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Estimation of the Monthly Albedo of the Earth's Atmosphere over Sokoto, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. The data for the work was sourced and analyzed by author DOA. Author DOA also design the study, draft and edited the manuscript. Author MII assisted in literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

In this study, the shortwave solar energy balancing at the edge of the earth's atmosphere was employed to estimate the variation of albedo for Sokoto, Nigeria (Latitude 13.02°N, Longitude 05.25°E and altitude 350.8 m above sea level). The measured meteorological parameters of monthly average daily global solar radiation, minimum and maximum temperature, relative humidity and rainfall during a period of thirty one years (1980-2010) were utilized in this study. The results show that the albedo depicts direct opposite relationship with the clearness index, an inverse relationship with the emitting earth's surface temperature and direct relationship with the wavelength for the study area. The highest value of albedo simulated was in the month of August (0.4925) and the lowest in the month of November (0.3185). The emitting earth surface temperature for each month ranged between 235.2214 K in August and 253.2080 K in November, these values agrees closely to the standard emitting earth surface temperature (255.0000 K). The maximum emitting wavelength revealed that the radiation is longwave and are found within the infrared region of the electromagnetic spectrum. The albedo deduced from this study ranged from 0.3185 to 0.4925 which are consistent with the possible values of albedo of different surface covering the earth's surface and agrees closely to the standard planetary albedo (0.3000). The

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estimated albedo is an important input parameter in evaluating solar energy collectors, radiative transfer in the atmosphere and studies dealing with thermal balance in the atmosphere. The variation of albedo with rainfall revealed that the highest and lowest albedo were observed in August and November where the region has its peak value in rainy season and onset of dry season. The highest albedo observed corresponds to the lowest solar radiation in August. The highest albedo observed in August corresponds to the minimum temperature attained in August when it decreases during the rainy season. The albedo and relative humidity depicts almost similar pattern and attained their highest values in August. The regression equations for estimating the albedo in relation to other parameters revealed that the clearness index and rainfall contributes most in albedo estimation for the study area under investigation and regions with similar climatic information.

Keywords: Albedo; solar radiation; surface temperature; wavelength; Sokoto; Nigeria.

1. INTRODUCTION

The sun is the star closest to the earth, and its radiant energy is practically the only source of energy that influences atmospheric motions and earth's climate [1]. Among the renewable energy resources, only solar energy has the greatest potentiality, availability and is free from environmental hazard [2]. The solar radiation reaching the Earth's surface depends upon the climatic condition of the location, hence, the study of what happens to sunlight as it passes through the atmosphere is crucial to many aspects of science and general knowledge [3]. Over the years, the amount of solar radiation reaching the Earth's surface is being modified through reflection, scattering and absorption in the atmosphere. The fraction of the incident solar radiation that is reflected and scattered back into space is called albedo.

Albedo is related to reflection of solar radiation at a surface and therefore defined in terms of it, as the ratio of the reflected solar radiation to the incident solar radiation at the surface, i.e., H_r/H_o. The extraterrestrial radiation, H_o at the edge of the atmosphere, from the sun, is considered the incident solar radiation. Albedo or reflection co-efficient is also known as reflectance or reflectivity of a surface; by this, the surface albedo of the Earth is regarded the same as planetary albedo by many scientists [1]. The average overall albedo of the Earth, its planetary albedo, is about 0.3. This fraction of incoming radiation is reflected back into space. The other 0.7 part of the incoming solar radiation is absorbed by our planet [4]. It is assumed however that the reflected radiation, H_r, is both diffuse and specular in nature, that is, it is diffuse if the reflected radiation is uniform or isotropic in all angular directions, and specular if the surface of reflection is smooth with respect to the wavelength of the incident radiation such that the laws of reflection are satisfied [1].

It was said by [5] that the observed albedo assumed that the radiation field is isotropic. Albedo, as a property of a surface, therefore, can be used to determine the brightness of a surface. According to [6], materials with high albedo and emittance attain low temperature when exposed to solar radiation, and therefore reduce transference of heat to their surroundings. Thus albedo is an important input parameter or quantity in evaluating the total insolation on a building or a solar energy collector. It is also important in the studies dealing with thermal balance in the atmosphere. The Earth's albedo affects the amount of Sun-light the planet absorbs. It plays a major role in the energy balance of the Earth's surface, as it defines the rate of the absorbed portion of the incident solar radiation. Hence, it has a direct effect on Earth's energy budget and, therefore, global temperatures. If the Earth receives more energy from the Sun than it sends back to space, the Earth gets warmer. On the other hand, if the Earth reflects more of the Sun's energy than it absorbs, the Earth gets colder. Some studies on the albedo of the Earth's atmosphere for different locations have been investigated. [3] Estimated the albedo for Kano, Nigeria. In their studies they obtained maximum albedo of 0.58 in August (the peak of cloud activity) while the minimum albedo of 0.41 in November (the onset of dry season) using global solar radiation data for Kano, Nigeria during the period of 34 years (1977-2010) obtained from the International Institute for Tropical Agriculture, Ibadan, Nigeria. In the study carried out by [4] they obtained the albedo for Ilorin, Nigeria ranging between 0.361 and 0.644 using global solar radiation data measured at the Department of Physics in the year 2000. The highest albedo recorded was 0.644 at the peak period of cloud activity in August and the lowest was 0.361 in November when it was relatively cloudless and dustless. Seven years later the study carried out by [4] was expanded, the values of albedo obtained was confirmed, however, approximated by the leading author in [7]. In another development, [8] adopt the model for shortwave solar energy balancing at the edge of earth atmosphere to estimate the albedo for Makurdi, Nigeria. The results indicated that the highest albedo of 0.7 in August and the lowest of 0.5 in November were estimated using global solar radiation data covering the period (2000-2010) obtained from the Air Force Base, Makurdi, Nigeria. In a related study [9] obtained albedo at Maceio, Brazil as 0.47 and 0.41 during the rainy and dry seasons respectively.

The aim of this present work is to (i) estimate the value of the earth's albedo at Sokoto, Nigeria, (ii) compare the emitting earth surface temperature for the study area to the standard value of emitting surface temperature of the earth (iii) to verify the type of radiation based on the values of the wavelength obtained for the study area (iv) obtain a regression equation relating the albedo and the estimated and meteorological parameters (v) investigate the variation of albedo with the meteorological parameters.

2. STUDY AREA

Sokoto (Fig. 1), the capital of Sokoto state is a city located in the extreme northwest of Nigeria, near the confluence of the Sokoto River and the Rima River. Sokoto is in the dry Sahel surrounded by sandy savannah and isolated hills. Rainfall in Sokoto State as in other parts of Nigeria is dominantly controlled by the movement and pulsation of the ITD (Inter-Tropical Discontinuity) [10]. Similar to other extreme northern parts of the country, rainfall in Sokoto State is very erratic and unpredictable with irregular onsets and cessations which adversely affect the duration of the cropping seasons. The maximum daytime temperatures are generally under 40℃ (104.0℉) most of the year, and the dryness makes the heat bearable. The warmest months are February to April, where daytime temperatures can exceed 45℃ (113.0 ℉). The highest recorded temperature is 47.2℃ (117.0℉), which is also the highest recorded temperature in Nigeria [11]. The rainy season is from June to October, during which showers are a daily occurrence. The showers rarely last long and are a far cry from the regular torrential showers known in many tropical regions. From late October to February, during the 'cold season', the climate is dominated by the harmattan wind blowing Sahara dust over the land. The dust dims the sunlight, thereby

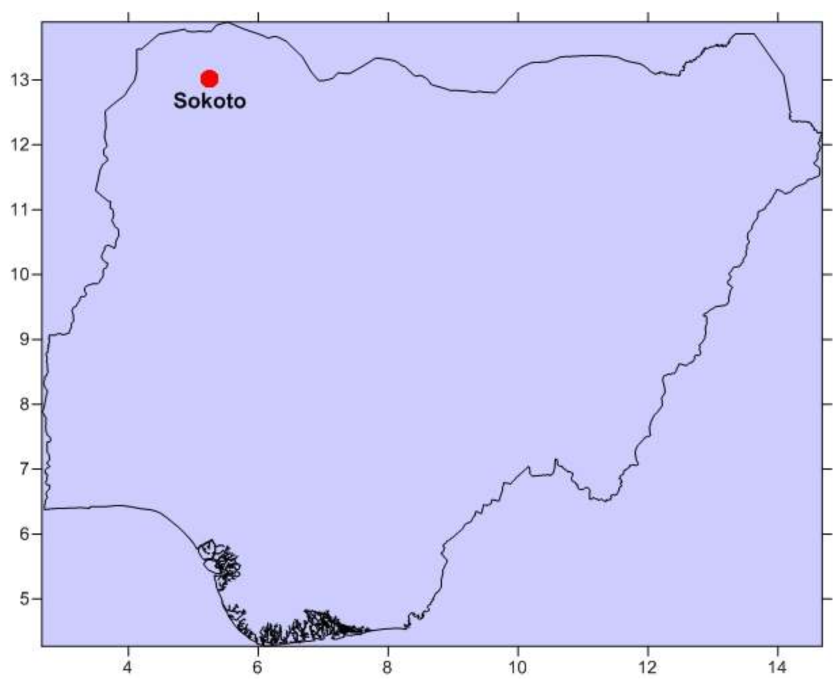

Fig. 1. Map of Nigeria showing the study area

lowering temperatures significantly and also leading to the inconvenience of dust everywhere in the house.

There are two major seasons in Sokoto, namely wet and dry. The dry season starts from October, and lasts up to April in some parts and may extend to May or June in other parts. The wet season on the other hand begins in most parts of the state in May and lasts up to September, or October. The harmattan, a dry, cold and fairly dusty wind is experienced in the state between November and February. Heat is more severe in the state in March and April. But the weather in the state is always cold in the morning and hot in the afternoons, save in peak harmattan period. The topography of the state is dominated by the famous Hausa plain of northern Nigeria. As of 2006 it has a population of 427,760. Agriculture is the mainstay of the people [12].

3. METHODOLOGY

The monthly mean daily measured global solar radiation, minimum and maximum temperature, relative humidity and rainfall data used in this present work was obtained from the Nigerian Meteorological Agency (NIMET). The period under focus is thirty one years (1980 – 2010). The mean temperature was obtained by taken the average of the minimum and maximum temperature. The extraterrestrial radiation, H_0 is the solar radiation received at the top of the Earth's atmosphere from the sun on a horizontal surface and is considered as the incident solar radiation. The monthly mean daily extraterrestrial radiation, H_0 on a horizontal surface was computed from the expression given by [13] as:

$$H_o = \left(\frac{24}{\pi}\right) I_{sc} \left[1 + 0.033 Cos\left(\frac{360n}{365}\right)\right] \left[Cos\varphi Cos\delta Sin W_s + \left(\frac{2\pi W_s}{360}\right) Sin\varphi Sin\delta\right] \quad (1)$$

where I_{sc} is the solar constant (=1367 Wm^{-2}), φ is the latitude of the site, δ is the solar declination and W_s is the mean sunrise hour angle for the given month and n is the number of days of the year starting from 1^{st} of January to 31^{st} of December.

The solar declination, δ and the mean sunrise hour angle, W_s can be calculated using the following equation [1] and [14]:

$$\delta = 23.45 sin\left\{360\left(\frac{284+n}{365}\right)\right\} \quad (2)$$

$$W_s = Cos^{-1}(-tan\varphi tan\delta) \quad (3)$$

According to [7] and [15] shortwave solar energy balancing at the edge of the Earth's atmosphere can be computed using the expression:

$$\frac{H_m}{H_0} + \frac{H_a}{H_0} + \frac{H_r}{H_0} = 1 \quad (4)$$

where H_m is the measured global solar radiation ($MJm^{-2}day^{-1}$), H_0 is the extraterrestrial radiation ($MJm^{-2}day^{-1}$), the ratio $\frac{H_m}{H_0}$ is the fraction of the extraterrestrial radiation, H_0 transmitted through the atmosphere to the ground surface, and is known as the clearness index [16,17], H_a is the absorbed solar radiation, the ratio $\frac{H_a}{H_0}$ is the solar energy fraction absorbed, and is known as the absorption co-efficient or absorbance, and $\frac{H_r}{H_0}$ is the solar energy fraction reflected back to space, and is known as the reflection co-efficient or reflectance [15] and H_r is the shortwave reflected radiation. According to the study carried out by [15]. The ratio $\frac{H_a}{H_0}$ was found to be very small in value compared with the other ratios given in equation (4) and therefore negligible, i.e., $\frac{H_a}{H_0} \ll 1$

Therefore equation (4) becomes

$$\frac{H_m}{H_0} + \frac{H_r}{H_0} \approx 1 \quad (5)$$

From this, an expression for estimating the reflectivity or albedo was obtained as

$$\frac{H_r}{H_0} = 1 - \frac{H_m}{H_0} \quad (6)$$

The flux density of longwave radiation emitted by the Earth, F_E, given by the Stefan-Boltzmann law [18] is expressed as

$$F_E = \sigma T_E{}^4 \quad (7)$$

where σ is the universal Stefan-Boltzman constant, $\sigma = 5.67 \times 10^{-8}\, Wm^{-2}K^{-4}$ and T_E is the Earth's temperature, in Kelvin (K). F_E is also given [18] as

$$F_E = \frac{\left(1-\frac{H_r}{H_0}\right)F_s}{4} \quad (8)$$

where $\frac{H_r}{H_0}$ is the planetary albedo of the Earth for the study area and F_s is the flux density of solar radiation incident upon the Earth ($1368\ Wm^{-2}$).

Combining equations (7) and (8), the following equation was obtained that relates the surface temperature of the Earth, T_E to its albedo for the study area [18,19] as

$$T_E = \left[\left(\frac{\left(1-\frac{H_r}{H_0}\right)F_s}{4\sigma}\right)\right]^{1/4} \quad (9)$$

Equation (9) indicates that the temperature T_E would decrease as albedo increases.

In atmospheric science the term "shortwave" $(\lambda < 4\,\mu m)$ refers to the wavelength band that carries most of the energy associated with solar radiation and "longwave" $(\lambda > 4\,\mu m)$ refers to the band that encompasses most of the terrestrial (Earth-emitted) radiation [18]. In the radiative transfer literature, the spectrum is typically divided into the regions shown in Fig. 2. The relatively narrow visible region, which extends from wavelengths of 0.39 to 0.76 μm, is defined by the range of wavelengths that the human eye is capable of sensing [18]. The near infrared region, which extends from the boundary of the visible up to $\sim 4\,\mu m$, is dominated by solar radiation, whereas the remainder of the infrared region is dominated by terrestrial (i.e., Earth emitted) radiation [18]. Microwave radiation is not important in the Earth's energy balance but it is widely used in remote sensing because it is capable of penetrating through clouds [18]. The maximum wavelength of emission at temperature, T_E is given by the Wien's displacement law [18] as

$$\lambda_m = \frac{2897}{T_E} \quad (10)$$

λ_m is expressed in micrometers and T_E in degrees Kelvin.

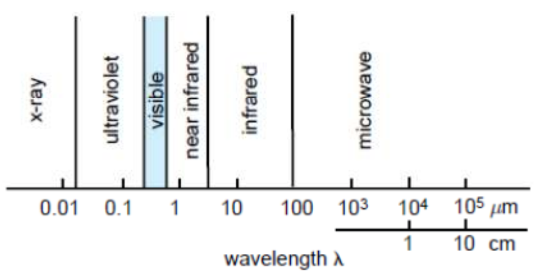

Fig. 2. The electromagnetic spectrum [18]

4. RESULTS AND DISCUSSION

Table 1 shows the variation of the monthly average daily albedo, clearness index, short wave reflected radiation, surface temperature and wavelength for the study area. The monthly average daily albedo, shortwave reflected radiation and the maximum emitting wavelength, decreases slightly from the months of January to February, increases from the month of March to August, decreases from the month of September to November and increases slightly in December. The clearness index and surface temperature shows opposite relationship for the study area under investigation.

4.1 Regression Equation Relating the Albedo and other Parameters

The regression equation relating the albedo and other estimated parameters is given by the expression:

$$\frac{H_r}{H_0} = 1.00 - 1.00\frac{H_m}{H_0} + 1.013 \times 10^{-17} H_r - 6.82 \times 10^{-6} T - 8.20 \times 10^{-15} \lambda \quad (11)$$

where λ is the wavelength and the other terms have been defined previously. The coefficient of determination $R^2 = 100\%$ is obtained for this present regression analysis.

The p-values for the estimated parameters are $\frac{H_m}{H_0} = 7.43 \times 10^{-90}$, $H_r = 0.302$, $T = 0.743$ and $\lambda = 0.749$. This shows that the clearness index with the least p-value contributes most to albedo estimation while the wavelength with the highest p-value contributes least as compared to H_r and T.

The regression equation relating the albedo (H_r/H_0) and the measured global solar radiation (H_{mea}), mean temperature (T_{mean}) relative humidity (RH) and the rainfall (RF) is given by the expression:

$$\frac{H_r}{H_0} = 0.258 - 0.00622 H_{mea} + 0.00806 T_{mean} - 0.000204 RH + 0.000783 RF \quad (12)$$

The coefficient of determination $R^2 = 96.6\%$ is obtained for this present regression analysis.

The p-values for the meteorological parameters are $H_{mea} = 0.4253$, $T_{mean} = 0.02719$ $RH = 0.6937$ and $RF = 0.00254$. The results of the analysis show that the rainfall with the least p-value contributes most to albedo estimation as compared to the global solar radiation, mean temperature and relative humidity.

Table 1. Monthly average daily albedo, clearness index, short wave reflected radiation, surface temperature and wavelength for Sokoto (1980 – 2010)

Month	H_r/H_0	H_m/H_0	Hr ($MJm^{-2}d^{-1}$)	T (K)	Wavelength (μm)
Jan	0.3370	0.6630	10.2961	251.4678	11.5204
Feb	0.3364	0.6636	11.2190	251.5290	11.5176
Mar	0.3606	0.6394	13.0898	249.2033	11.6250
Apr	0.3934	0.6066	14.9463	245.9420	11.7792
May	0.4229	0.5771	16.1376	242.9000	11.9267
Jun	0.4435	0.5565	16.7861	240.7037	12.0355
Jul	0.4894	0.5106	18.5270	235.5727	12.2977
Aug	0.4925	0.5075	18.6248	235.2214	12.3161
Sep	0.4183	0.5817	15.3491	243.3787	11.9033
Oct	0.3550	0.6450	12.0961	249.7481	11.5997
Nov	0.3185	0.6815	9.8973	253.2080	11.4412
Dec	0.3372	0.6628	9.9613	251.4533	11.5210

4.2 Variation of Albedo, Surface Temperature and Maximum Wavelength

Fig. 3 shows the monthly average daily planetary albedo for the study area. The figure indicates that high values of albedo were recorded in the months of July, August and September with the highest in August (0.4925) and relatively low values in the months of October, November and December with the lowest in November (0.3185). The highest value of albedo recorded in the month of August shows that this is the month where we have the peak of rainy season in the study area and a predominantly cloudy month, attest to the fact that reflection of solar radiation by the planet earth in this region, are mostly due to clouds, aerosols and air molecules of which cloud is the chief. The surface albedo obtained for the study area ranged between 0.3185 and 0.4925 with the highest value in the month of August (0.4925) during the peak period of rainy season and the lowest in November (0.3185) during the onset of dry season when it was relatively cloudless and dustless. The values of the albedo obtained for this study area under investigation compares favourably well with previous studies such as that of [4] where they obtained the albedo for Ilorin, Nigeria ranging between 0.361 and 0.644. The highest albedo recorded was 0.644 at the peak period of cloud activity in August and the lowest was 0.361 in November when it was relatively cloudless and dustless. [3] Estimated the albedo for Kano, Nigeria. In their studies they obtained maximum albedo of 0.58 in August (the peak of cloud activity) while the minimum albedo of 0.41 in November (the onset of dry season). In another development, [8] adopt the model for shortwave solar energy balancing at the edge of earth atmosphere to estimate the albedo for Makurdi, Nigeria. The results indicated that the highest albedo of 0.7 in August and the lowest of 0.5 in November were obtained.

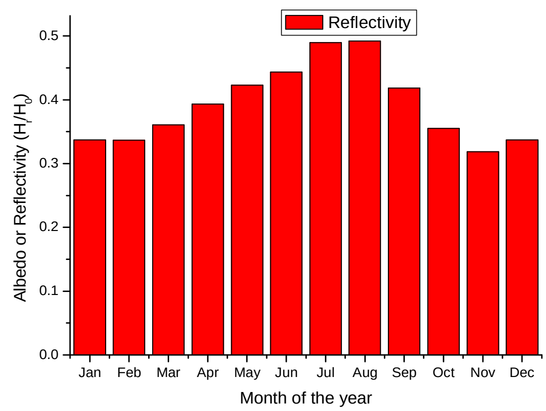

Fig. 3. Monthly average daily reflectivity for Sokoto (1980 – 2010)

Fig. 4 shows the variation of the emitted temperature by the earth for the study area. The highest temperature was recorded in the month of November (253.2080 K) as this is expected because the albedo is low during this period, thereby allowing more radiation into the earth which consequently increases the temperature. The lowest temperature was recorded in the month of August (235.2214 K), this is the most cloudy month for this region, where the rainy season is at its peak; the low temperature is expected, due to high reflection of solar radiation. In this present study, the surface temperature ranged between the values 235.2214 K – 253.2080 K which compares favorably well with standard value for the emitting surface temperature of the earth (255.0000 K) at albedo of 0.300 [18]. The results revealed that there is an inverse relationship between the earth emitting surface temperature and the planetary albedo.

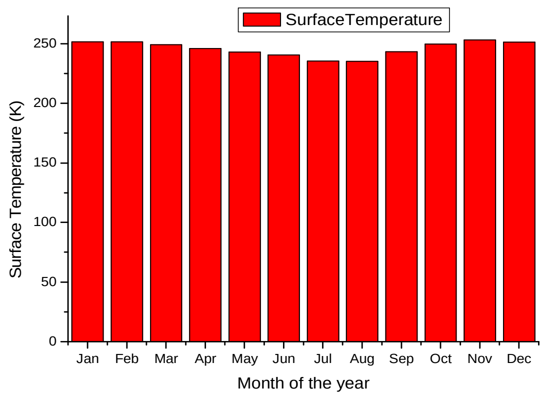

Fig. 4. Monthly average daily surface temperature for Sokoto (1980 – 2010)

Fig. 5 shows the variation of monthly average daily maximum emitting wavelength for the study area. The highest peak wavelength was estimated in the month of August (12.3161 μm) and the lowest in the month of November (11.4412 μm). The peak wavelength ranged in the values between 11.4412 μm – 12.3161 μm this values agrees with that reported in radiative transfer literatures, that for longwave radiation $(\lambda > 4\,\mu m)$ [18] this shows that the radiation is terrestrial (Earth emitted), and therefore within the infrared region.

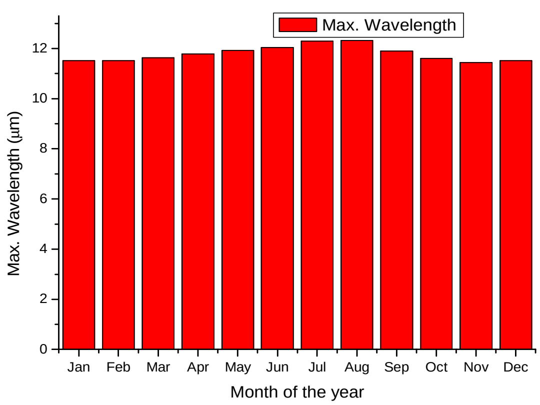

Fig. 5. Monthly average daily wavelength for Sokoto (1980 – 2010)

4.3 Comparison between Albedo and Clearness Index

Fig. 6 compares the variation of the reflectance, reflectivity or albedo and the clearness index for the study area during the study period, the figure shows that the reflectance have opposite characteristics to the clearness index. The magnitude of the reflectance indicates the degree of brightness of the surface and the amount of the solar radiation reflected back to space. Therefore, when the sky is relatively cloudless, albedo or reflection coefficient would be relatively small, in this case, more radiation would be available to solar energy devices on the earth. The measured solar radiation (H_m) and the shortwave reflected radiation (H_r) are both fractions of the extraterrestrial radiation (H_0), thus, the clearness index and reflectance can be compared. The values of the clearness index are larger than those of the reflectance, throughout the months for the study area, the implication of this, is that, since the solar radiation (H_m) is towards the ground surface and the shortwave reflected radiation (H_r) is towards the space, thus, the global solar radiation (H_m) received on the Earth's surface is more than the reflected radiation (H_r) lost to space throughout the months in the study area, during the period of study; indicating the availability of abundant solar radiation in the region. However, almost similar values were observed in the months of July and August; the closest was in the month of August (1.50% difference), this is where the region is said to have its peak value of albedo during the rainy season. The highest and lowest values of clearness index was observed in the months of November and August respectively while the highest and lowest values of albedo was observed in the months of August and November respectively confirming their opposite relationship as depicted in the figure.

4.4 Variation of Albedo with Meteorological Parameters

Fig. 7 show that the pattern of variation of rainfall with albedo has almost similar pattern. This indicates that the rainfall is an important parameter to be considered for albedo estimation. The rainfall and albedo has almost constant values from January to February. The rainfall increases slightly from February to March and remain almost constant from March to April. There is a steady increase from April to its maximum value in August which corresponds to the highest value of albedo observed for the study area. The rainfall and albedo decreases from August to November where the onset of dry season commences and this corresponds to the lowest albedo observed. It is clear from the figure that there is little or no rainfall from November to

April which is the period of dry season, similar to most parts of the country. It was observed that rainfall becomes pronounced from May and last to October with its peak value in August. The results of regression analysis revealed that rainfall is the most important meteorological parameter that contributes to albedo estimation as compared to other parameters considered in this present study.

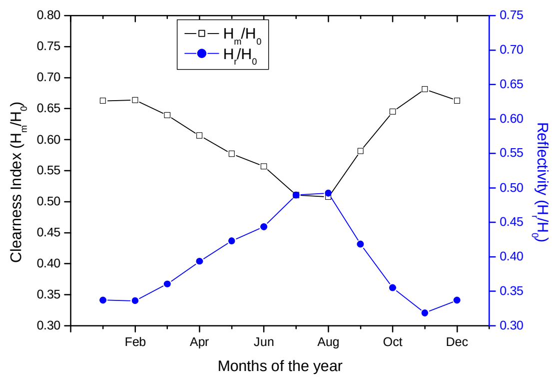

Fig. 6. Comparison between the reflectivity (H_r/H_0) and the clearness index (H_m/H_0)

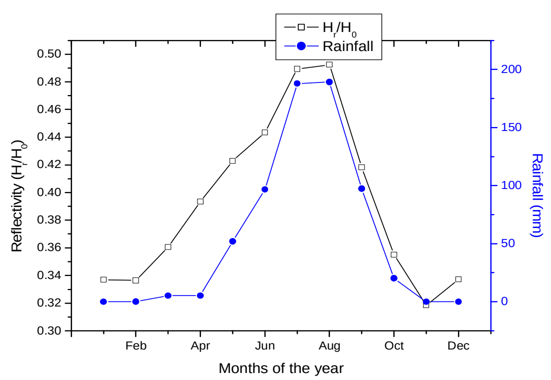

Fig. 7. Variation of monthly mean rainfall with reflectivity for Sokoto (1980 – 2010)

In Fig. 8 the highest reflectivity (albedo) recorded in the month of August corresponds to the lowest solar radiation observed in August where we have the peak of rainy season in the study area. The implication is that probably more radiation was reflected back to space than received on the surface of the earth in this month which led to low surface temperature of the earth and high albedo. On the other hand, it is expected that the lowest albedo recorded in the month of November should correspond to the highest solar radiation in the same month; but, occurred during the onset of dry season, this may probably be due to atmospheric variability. However, in general, the result indicated that high values of solar radiation correspond to low albedo and low values of solar radiation correspond to high albedo. The results also show that the variation of solar radiation with albedo depicts almost a direct opposite relationship. This study is in line with that reported by [3].

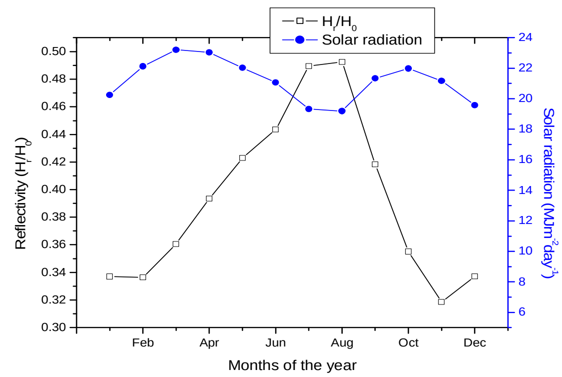

Fig. 8. Variation of monthly mean global solar radiation with reflectivity for Sokoto (1980 – 2010)

In Fig. 9 the temperature increases from January to April and decreases from April to a minimum value in August. The minimum value attained in August corresponds to the highest albedo observed. The decrease in temperature from May to August is an indication of rainy season. However, the rainfall last to October, but, the maximum rainfall occurs in the month of August almost throughout the years for the study area. Since rainfall for this region is very erratic and unpredictable the season sometimes is from June to October. The temperature increases subsequently from August to October and drop from October to December. It was observed that the temperature decreases from October to February. This is the cold season for the study area when the climate is dominated by harmattan wind blowing sahara dust over land. It was expected that the temperature should increase just like most of the coastal regions in Nigeria, but, decreases because of the dust particles in the atmosphere that dims the sunlight. The onset of the dry/harmattan season in November corresponds to the lowest albedo observed.

Fig. 10 shows that the pattern of variation of relative humidity with albedo have almost similar trend. This is an indication that the moisture content in the atmosphere may be considered to give reasonable estimates of the albedo when there is no rainfall data. The relative humidity slightly decreases from January to February. The relative humidity and albedo increases from February and attained their maximum value in August. The implication is that the highest relative humidity in August corresponds to the highest albedo in the same month. The relative humidity and albedo decreases from August to November and increases slightly to December. The implication is that the onset of dry/harmattan season in November corresponds to where we have the lowest albedo for the study area under investigation.

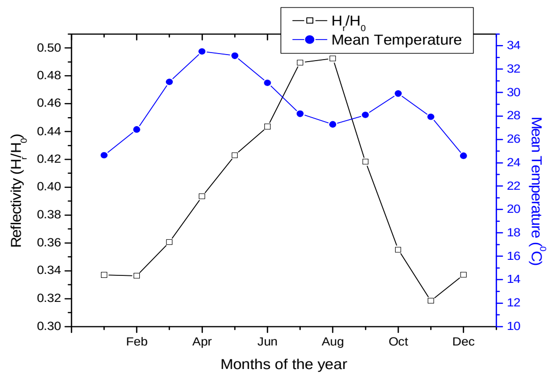

Fig. 9. Variation of monthly mean temperature with reflectivity for Sokoto (1980-2010)

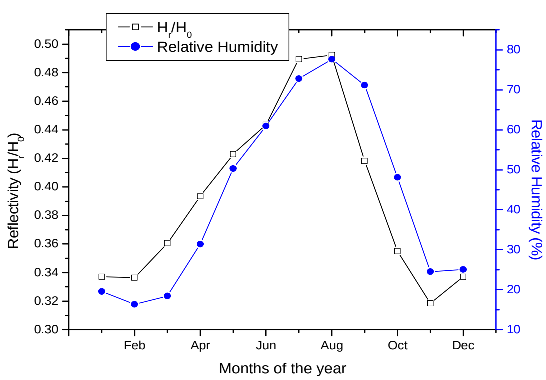

Fig. 10. Variation of monthly mean relative humidity with reflectivity for Sokoto (1980-2010)

5. CONCLUSION

The surface albedo for Sokoto, Nigeria (Latitude 13.02^0N, Longitude 05.25^0E and altitude 350.8 m above sea level) during the period under study was simulated using the shortwave solar energy balancing at the edge of the earth's atmosphere. The surface albedo ranged between 0.3185 and 0.4925 for the study area. These values seems to be slightly higher when compared to the standard average value of earth's surface albedo (0.3000); although, compares favourably well with previous research studies and within the range of surface albedo values found for different locations considered acceptable by other researchers which varies from 0 for no reflection to 1 for complete reflection of light striking the surface. The atmospheric factors influencing the reflection and scattering of solar radiation are clouds, aerosols, air molecules and particles with clouds being the most. The highest value of albedo and the least albedo was found in the months of August and November respectively for the study area. The surface temperatures ranged between 235.2214 K and 253.2080 K and are in close agreement with the standard emitting surface temperature (255.0000 K). The maximum emitting wavelength ranged between 12.3161 μm in August and 11.4412 μm in November which confirms longwave radiation $(\lambda > 4\,\mu m)$ and fall within the infrared region of the electromagnetic spectrum. The variation of albedo and rainfall revealed that the highest and lowest albedo were observed in August and November where the region has its peak value in rainy season and onset of dry season. The variation of albedo with solar radiation revealed that the highest albedo observed in the month of August corresponds to the lowest solar radiation observed in August. The variation of albedo with temperature revealed that the decrease in temperature during the rainy season from April until it attained its minimum value in August corresponds to the highest albedo observed. The variation of albedo with relative humidity gives almost similar pattern with both having their peak value in August. The regression equations showed that the clearness index and rainfall contributes most in the estimation of albedo for the cases of comparison evaluated. It is believed that this present research provides important input parameters in evaluating solar energy collector, relevant parameter in radiative transfer in the atmosphere and studies dealing with thermal balance in the atmosphere for the study area and regions with similar climatic information.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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