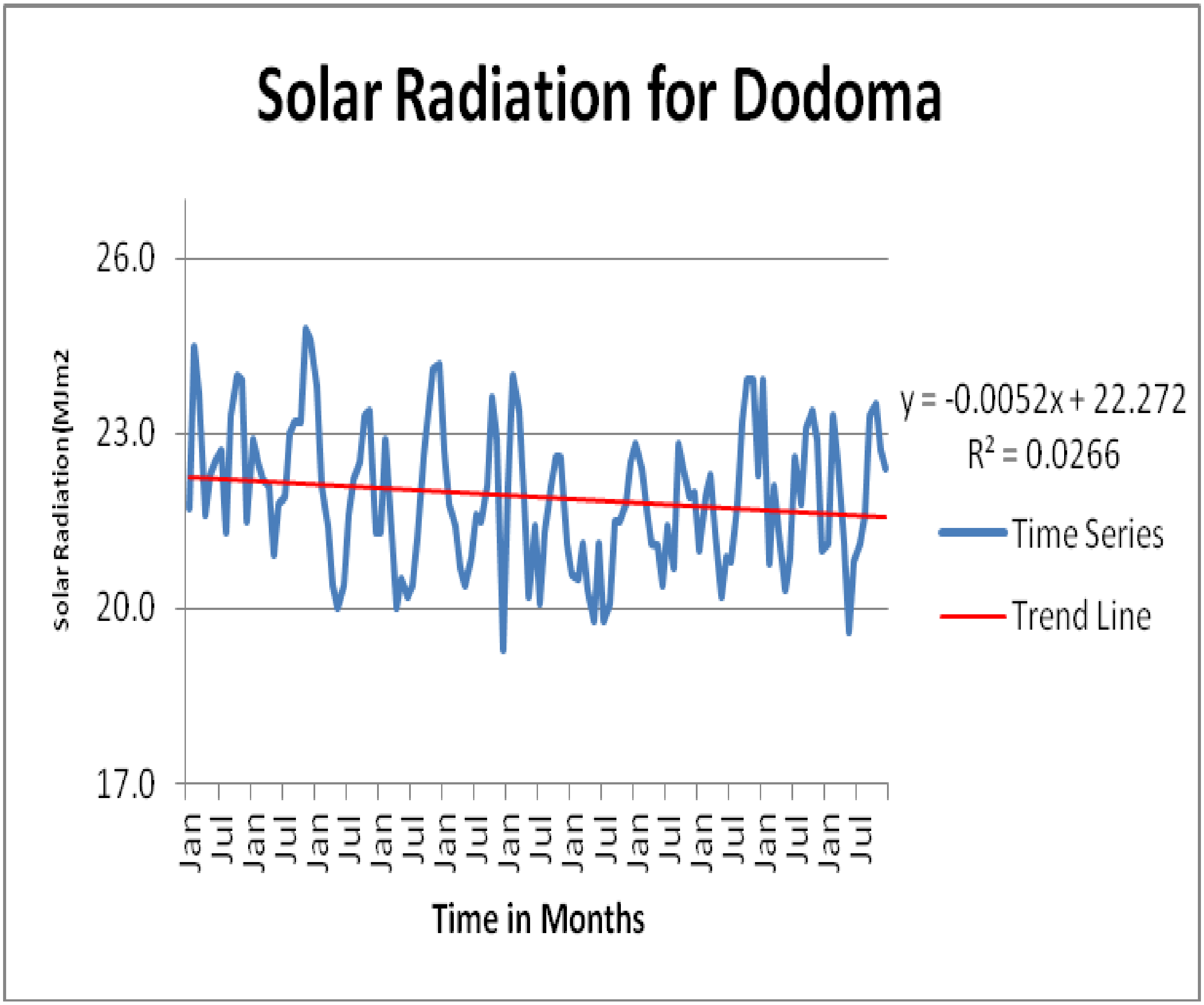

Figure 4(a).Trend for solar radiation in Dodoma

Solar radiation found to be in high amount at Dodoma. Generally, it was found that radiation varies on July to Dec. is higher and low on Jan to May most of the year. The trend shows that 2002 to 2012 radiation decreases.

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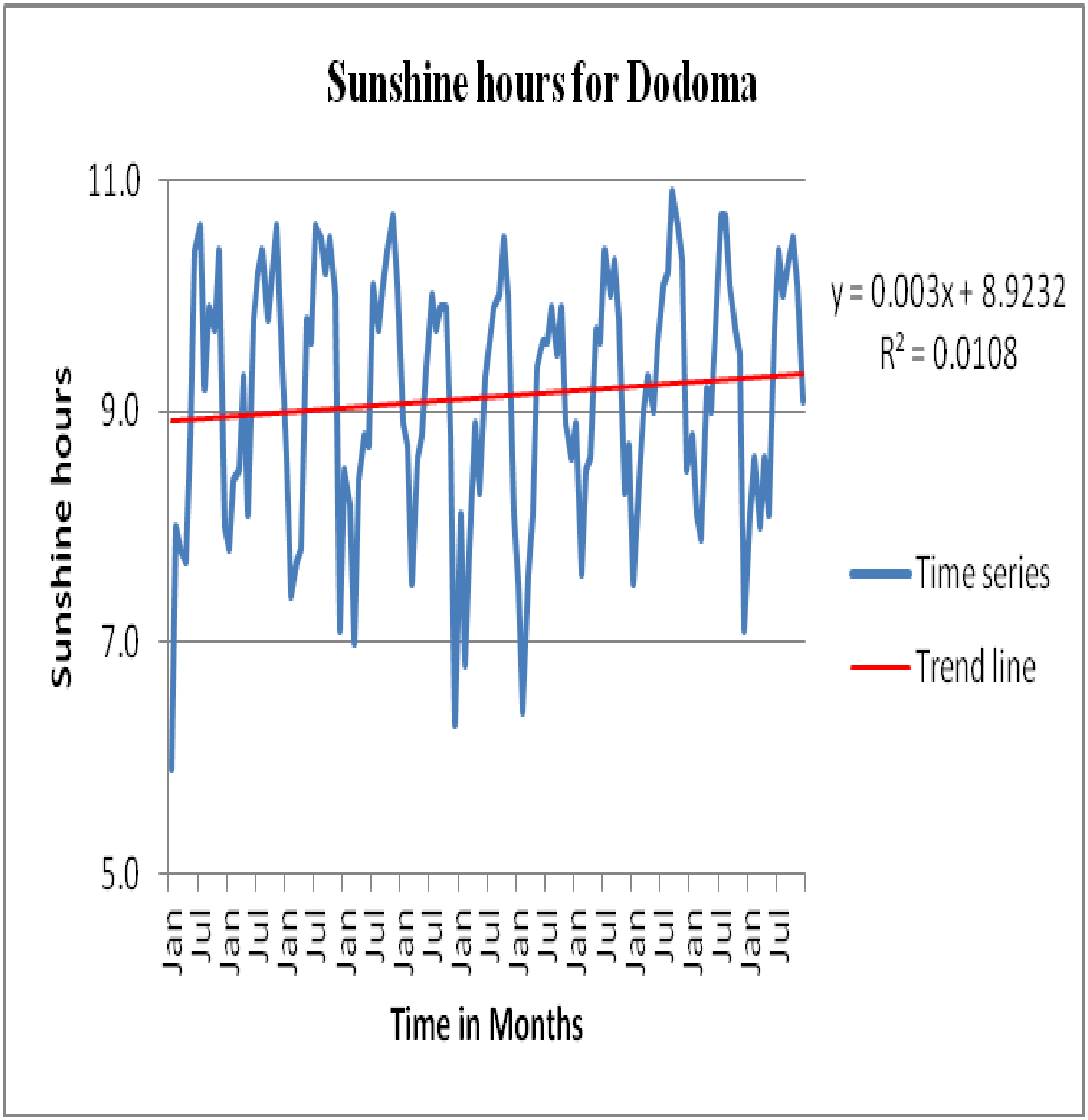


Figure 4(b).Trend for sunshine hours in Dodoma

From 2002 to 2012 sunshine hours indicated a generally increasing trend (positive).This shows that Dodoma experience most of sunshine hours day, but June to Nov. have higher sunshine hours and low at Jan to May

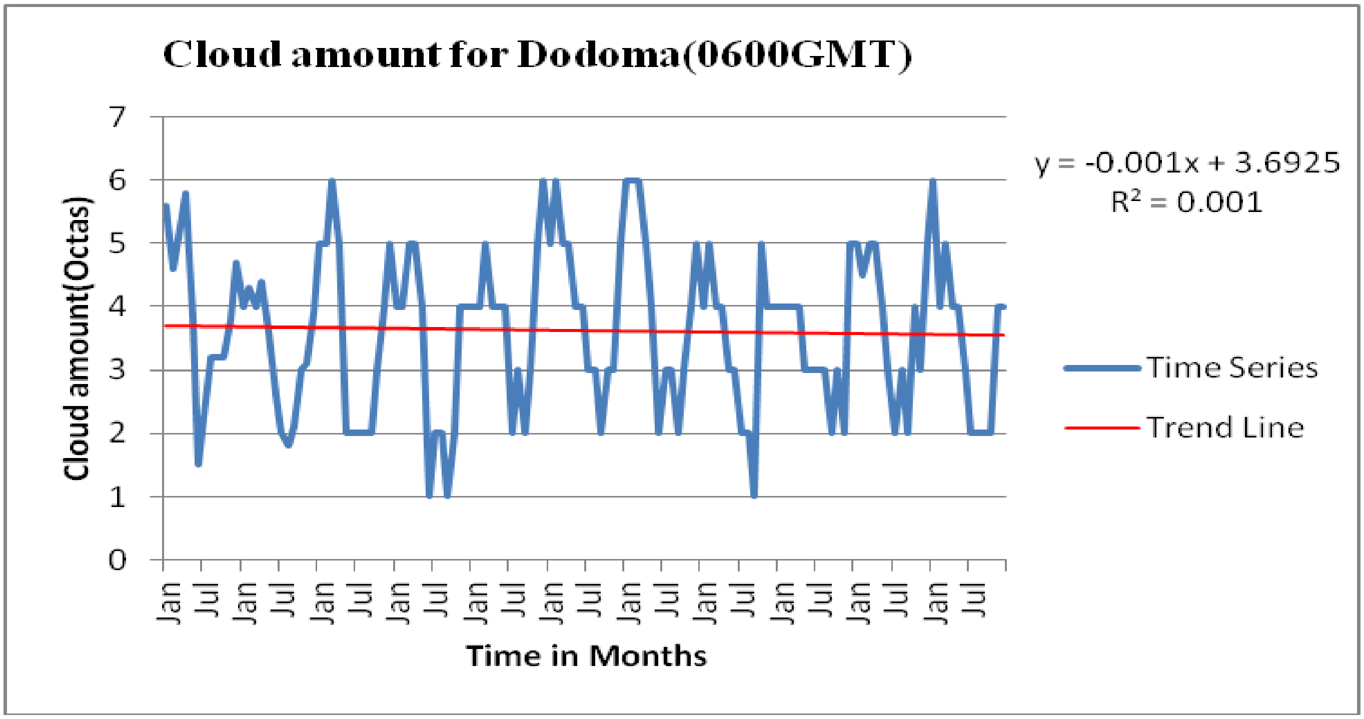


Figure 4(c). Trend for cloud amount in Dodoma (0600GMT)

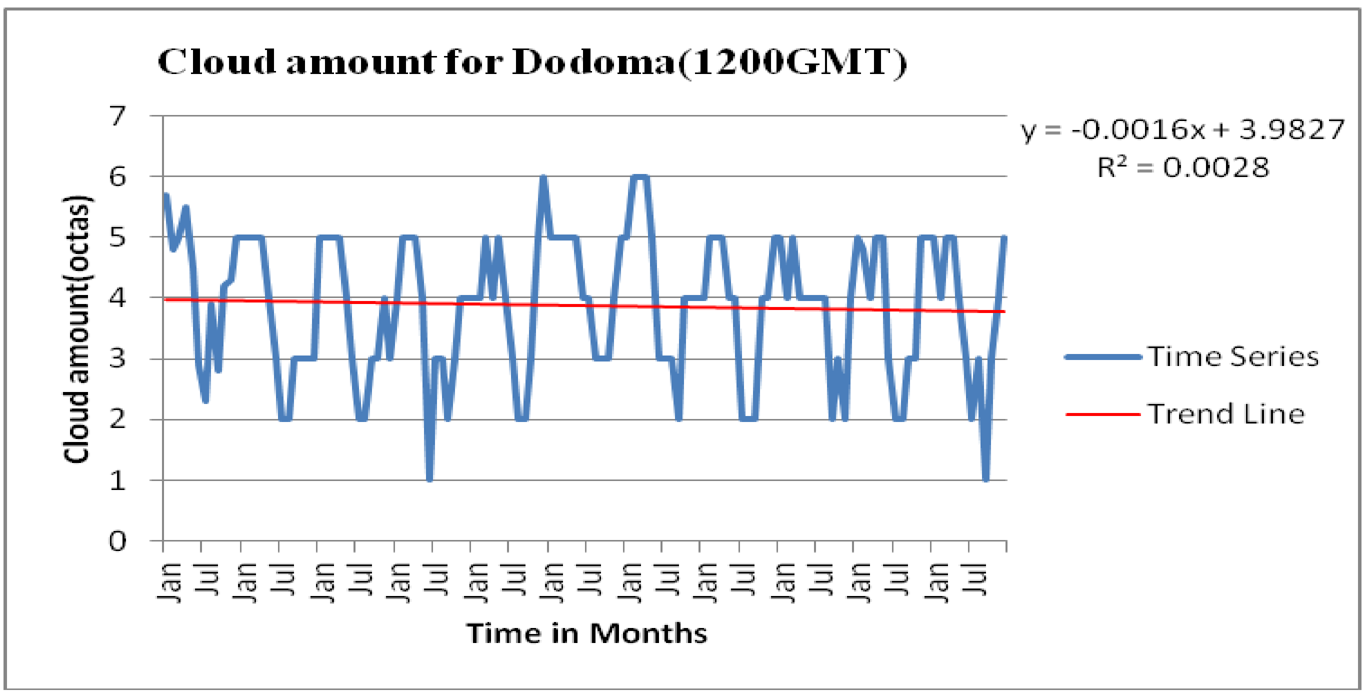


Figure 4(c). Trend for cloud amount in Dodoma (1200GMT)

The trend of cloud at 0600GMT and 1200GMT decreases, this shows that the amount of cloud is maximum at Dec to Apr and minimum at May to Nov. This indicates that most of the time of the year the amount of cloud is low.

4.2.2 TABORA

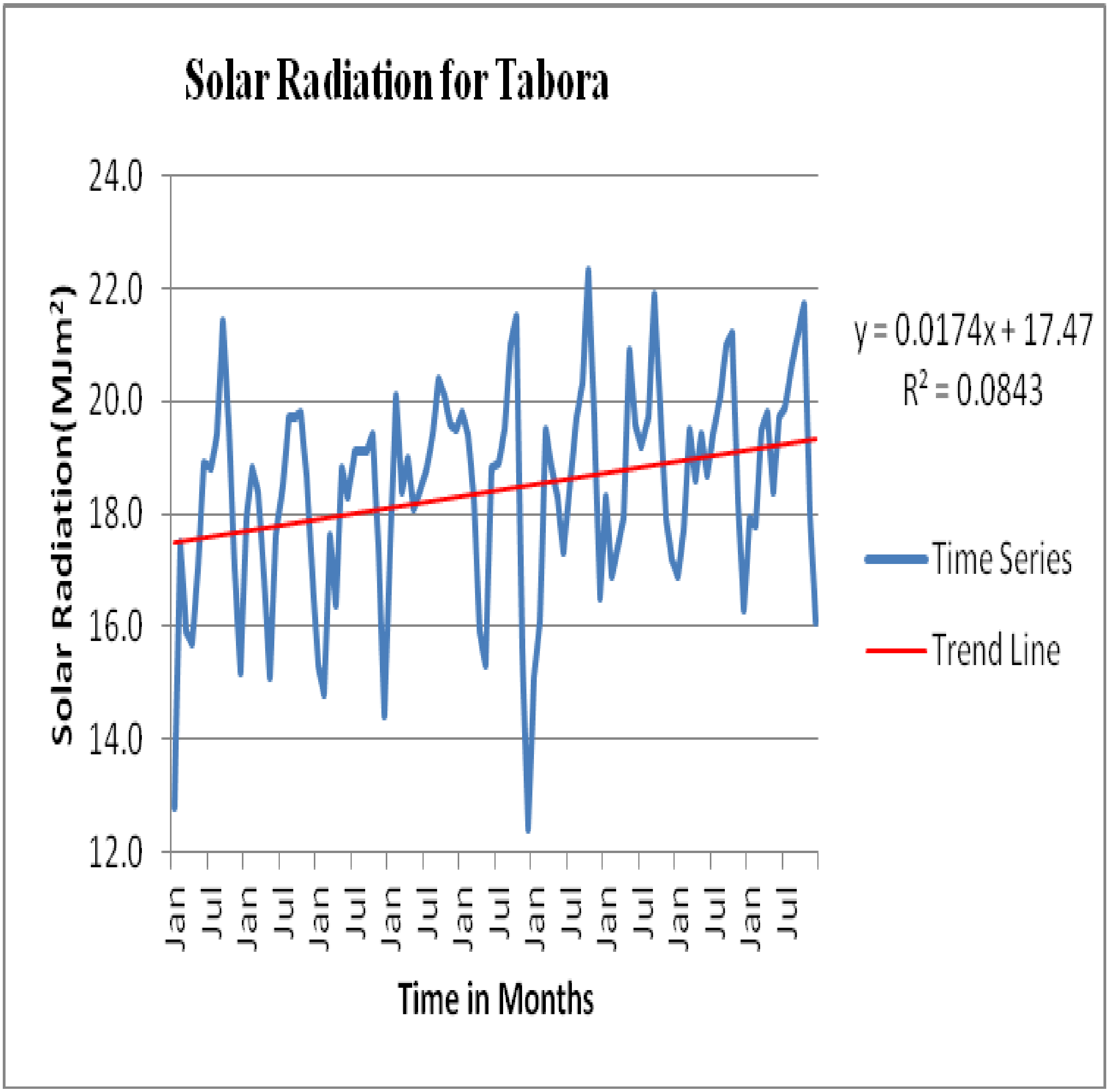


Figure 5(a).Trend for Tabora Solar radiation.

The trend of solar radiation of Tabora from 2002 to 2012 is incresing.

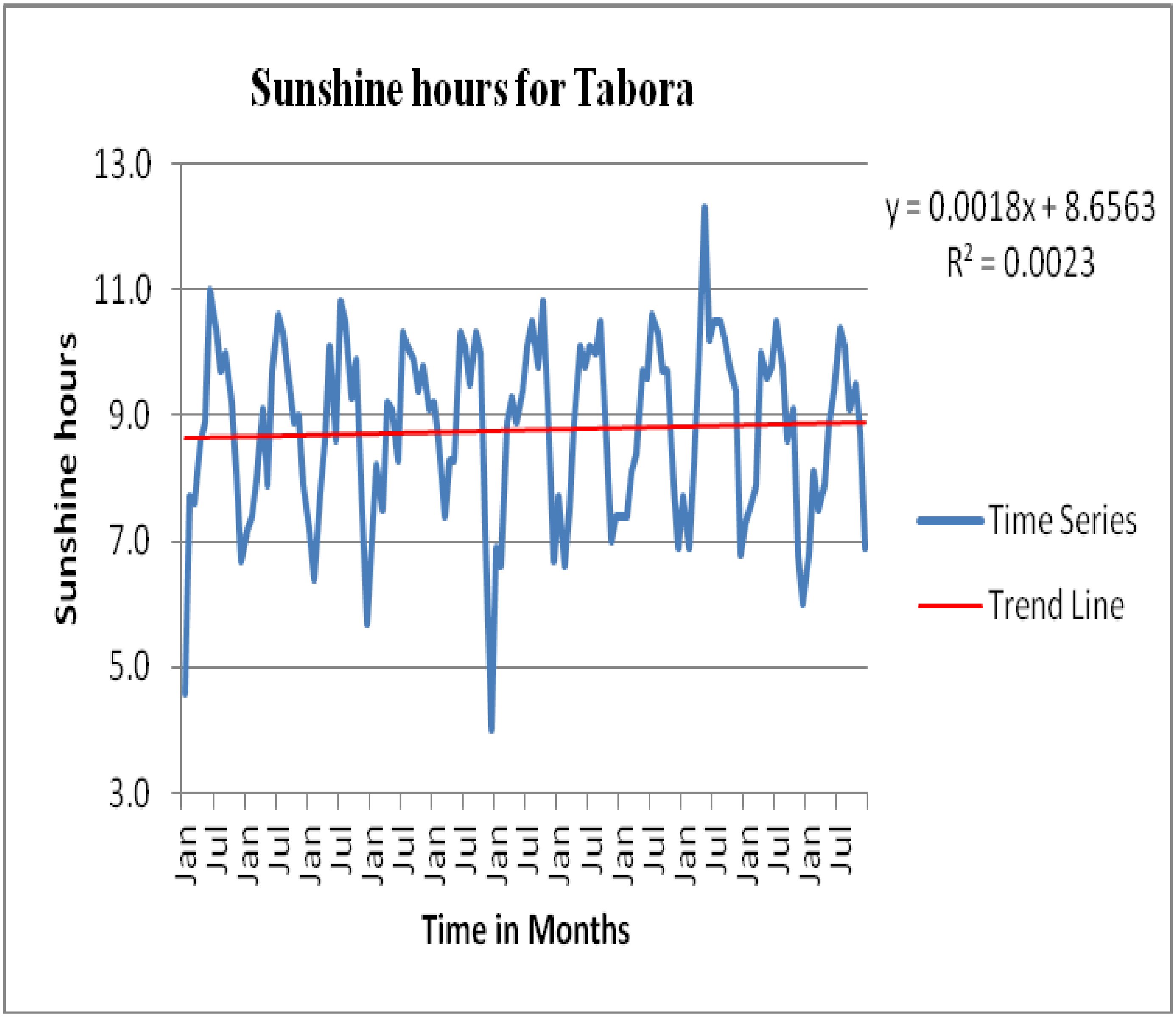


Figure 5(b).Trend for Tabora sunshine hours

Also sunshine is higher on Jun to Nov and low at Dec to May,this means Tabora experience most of time sunshine hours of the year.Trend incresing

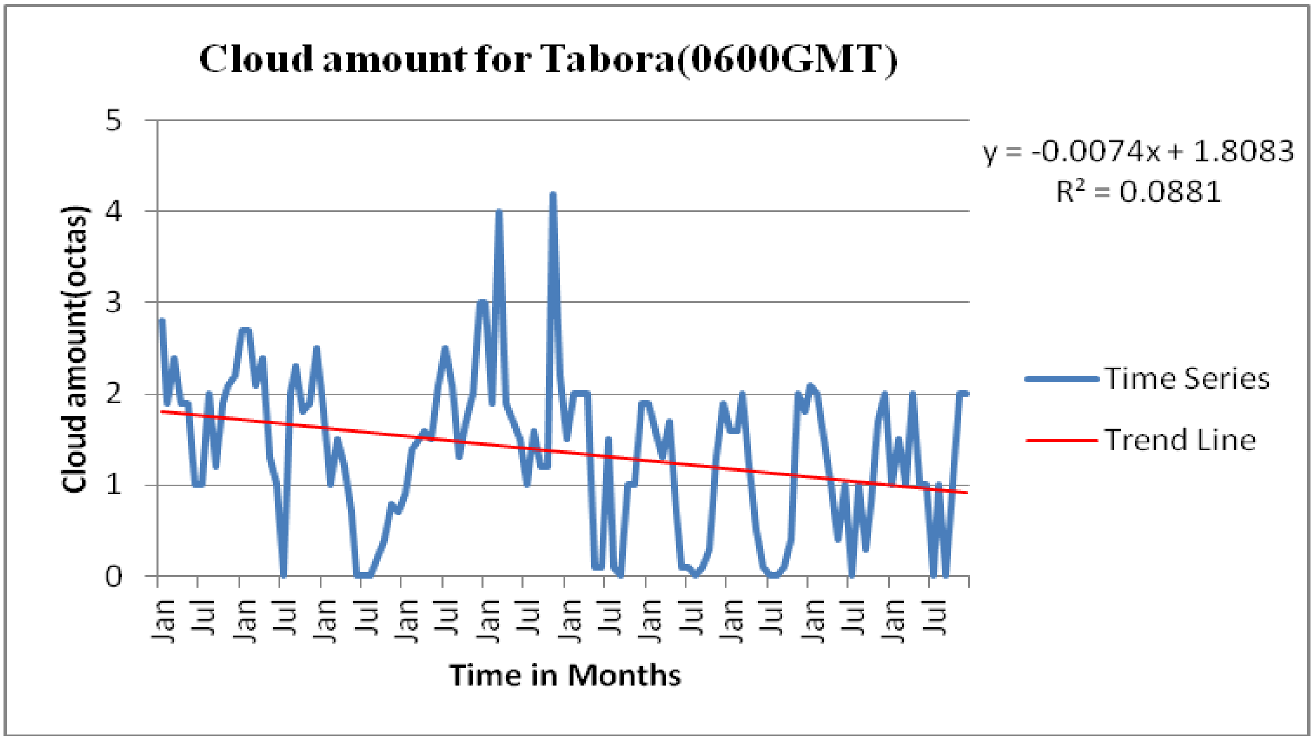


Figure 5(c).Trend for Tabora cloud amount (0600GMT)

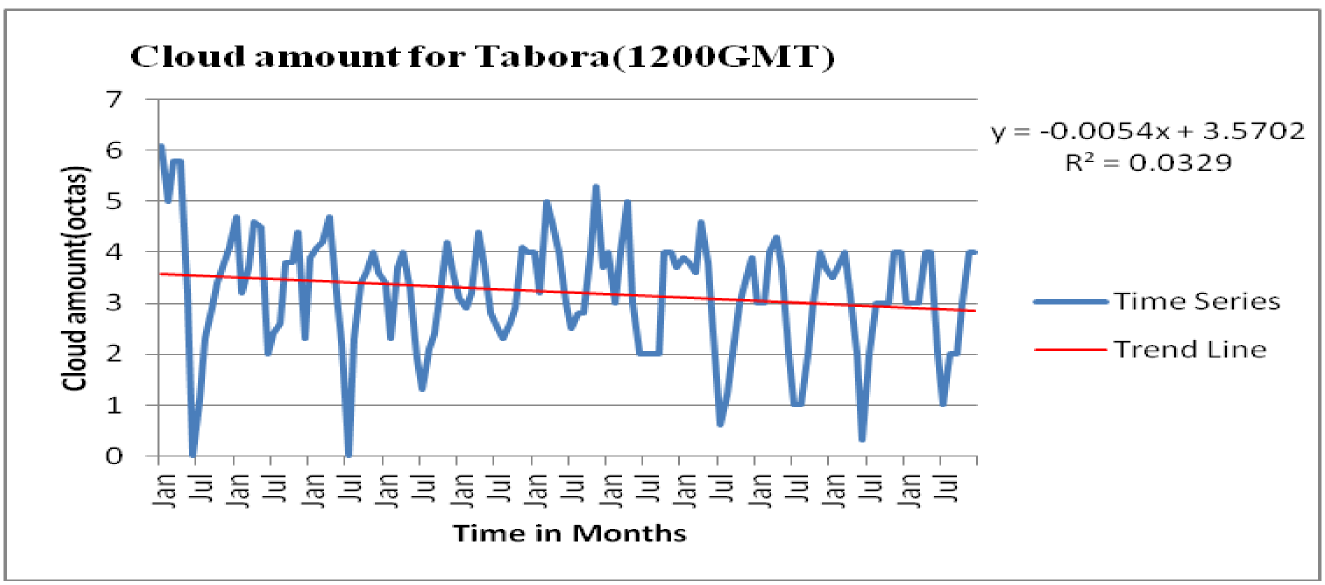


Figure 5(d).Trend for Tabora cloud amount (1200GMT)

Cloud amount at 0600GMT and 1200GMT found to be higher on Dec to May and low at Jun to Nov.The trend shows that 2002 to 2012 cloud amount decreases(negative).This means Tabora experience few amount of cloud as years goes

4.3 Spatial analysis

The spatial annual radiation, sunshine hours and cloud amount was analyzed over two stations Tabora and Dodoma. Results as shown below.

4.3.1 Radiation

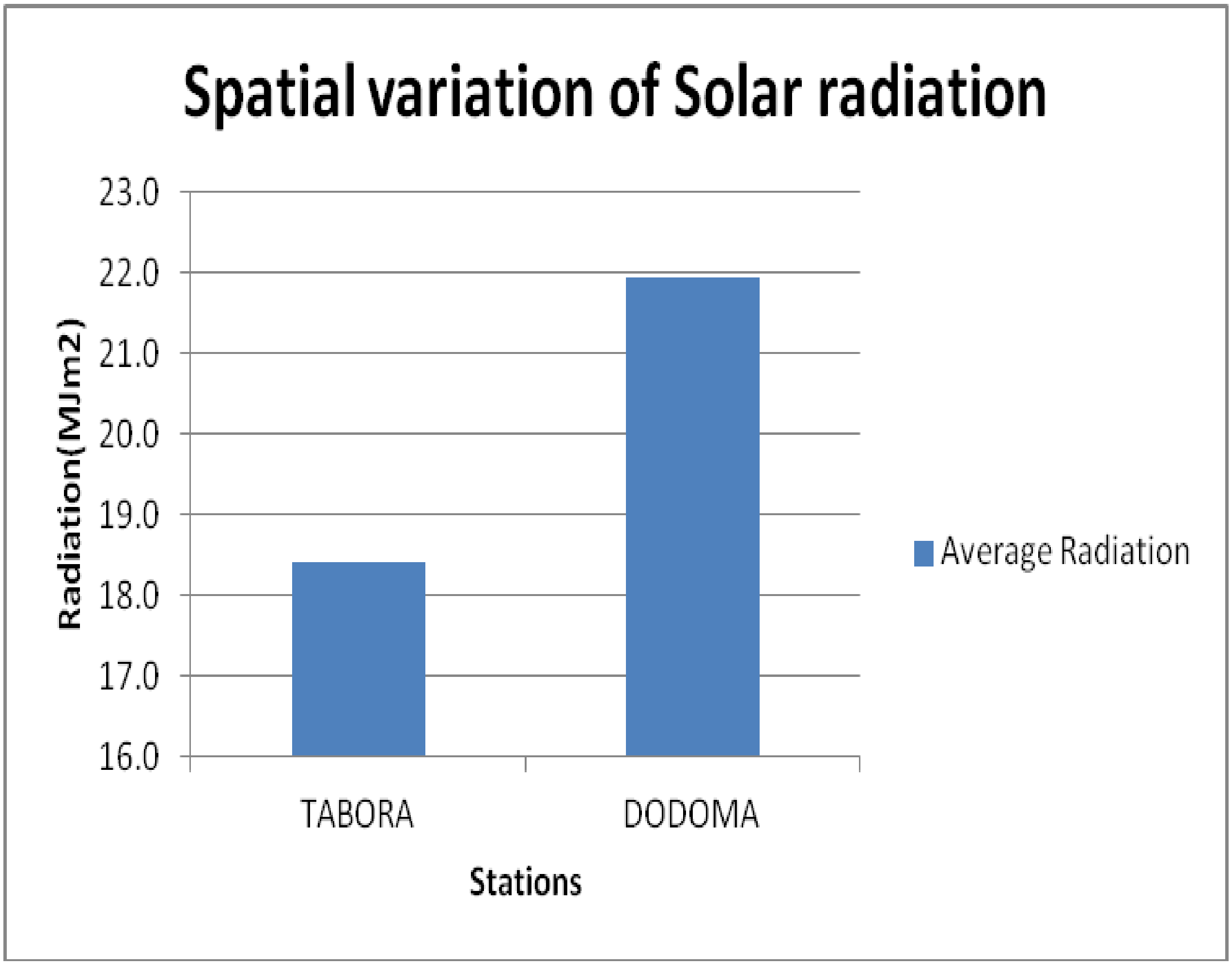


Figure 6(a) Variation of Solar radiation for Tabora and Dodoma.

The results show that Dodoma experience high amount of average radiation, sunshine hours and clouds amounts than Tabora

4.3.2 Sunshine hours

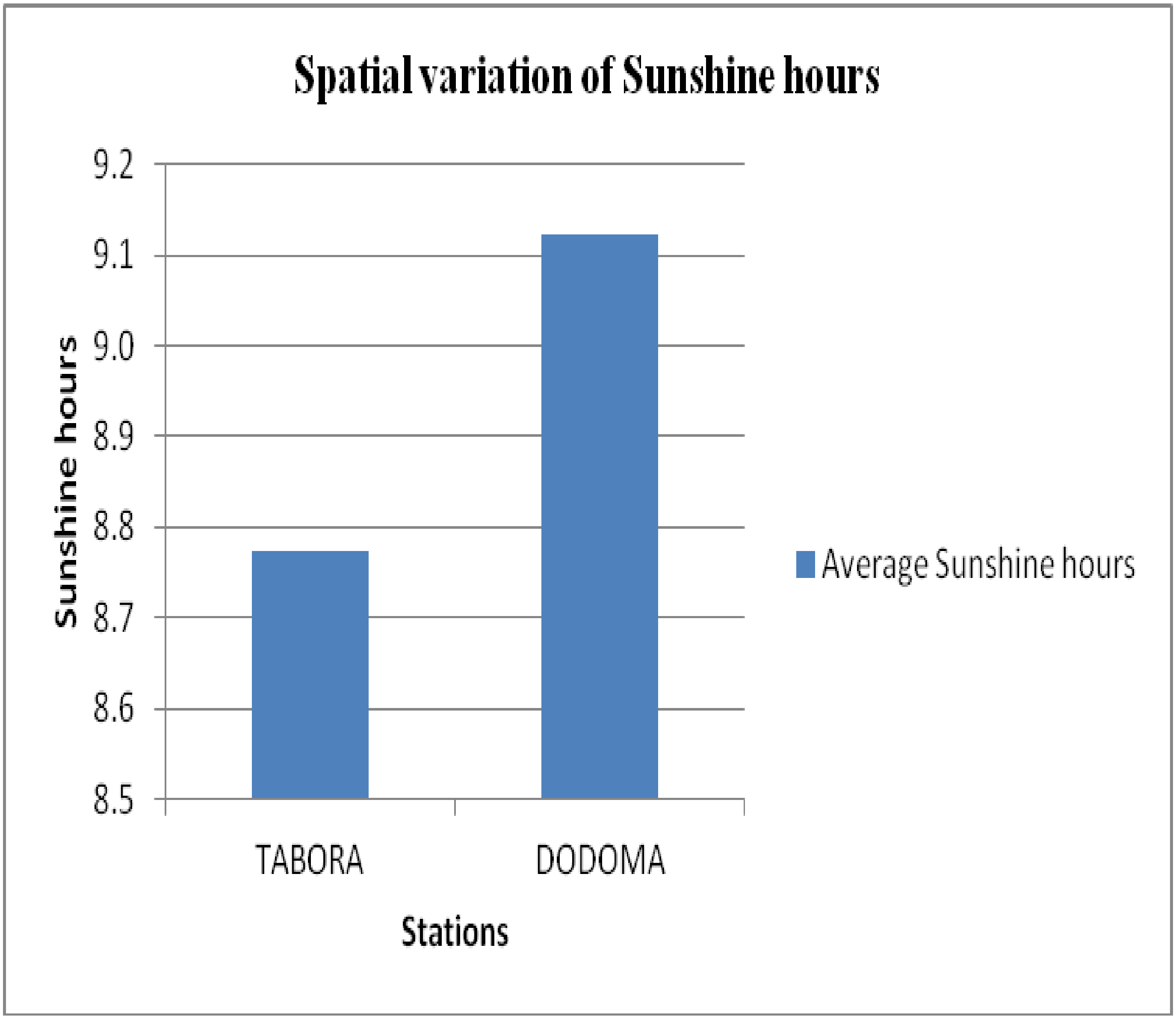
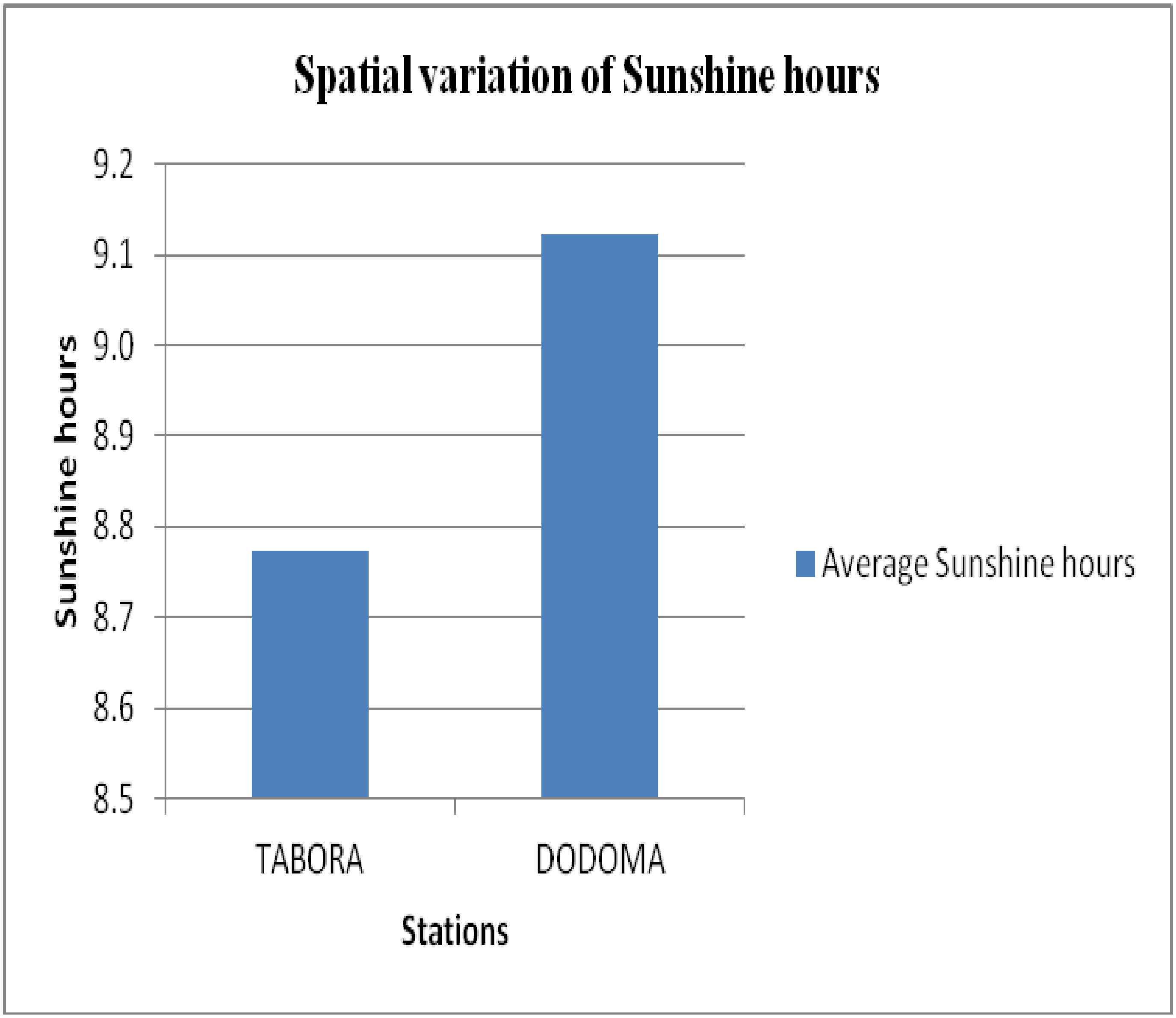


Figure 6(b).Variation of sunshine hours for Tabora and Dodoma.

The results show that Dodoma experience high amount of average radiation, sunshine hours and clouds amounts than Tabora

4.3.3 Cloud amount



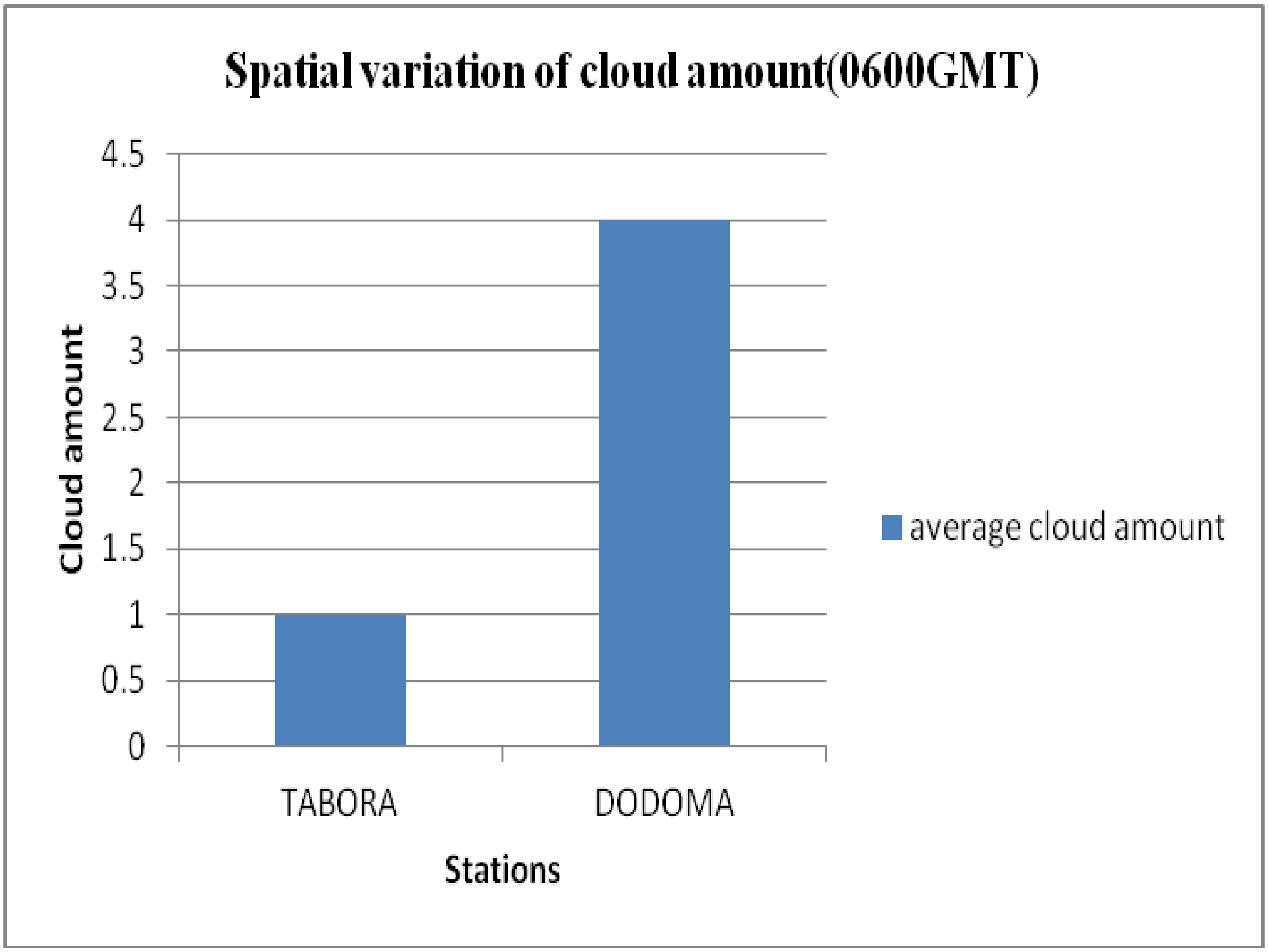


Figure 6(c).Variation of cloud amount (0600GMT) for Tabora and Dodoma.

The results show that Dodoma experience high amount of average radiation, sunshine hours and clouds amounts than Tabora

4.4 Variation of data

4.4.1 MONTHLY MEAN CLOUD AMOUNT

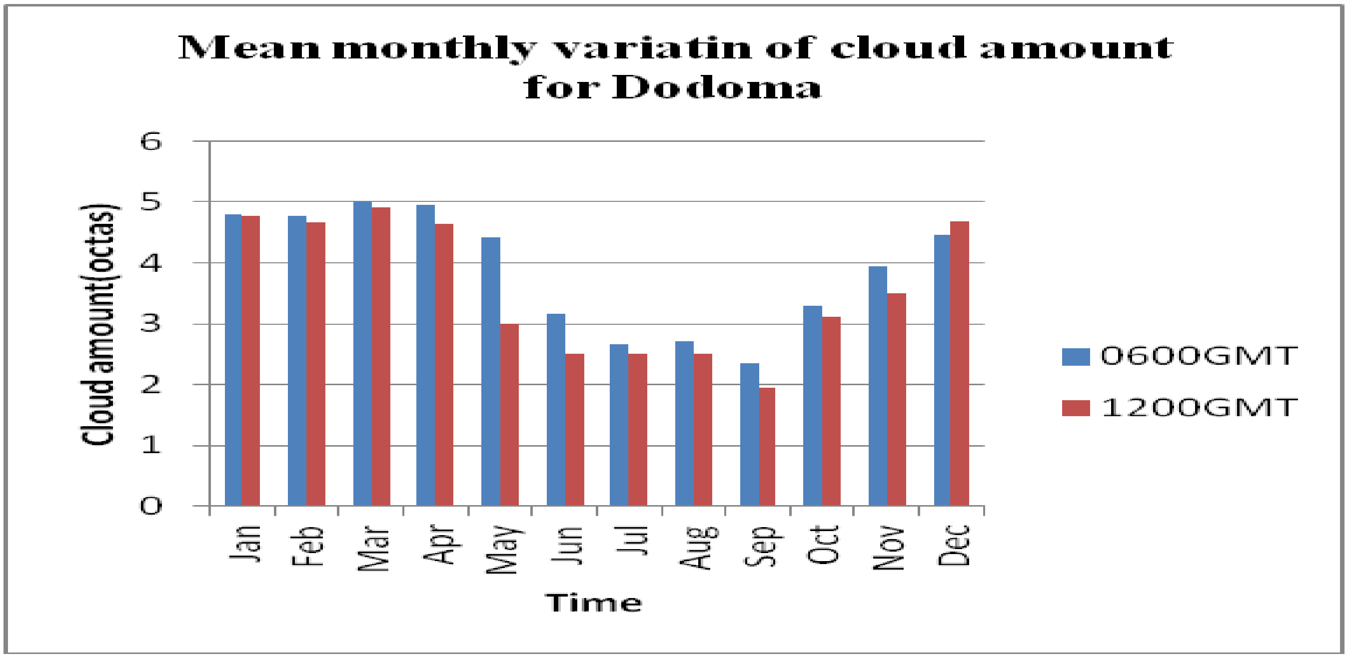


Figure 7(a) Mean monthly variation of cloud amount for Dodoma.

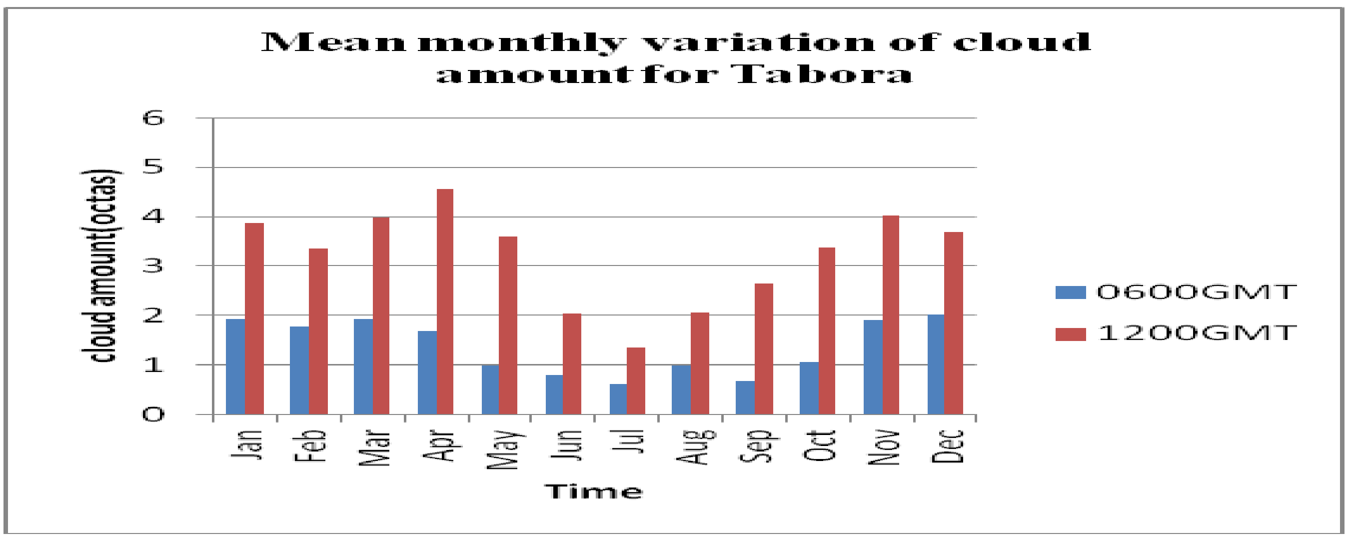


Figure 7(b). Mean monthly variation of cloud amount for Tabora.

Lowest amounts of cloud cover were observed from Jun to Oct at Dodoma and Tabora. While highest amounts of cloud cover were observed in Nov to May

From the above observations, a solar panel would thus be less efficient on the cloudiest months but would deliver adequate output on the less cloudy months

4.4.2 MONTHLY MEAN SUNSHINE HOURS

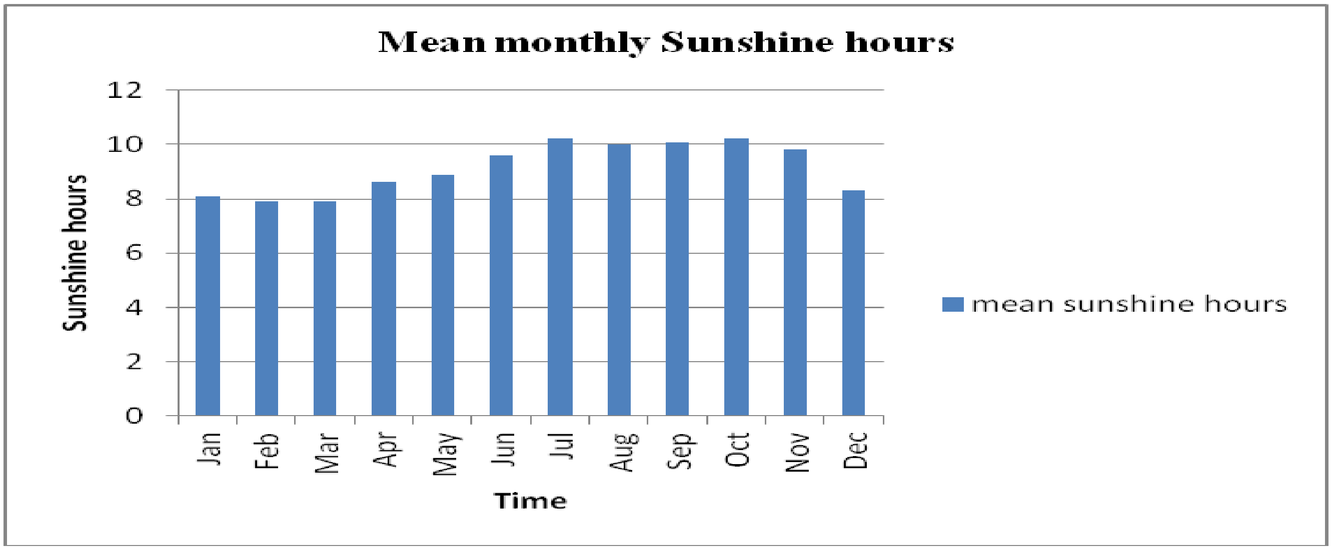


Figure 8(a). Mean monthly sunshine hours for Dodoma

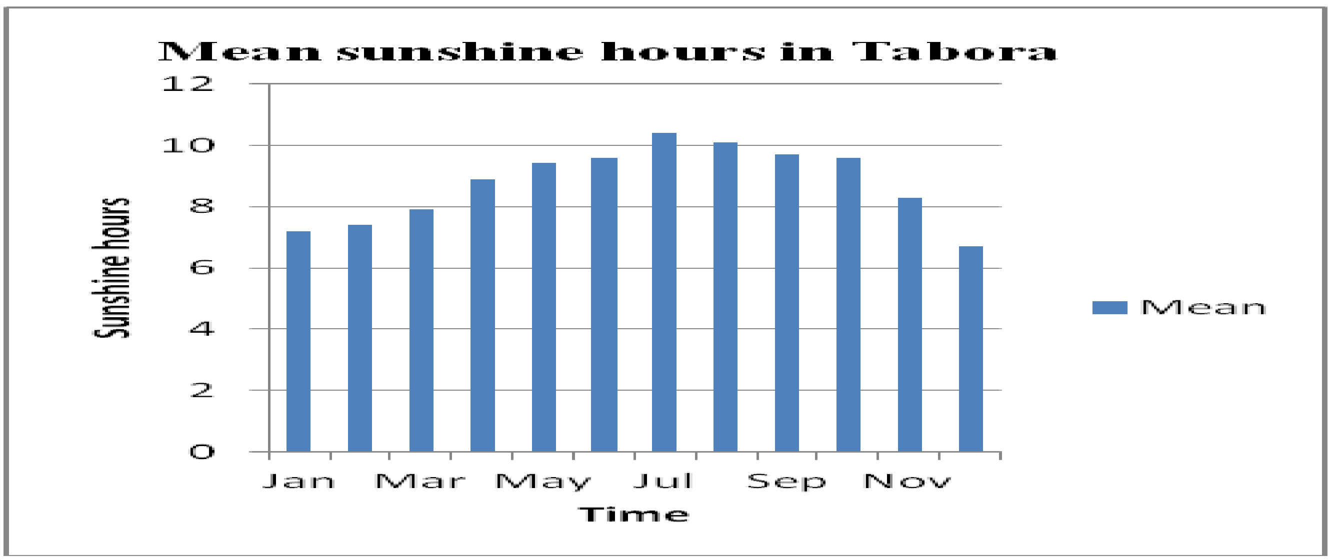


Figure 8(b). Mean monthly sunshine hours for Tabora.

From the above graph monthly the months with the lowest mean sunshine hours are Dec to Apr, while those with the highest values are from May to Nov.

For solar electricity to be successful there must be high solar radiation. This means that peak sunshine hours should be 5 or more throughout the year. This shows that the more sunlight a solar cell is exposed to the more its efficiency. From it shows that solar electricity would be beneficial since almost all months have more than 5 peak hours.

4.4.3MONTHLY MEAN SOLAR RADIATION

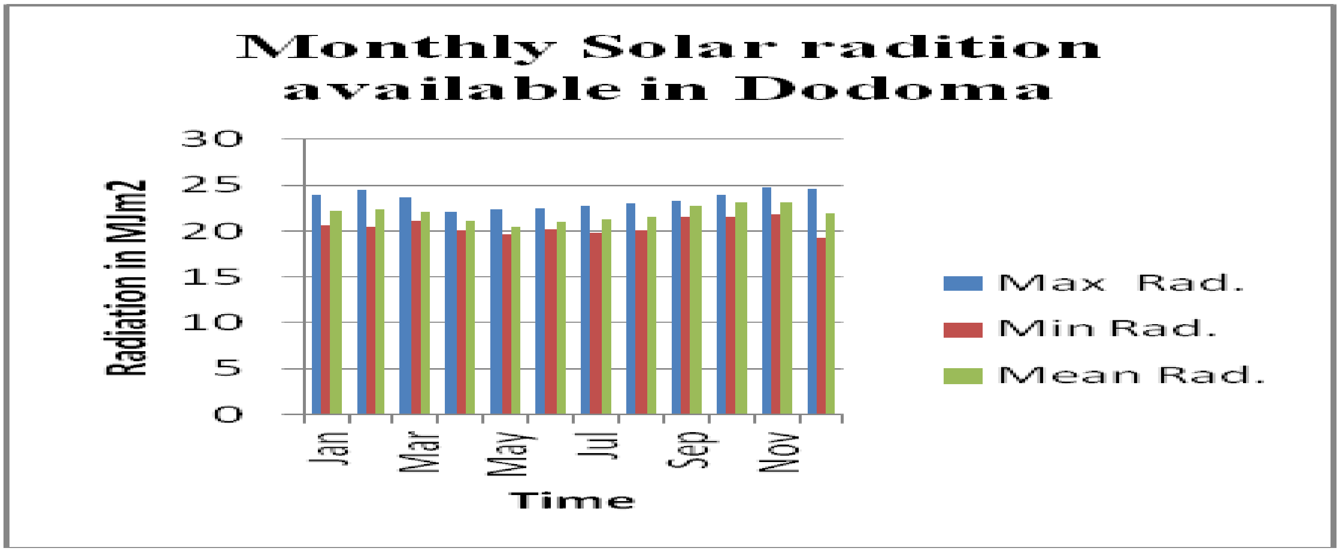


Figure 9(a). Mean monthly solar radiation for Dodoma.

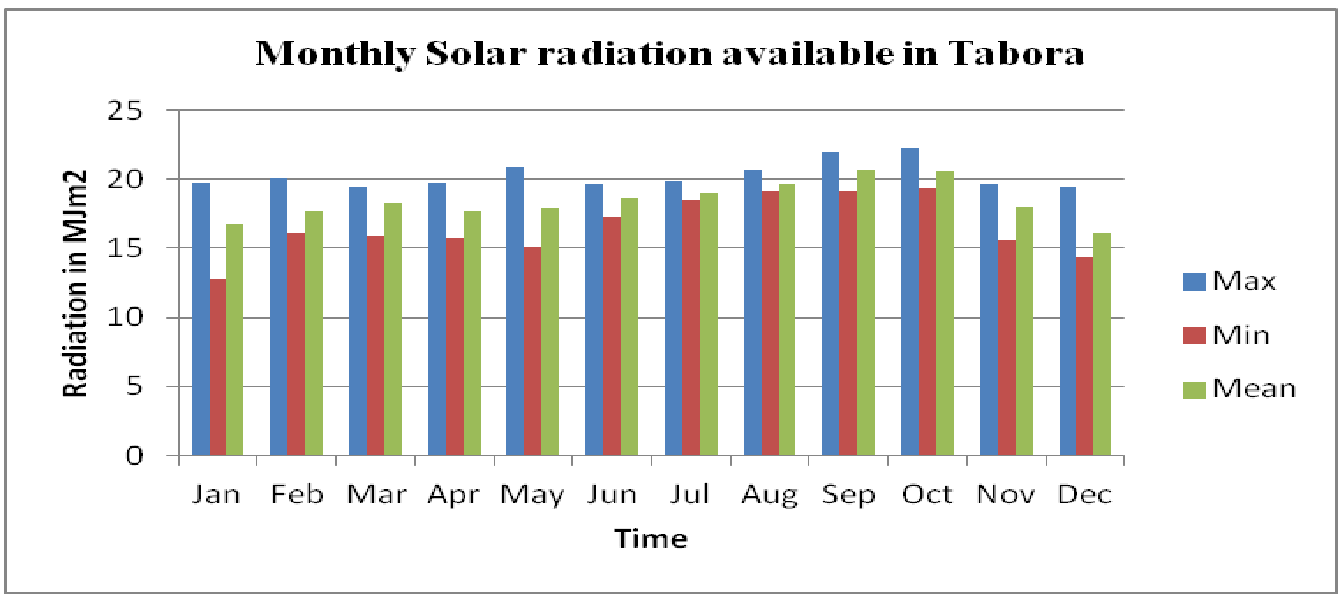


Figure 9(b).Mean monthly solar radiation for Tabora.

The amounts of solar radiation are found to be high throughout the year in both Dodoma and Tabora.

Comparing the mean monthly sunshine hours, mean monthly radiation and cloud cover, it is evident that Dodoma and Tabora has been found to be a fairly promising site for solar energy harvesting.

CONCLUSION

It has been noted from this study that solar radiation is low during the period of high amount of cloud cover (Dec to Apr) during this period Dodoma and Tabora experienced low time of sunshine hours, which lead to low amount of solar energy viability. So during cloudy weather, the solar system must be designed in such a way that modules produce enough power or on other hand excess energy may be produced during sunny months.

Also the study indicate that solar energy viability is more efficiency from May to Nov,at this period cloud amount are few, solar radiation is high and sunshine hours are high. During this period sunshine rays are in high amount and almost found throughout.

From this research, it can be concluded that solar energy are available at Dodoma and Tabora. Residence can turn up on using this energy since is highly reliable and requires little maintenance.

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