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MORALITY BEFORE KNOWLEDGE

Assessment of solar radiation potential for solar drying technology of fruits and vegetables

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ABSTRACT

Background: Malawi gets a lot of sunshine because it is positioned astride the equation. It is abundant since it is a renewable energy source. Absence of information about solar radiation availability is the main obstacle to resource use. With the goal of minimizing post-harvest losses, this study evaluates Malawi's sun radiation potential for drying fruits and vegetables. **Methods:** Using pyranometers as instruments, automatic weather stations in the districts of Mzimba, Lilongwe, Dedza, Ntcheu, Salima, Mwanza, Thyolo, Mulanje, and Chiradzulu were used to gather secondary data. The Department of Climate Change and Meteorological Services (DCCMS) supplied the primary data, which covered a brief three years (2017 to 2020). Three years' worth of historical data was taken into consideration in order to obtain more significant trends and data validation. Excel and Rstudio were used to evaluate the data in terms of daily and seasonal fluctuation and mapping, respectively. **Findings:** It is evident from the irradiation map and daily and seasonal variance trends that certain regions of Malawi experience more insolation than others. This results from ITCZ, which affects how the seasons change. These findings will be used to determine which Malawian districts will benefit from the installation of solar dryers by having higher levels of insolation. **Conclusion:** Further study of solar radiation received on inclined and horizontal planes is what this research suggests should be done. **Novelty/Originality of this Study:** This study introduces a novel approach to using solar drying methods for preserving fruits and vegetables in Malawi, addressing the high post-harvest losses in various districts. By focusing on the application of solar drying systems tailored to local solar radiation conditions, the research highlights the importance of harnessing diffuse solar radiation, which is often overlooked, thereby offering a more sustainable and cost-effective alternative to traditional drying methods.

KEYWORDS: solar radiation; data collection; solar photovoltaic systems.

1. Introduction

Fruits and vegetables are very important agricultural produce from both producer and non-producer countries (Alemu and Ashenafi, 2022). These fruits and vegetables are the ultimate source of dietary nutrients mostly like vitamins, proteins, minerals and even fibers. According to (Atungulu et al., 2004; Suresh Kumar, n.d.; Wakjira, 2010) state that fruits and vegetables are regarded as highly perishable and bulky commodities as they contain moisture approximately to more than 80%. Fruits and vegetables being considered as perishable and bulky commodities as a result contain high amounts of moisture content, which implies that these can be easily damaged and spoiled (Alegbeleye et al., 2022). So, these agricultural products need to be preserved by using different drying methods of preservation such as sun drying, mechanized and solar drying methods, in order to reduce some losses incurred by most farmers involved in fruits and vegetables farming (Suresh et al., 2023). In this study, only the solar drying method was adopted which dealt with the

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actions of bacteria, yeast, and molds that mostly causes spoilage of fruits and vegetables. So, this method of drying reduces the amount of moisture for fruits and vegetables in order to be preserved. When these agricultural commodities contain a lot of moistures, what happens is that they end up creating a conducive environment for bacteria, yeast and mold multiplication. If these agricultural commodities are properly dried, it means there will be no moisture visible when it is cut (Amit et al., 2017).

Another scenario which needs to be observed when working with solar drying methods is the length of time to be taken to dry these fruits and vegetables (Devan et al., 2020; Natarajan et al., 2022). So, the length of time taken to dry the fruits and vegetables depends on how quickly a drier warms up the air and absorbs moisture from fruits and vegetables. This means that, when the solar drier warms up quickly, it will take less time to dry fruits and vegetables and when a solar drier warms up slowly, probably will take much time to warm up and absorb moisture from fruits and vegetables (Natarajan et al., 2022). The warming up and absorption of moisture from agricultural commodities also depends on meteorological conditions such as winds, humidity, and cloud coverage which can affect the intensity and magnitude of solar radiation received at the earth's surface. But there are some factors which determine the fastness of a solar drier to drive out moisture from these agricultural commodities (Goel et al., 2024). These factors are as follows: the air must be warm, air must be dry, and moving from the solar collector to the chamber of a drier and then out of the chamber continuously. In order to understand the dryness of the air, the measurement of relative humidity must be considered(Goel et al., 2024; Kilic et al., 2024; Radhakrishnan et al., 2024). The relative humidity tries to explain that when it is at 100%, it means that it has absorbed 100% of water from fruits and vegetables it can hold at that temperature. If the relative humidity of air is near 100%, then air must be heated up before it is directed into the chamber of the solar drier. So, the amount of energy which is added up, most of the time depends on the local climate (Azumah et al., 2024). Air temperature drops when the moisture has been absorbed from the fruits and vegetables and thus supplies some energy for drying. But when air is warm and dry enough, the fruits and vegetables will dry slowly with an addition of heating from the sun (Metwally et al., 2024; Ssemwanga et al., 2020).

The drying processes can be divided into three primary sorts or categories. These include mechanical and solar drying techniques that employ technology to remove moisture from fruits and vegetables, as well as sun drying techniques that use the sun directly. Because it can be controlled, solar drying is more effective than sun drying, but it also costs less to operate than mechanical drying. Because solar drying employs sunshine, a natural energy source, it is an inexpensive process. Jackson and Masry claim that the solar drying method can be applied both macro- and micro-scale, as well as on a commercial basis (Goel et al., 2024; Metwally et al., 2024; Radhakrishnan et al., 2024).

Any application of solar energy, such as solar drying techniques, necessitates an understanding of the solar radiation that is incident, either horizontally or inclinedly, on the surface of the planet (Goel et al., 2024; Janjai & Bala, 2012; Ssemwanga et al., 2020). Most scientists and designers will utilize their understanding of solar radiation or insolation to properly identify solar dryers and assess how well these devices operate at a given region or site. Understanding solar radiation can also be applied to photovoltaic and solar thermal systems (Thindwa et al., 2019). This requires a comprehensive examination and assessment of the incident solar radiation at each specific location. Proficiency in measurement, tracking techniques, and understanding the solar geometry are essential for designing and evaluating the performance of solar dryers (Goel et al., 2024; Metwally et al., 2024; Radhakrishnan et al., 2024; Suresh et al., 2023).

Malawi is one of the countries where people rely on farming for social economic activities. Most Farmers do over produce their fruits and vegetables which require to be preserved by solar drying systems like solar dryers in order to reduce losses (Chiwaula et al., 2020; Kilic et al., 2024; Ndukwu et al., 2018). So, the installation of these solar drying systems requires solar radiation data for evaluating the performance and designing of these solar dryers. According to (Kachaje et al., 2016; Warnatzsch and Reay, 2019)Malawi has been recognized as a leader in Central Africa for adopting solar radiation technologies, with numerous installations of photovoltaic systems and solar thermal systems. So, they discovered that most of these systems have been installed without any knowledge of the solar radiation. The main problem which led to this failure is the lack of capital because these systems are highly costly and have a long payback period (Ahmad et al., 2024). Though highly costly and long, these systems of energy source are environmentally friendly in terms of global warming and destruction of the ozone layer which plays a great role in everyday life. The goodness of the solar driers is a portable device, which means that can be moved from place to another and these solar drier devices cannot wear out easier, hence it has a long-life span. So, having good quality data of solar radiation or insolation is important in the field of renewable energy in connection with solar drying systems, even photovoltaic and thermal systems. Therefore, it is important for an assessment of solar radiation/ insolation because it will provide information about the installation of these drying systems, mostly solar dryers. Having knowledge or information about solar radiation enables someone to come up with the exact sizing and costing of a solar system such as a solar panel.

1.1 Literature review

Malawi benefits from consistent and abundant solar radiation, estimated at 4-6 kWh/m^2 per day, coupled with moderate to high temperatures, as outlined in Sessional Paper No. 4 on Energy (2004). Despite possessing significant renewable energy resources, Malawi's energy sector has not undergone comprehensive evaluation, mapping, or economic and technical viability assessments, as highlighted in the Ministry of Energy and Resources Strategic Plan 2008–2012. However, if these resources are effectively utilized, they hold substantial potential to contribute to Malawi's energy mix. According to the May 2011 draft investment plan for scaling up renewable energy initiatives under the same ministry, Malawi receives an average insolation of 4-6 kWh/m^2 per day.

Near the equator, the SWERA report (2008) indicates that Malawi experiences high solar radiation levels regulated by altitude and climatic variations. Recent studies, such as Nkhokwe (2019), have provided a more detailed analysis of solar conditions in Malawi than previous works. Comparatively, Barman (2011) notes that Nairobi receives approximately 2,100 kWh/m^2 annually on a horizontal surface, significantly more than Gothenburg, Sweden, which receives around 900 kWh/m^2. Despite variations, certain regions in Malawi's western areas experience yearly radiation levels exceeding 2,500 kWh/m^2 (Barman, 2011).

Studies like those by Ogallo and Runanu (1989) have divided the country into solar energy zones, aiding in effective planning of solar systems. Meanwhile, insights from Hankins (1995) and Mwangi (1998) underscore the viability of solar energy systems in Kenya, with potential for significant electrical energy production under favorable conditions. Marigi (1999) conducted site-specific studies revealing variations in solar radiation across different terrains, emphasizing the importance of accurate data for effective solar energy utilization strategies.

2. Methods

2.1 Study area

A survey was conducted in twelve districts across Malawi to implement solar dryers in each district. These districts have experienced notable population growth, which has driven an increased demand for energy to support the expanding agricultural production. This situation has highlighted the potential of solar drying as a method to reduce losses experienced by many farmers and retailers. This study was conducted in Blantyre City located in the southern part of the country, Latitude: -15° 47' 5.96" S and Longitude: 35°

00' 30.74" E. Blantyre was strategically chosen for the study because it is where most social-economic decisions are made as the city hosts a lot organization headquarters including the Department of Climate Change and Meteorological services. The study was extended to Chiradzulu and Thyolo districts including other districts within Malawi which have been selected to represent the majority of Malawians who live in rural areas as statistics say 85% of Malawians are in rural areas and where most farm agricultural commodities are produced. The Chichiri station and Met headquarter were taken to represent Blantyre district which is located in the southern part of the country. Blantyre district borders Thyolo and Chiradzulu districts. Blantyre District covers an approximate area of 500 km^2. The solar radiation in this area varies from a low of 18.4 to a high of 40.3, averaging at 25.7. The average annual sunshine duration is 28 days. Data collection was carried out at multiple meteorological and agrometeorological stations, as outlined in Chapter Four of the dissertation. One such station is the Chichiri Meteorological Station, situated near Blantyre town at an altitude of around 1600 meters above sea level (Getahun et al., 2021).

In Malawi, located at 1700 meters above sea level, the moderate climate affects the performance of solar dryers, particularly during the winter season (June/July) when temperatures drop to 10 degrees Celsius. The most favorable conditions for solar dryers occur during the sunniest and warmest parts of the year, typically from November to March, when high sunshine levels coincide with the sun being directly overhead the tropics. (Ahmad et al., 2024; Warnatzsch and Reay, 2019) states that this year's mean maximum solar radiation is 24 and sunshine is 34. Malawi experiences two rainy seasons, characterized by moderate rainfall. The cloudiest period follows the first rainy season, extending until December, with frequent overcast conditions and showers. Due to its proximity to the equator, Malawi experiences minimal seasonal variations, categorized into wet and dry seasons, with little variation in the timing of sunrise and sunset throughout the year. These seasonal variations significantly impact the intensity of insolation and consequently affect the performance of solar dryers.

2.2 Instruments

2.2.1 Kipp and Zonen

The pyranometer is an instrument designed for measuring solar radiation, featuring a black ceramic disk as its sensing element that absorbs radiant energy. This disk contains one hundred thermocouples arranged in a symmetrical pattern: thermocouples near the center (hot junctions) and others near the edge (cold junctions).

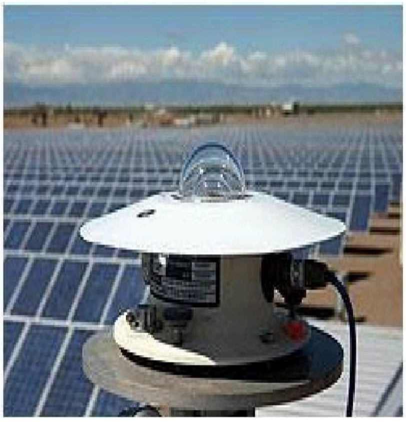

Fig. 1. Unshielded pyranometer for global solar radiation

The disk is thermally connected to the pyranometer body, which serves as a heat sink around its perimeter. When exposed to solar irradiation, heat transfers from the center to the edge of the disk. This temperature gradient across the thermal resistance of the disk generates an electromotive force (EMF), which is quantified using a voltmeter. Typically, the pyranometer is equipped with two glass domes: one for measuring global solar radiation (Figure 1), and another configuration (Figure 2) that shields the detector to assess diffuse solar radiation (Abdulkarim et al., 2020; Yohanna et al., 2011).

Figure 2. Shielded pyranometer for diffuse solar radiation

To convert the voltage from the pyranometer into solar energy in terms of megajoules per square meter (MJ/m^2), the following relation is typically used (Equation1):

$$\text{Solar energy } (\text{MJ/m}^2) = R \times L \qquad \text{(Eq. 1)}$$

After converting the recorded solar energy quantities to power density, which represents the solar output on Earth, the calculation involves dividing by the time taken to collect the data and converting from megajoules per square meter (MJ/m^2) to kilowatt-hours per square meter per day (kWh/m^2/day) (Abdulkarim et al., 2020; Warnatzsch and Reay, 2019; Yohanna et al., 2011).

2.3 Data processing and analysis

2.3.1 Quality control tests for radiation records

The quality of meteorological records used in this study underwent rigorous testing to ensure they met international standards for accuracy, completeness, and systematic recording. Major sources of errors in meteorological parameters or climatic data typically include issues with instrumentation, station conditions, recording and observation practices, transmission errors, as well as data coding, decoding, and processing.

Instrumentation errors often stem from the condition and accuracy of the instruments themselves. Changes in station conditions, such as exposure variations, can alter the microclimate around the station, leading to errors in climatic data. These factors highlight the importance of maintaining consistent and reliable conditions for meteorological measurements to minimize errors (Warnatzsch and Reay, 2019).

In this study, the quality of meteorological data was scrutinized for various types of errors, including those related to recording and observations, transmission, coding and decoding, and data processing. Recording and observation errors could arise from scale misreading, sensor issues, misinterpretation of units, or recorder failures. Transmission errors might result from failures in data transmission systems. Coding errors could occur during data coding or decoding, or from entry errors during data input. Processing errors might stem from faults in computer hardware or software, or from using incorrect initial information during data processing.

Historical data used in the study often contained missing values, necessitating the use of empirical formulas to interpolate and fill these gaps before extrapolating the data for analysis. Extrapolation was employed to analyze variations in solar radiation over time, as well as daily and seasonal trends. Line plots were utilized as a method to visualize the data, identify outliers, and apply equations to correct values, thereby reducing errors in measurements. This approach aimed to enhance the reliability and accuracy of the meteorological data used in the study.

2.3.2 Data analysis and time series analysis

This work has processed and analyzed the data comprising both diffuse and direct solar radiation for the period of 1990 to 2020 within 12 districts in Malawi. So, the hourly, monthly and annual variation are calculated. The seasonal and daily average maximum of global solar radiation and even direct and diffuse was seen in 2018 with 20.5W/m^2.

The trend analysis of hourly and yearly series of global solar radiation, diffuse, and direct solar radiation in 18 districts across Malawi shows an increase from 1990 to 2020. The highest recorded hourly and monthly values are 2527 W/m^2 and 30.4 W/m^2, respectively. These analyses were derived from historical data provided by the Department of Climate Change and Meteorological Services, which archived data for time analysis of daily and seasonal variations in solar radiation across the districts.

For daily variation, solar radiation values start low in the morning hours, increase as the day progresses towards noon, peak around midday, and then gradually decline as evening approaches. At night, solar radiation values drop to zero or near-zero levels, with occasional minor fluctuations due to radiative heat transfer from the Earth's surface. The maximum values typically occur around noon, reflecting the peak intensity of sunlight.

Seasonal variation in solar radiation shows higher values during the summer season compared to winter. This difference is due to the sun being directly overhead in Malawi during the summer, leading to increased solar energy received. Conversely, during winter, the sun's angle results in less direct radiation and lower solar energy inputs. These variations in solar radiation the whole day and across seasons are affected by meteorological factors such as cloud cover, humidity, and other atmospheric conditions, which can cause fluctuations in solar radiation values observed on the ground.

3. Results and Discussion

3.1 Monthly global solar radiation trends

Figure 3, 4, and 5 represent the average monthly, daily trends for global solar radiation at the Njolomole station in Ntcheu, Namitambo station in Chiradzulu and Mimosa station in Mulanje respectively. Figures 3, 4, and 5 show that in January, the amount of solar energy from the entire planet that reaches these areas rose, peaking in February and March. Even though the intensity was highest in March, it began to decline. This trend persisted in the months that followed, with the intensity reaching its lowest in June. After then, in August through September, the radiation intensity began to rise once more, peaking in October. Compared to February's peak, this one was higher. Additionally, it was noted that the intensity slightly increases in November before declining in December.

The fact that February happened during the summer, which is often hot, muggy, and less windy, was blamed for the peak radiation levels observed in the month, as depicted in figures 3, 4, and 5. March is when the short rainy seasons begin, and it's also when the insolation starts to decline. The mid-March rains end and continue into April. Consequently, April is the month that sees the most of the brief rains, with very little rain occurring during this month.

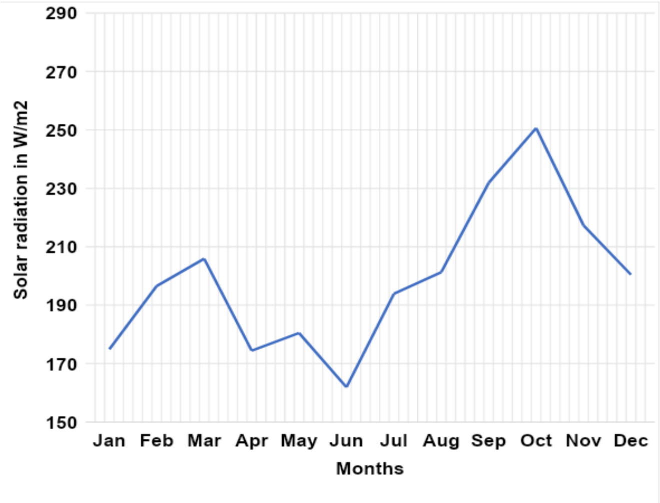

Fig. 3. 2020 monthly insolation trend for Njolemole station at Ntcheu

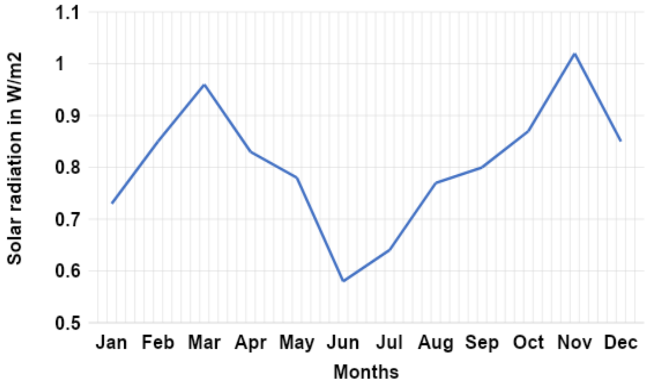

Fig. 4. 2018 Monthly insolation trend for Namitambo station at Chiradzulu

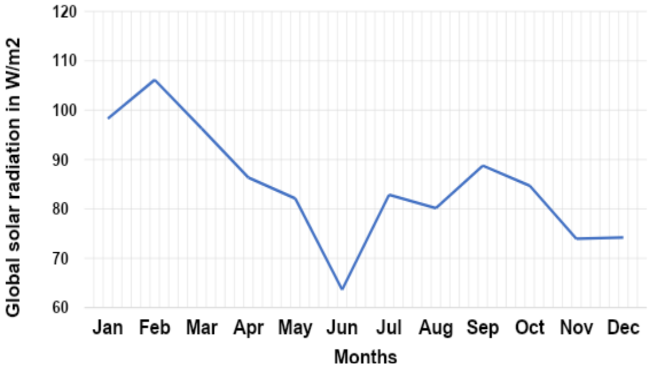

Fig. 5. 2020 Monthly insolation trend for Mimosa station at Mulanje

Beginning in May and lasting through August is the winter season. Because June is the month when the sun is furthest from the earth, radiation predictions are lower in this month. During this season, the three stations recorded the lowest levels of insolation. Low-level temperature inversions, particularly over the highlands, are typically accompanied by orographic low tropospheric clouds, or stratus, throughout this season. A large portion of the beam radiation is obstructed by the clouds and is either reflected back into the sky or absorbed by the water droplets. July actually experiences the lowest insolation as a result of this.

There is a lot of rain from September to November. The season is characterized by a lot of rain, clouds, and wetness. The months of October, November, and December see the most of the lengthy rains. Higher insolation is recorded in October and November, according to figures 3, 4, and 5. As a result of this insolation being higher than that of July and June, there is less radiation obstruction in those months. Throughout the year, the intensity also changes. When the sky is clear, it is at its maximum in December to February, and when they are cloudy, it is at its lowest in June to August. These findings are supported by the study's outcomes.

3.2 Daily variation of global solar radiation trends

Figure 6, 7, and 8 represent the average daily hourly trends for global and CMP6 solar radiation at Mimosa station in Mulanje, Chipoka station in Salima and Chidoole station in Mwanza respectively.

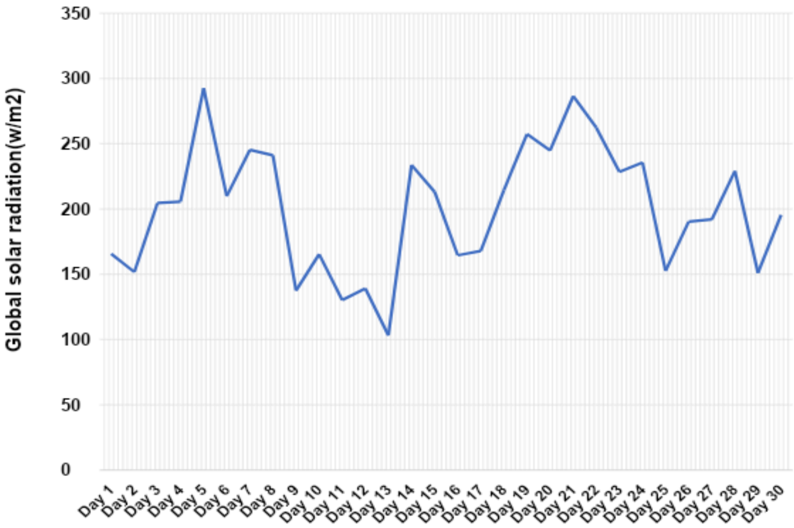

Fig. 6 . February 2019 average daily hourly global solar radiation at Mimosa station in Mulanje

Figures 6, 7, and 8 show that, on days 5 and 21, day 3 and 6, and final day 9 and 21, respectively, the global and CMP6 solar radiation reaching these places rose in intensity. Despite the intensity being high these days, it fluctuates continuously day by day of the month. The radiation intensity then keeps on increasing and decreasing again due to some of the meteorological parameters present in the atmosphere such as clouds, smoke, haze and many more. If these parameters are in large amounts cause the intensity to decrease on that day and tend to increase when the sky is clear. These meteorological conditions also affect the intensity of solar radiation during a day.

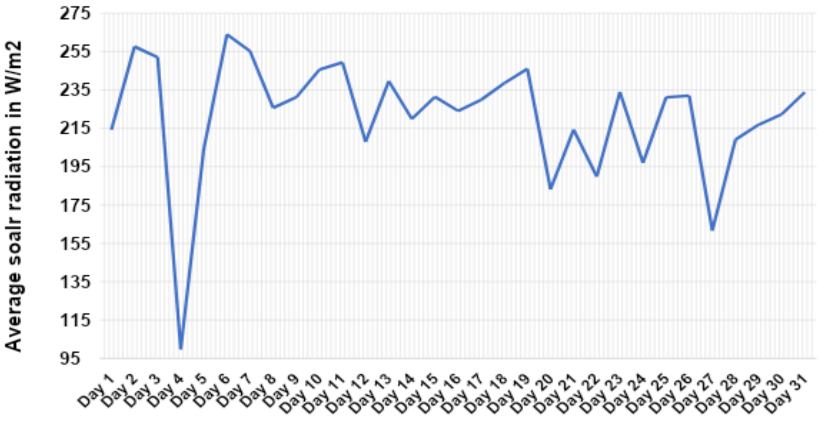

Fig. 7. January 2020 average Daily hourly CMP6 Solar radiation for Chipoka station at Salima

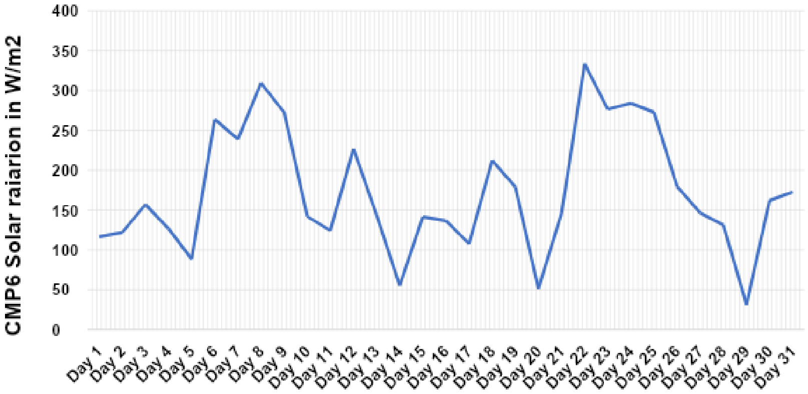

Fig. 8. December 2019 average Daily hourly CMP6 Solar radiation for Chidoole station at Mwanza

3.3 Hourly variation of solar radiation

Figure 9, 10, 11 and 12 explained how solar radiation changes hour after hour. The figures 9 and 11 showed solar radiation during the summer season which starts at 05:00 AM and ends at 18:00 PM. It is noted that the insolation strength increases and peaks first at 9:00 and 10:00 in the morning, then again at 12:00 and 13:00 in the afternoon. Thereafter, it gets decreased up around 18:00 PM.

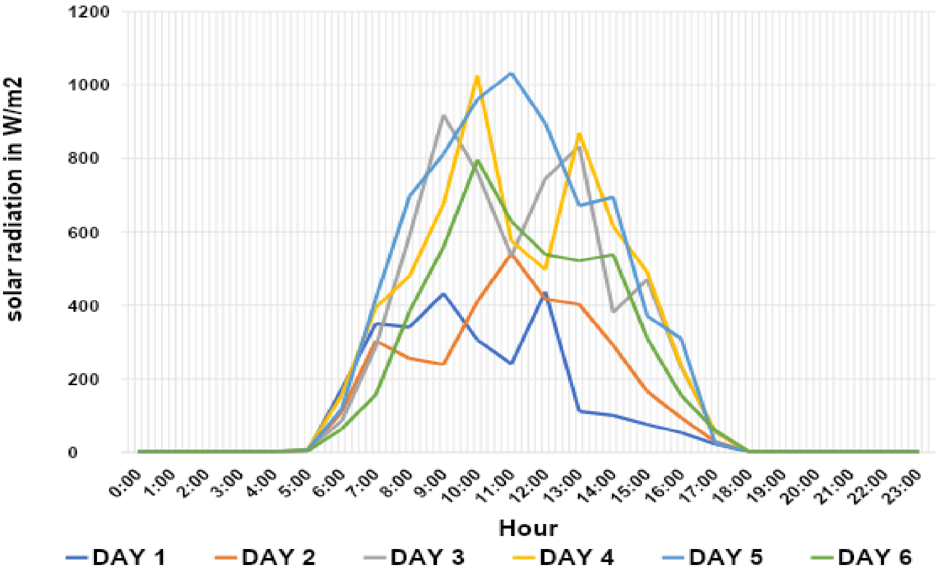

Fig. 9. 3 October, 2018 diurnal solar radiation trend for Njolemole station in Ntcheu

The fluctuation of these solar radiation intensity was a result of the presence of meteorological parameters like clouds, haze, smoke and other aerosols which absorbed, reflected and scattered the lights. From the 10 and 12, showed hourly insolation during the winter season. It has also been observed that the solar radiation starts around 06:00 AM and reaches a first peak at 09:00 AM and then second peak at 13:00 PM and finally decreases around 18:00 Pm. This indicated that during the summer season the solar radiation starts early as compared to winter season. This was a result of earth's orbit's shape. Whereas, during the summer the sun was near the earth and winter was further into the earth.

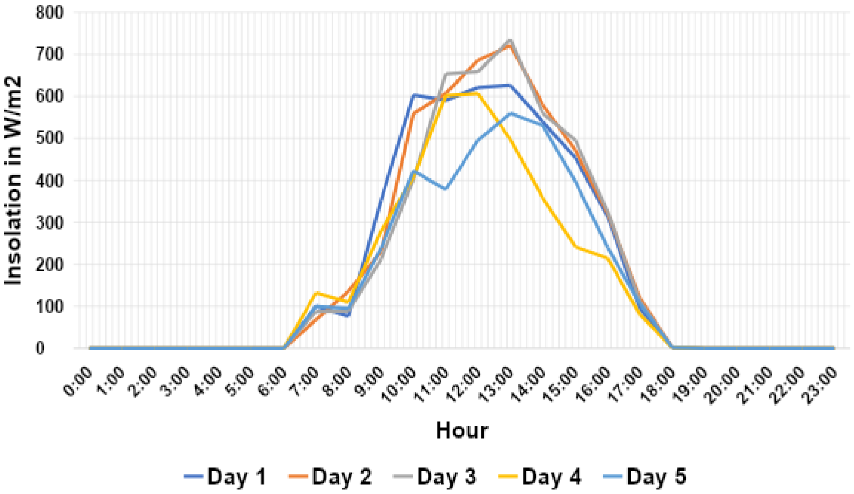

Fig. 10. 23 June, 2020 diurnal solar radiation variation for Chidoole station in Mwanza

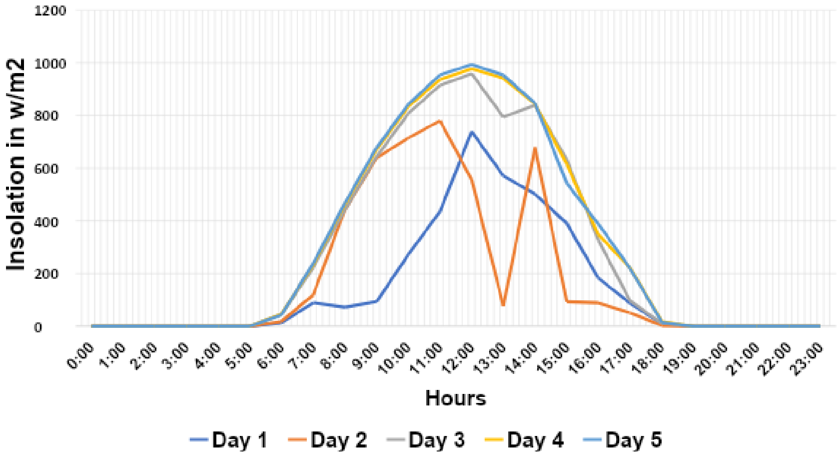

Fig. 11. 17 November, 2020 diurnal solar radiation variation for Namitambo station in chiradzulu.

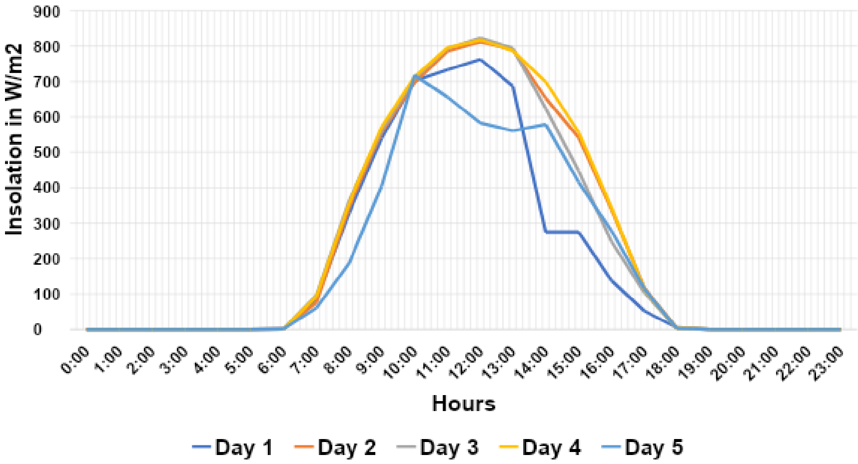

Fig. 12. 4 2019, May diurnal variation of solar radiation for Mpherembe station in Mzimba

3.4 Factors influencing the area's solar radiation

This investigation unequivocally demonstrated the existence of significant seasonal and diurnal fluctuations that impact the amount of solar electricity that is available. Climate has a bigger impact on how much solar radiation is received. It has been noted that when the long rains arrive, radiation exposure reduces. Furthermore, the cold season has a significant effect on the quantity of beam radiation received. The majority of the beam radiation is often shielded during the brief rainy season because of the high levels of moisture and clouds. The Intertropical Convergence Zone's (ITCZ) seasonal migration regulates the rainy season. It is a short band of extremely low pressure and intense precipitation that develops close to the equator of the planet. From October to April, the ITCZ migrates northward throughout Malawi. Due to this, Malawi has two separate wet seasons: the lengthy October through December rainy season and the shorter March through May rainy season. The rotation and revolution of the planet have an impact on insolation in this area as well. As a result, the sun's course changes depending on the time of day, season, and location on the surface of the earth. The earth's axis tilts 23.5 degrees, which alters the angle at which solar radiation strikes the surface of the planet and results in fluctuations in day duration that are seasonal and latitudinally. The sun's apparent alignment with the equator, tropic of cancer, or tropic of Capricorn is caused by this tilt.

3.5 Results showing the mapping of the potential areas where the solar energy can be harnessed over the area of study

The explanation of the process for creating an irradiation map was one of the objectives of this chapter four. So far, this research has discussed how to provide topography to calculate the amount of radiation, how to account for cast shadows for each hour, and how to calculate the values for each instant. Therefore, these actions must be taken in order to use the previously mentioned principles and obtain the irradiation maps. The zone that will be taken into consideration must be defined first. Malawi as my goal in this chapter. Utilizing a triangulation mesh, this goal was accomplished. A table showing the coordinates and elevations of the seven measurement stations is shown below.

Table 1. Geolocation of different measurement stations on Malawi

Station	Label	Latitude	longitude	Height
Chidoole(Mwanza)	C0	-15.46674	34.4992	929
Namitambo(Chiradzulo)	C1	-15.84052	35.27428	806
Lutchenza(Thyolo)	C2	-16.01087	35.29154	703
Njolomole(Ntcheu)	C3	-11.670277	28.647500	1402
Mimosa (Mulanje)	C4	-16.33555556	35.65833333	645.3
Mpherembe(Mzimba)	C5	-11.286	33.604	1186
Chipoka(Salima)	C6	-15.789	35.005	1038

Using elevation and albedo maps simultaneously, a refinement/refinement technique was used to create a triangulation mesh that was tailored to the geographical features of the terrain based on the albedo and topography data. Since albedo and height must be known at every mesh point, they must be interpolated from mapping of elevation and albedo, respectively. Once all of the irradiance values have been determined for each time step, we must integrate the irradiance, for instance across a day, in order to determine the real energy in the form of radiation that reaches any point of the mesh. RStudio must be used in order to integrate these numerical values and acquire the daily radiations. For example, the action flow to generate irradiation values starts with the hourly clear sky radiation calculation for all days, followed by numerical integration by watching the clear sky index and interpolation to the irradiation for real sky conditions.

Since we've come this far, we ought to be able to create maps of radiation exposure over time. R-studio software was used to map the data for this investigation. It is simple to turn these numerical values into an image because we can obtain values for any location on the mesh as well as for a day or a month. For instance, the maps of Malawi's solar radiation, which include both global solar radiation, are visible.

The Figure 13 below shows that other areas have more potential in solar energy compared to other areas. Northern part of Malawi has the highest potential seconded by

Lakeshore and Central areas. The map further shows that there is also high potential in the very Southern tip of Malawi. The map also showed that most of the areas in the Southern highlands of Malawi have low solar energy potential. However, the minimum average is very good as far as the utilization of solar energy is concerned.

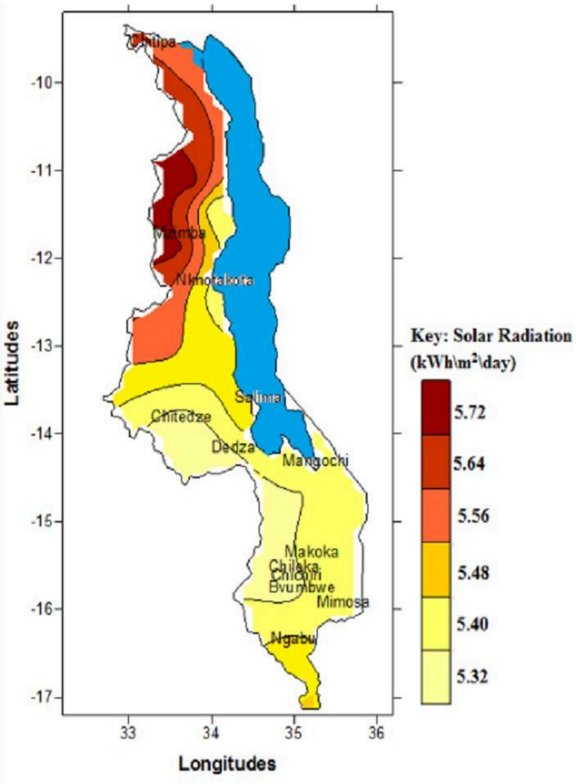

Fig. 13. Irradiation map of Malawi

If we take a look at the obtained results from figure 13, we can see that the data measured at meteorological stations contributed substantially to understanding of the solar radiation availability and variability in Malawi. The measurements also help to improve accuracy of the solar model of Malawi. Now, these models can produce more accurate solar and meteorological data for any location.

3.6 Discussion

The main purpose of the project was to assess the solar radiation potential for drying of fruits and vegetables in Malawi. The results obtained were to be used in identifying the districts which have a high rate of post-harvest losses and high demand for the solar drying method. These solar dryers are to substitute other methods of drying such as sun drying. The solar drying system is a very important method of drying because its operations can be controlled, at the same time it improves hygiene of the products as compared to the sun drying.

From the findings, 71% of the districts indicated high rates of post-harvest losses. Due to these findings, solar drying methods need to be adopted in these districts in order to reduce post-harvest losses incurred by most Farmers, Retailers and Wholesalers. The results also showed that Malawi has abundant insolation in most of districts such as Mwanza, Thyolo, Salima, Ntcheu and Mzimba which favor the installation of solar drier systems.

Although some districts have indicated high demand for these systems, the current study faced a lot of limitations and weaknesses. For instance, hostility of people, especially in the northern region to provide data on interview sessions during the survey phase. Another limitation based on accuracy of solar radiation data. The solar radiation data from other districts had a lot of missing gaps. Finally, there was a problem at the Mimosa station in Mulanje to open the data logger, due to malfunctioning of locks.

4. Conclusions

The research underscores Malawi's abundant solar energy potential, with daily insolation levels ranging from 0.02 $KWh/m^2/day$ to 0.7 $KWh/m^2/day$, supporting the year-round operation of solar drying technology, photovoltaic systems, and solar thermal systems. The clearness index indicates substantial beam solar radiation throughout the year, except during the period from December to March, which makes the region highly suitable for solar installations. Even in the absence of direct sunlight, these systems can effectively operate using diffuse solar radiation, which contributes between 30% to 50% of the total global solar radiation.

The emphasis on diffuse solar radiation underscores the importance for designers, engineers, and manufacturers to integrate it into their designs. The study also highlights that the implementation of solar drying systems hinges on local solar radiation levels and user demand from sectors such as retailers and farmers, although the high costs associated with these technologies remain a significant challenge.

Furthermore, it is recommended to establish ground stations specifically designed to capture comprehensive data on solar energy systems. These stations should be equipped with instruments capable of measuring diffuse, direct, and global solar radiation. Data collection devices should be integrated to facilitate efficient data retrieval and storage, thereby enabling further research on solar radiation resources, especially on inclined surfaces where altitude considerations can play a crucial role in accurately assessing available solar radiation.

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Author Contribution

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The authors declare no conflict of interest.

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