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Forecasting the Diffuse Solar Radiation by using a New Modeling over Saudi Arabia

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Abstract: Within the arranging and execution assessment of solar energy projects, particularly within the planning and estimation of solar photovoltaic sources as elective energy sources within the future, exact evaluation of Diffuse Solar Radiation (DSR) is one of the essential and basic issues. The target of this article is to use the new model to predict DSR in four different locations in Saudi Arabia. The author explored the available meteorological and radiation data. The data covers the 25 years from 1990 to 2014 and were measured at Al-Baha, Abha, Jeddah and Taif locations in Saudi Arabia. Through detailed statistical evaluation and analysis, 19 empirical models were tested to construct the best empirical model to estimate the monthly average daily DSR of Saudi Arabia. Using widely used statistical errors, namely MBE, MPE, RMSE, U_{95} , R, t-test and GPI the proposed correlation model was compared with 19 models provided in the literature. Through this analysis, the cubic empirical equation model is selected as the good model. Compared with these existing models, this model reveals accurate results with minimal statistical errors. Based on these results, Model 22 gives the highest GPI value. The conclusion is the cubic equation model of the diffusion fraction (i.e., $D/G = 0.215 + 2.123 (S/S_0) - 3.547(S/S_0)^2 + 5.142 (S/S_0)^3$) is the best agreement model that has been mentioned in the previous discussion. This model is a generalized equation in Saudi Arabia, which can forecast the monthly average daily diffuse radiation on the horizontal plane at any site under similar climatic conditions without the measured climatic conditions. Experts or architects can use this model to perform site selection and technical and financial evaluation of solar energy applications and photovoltaic technology.

Keyword: Diffuse Solar Radiation (DSR), Statistical Indicators, Solar Energy, Meteorological Data and Empirical Model

Introduction

Solar radiation data is the basic input for solar applications, such as photovoltaic, solar thermal systems and passive solar design. The data should be reliable and can be used at any time to design, optimize and evaluate the performance of solar technology at any site. However, it is not economically feasible to install solar radiation measuring instruments wherever possible. Therefore, the use of mathematical models to forecast the solar radiation in a given area has proved to be a viable option based on the measurement results of limited locations (Li *et al.*, 2015; Shukla *et al.*, 2015a). Unfortunately, in many developing countries, solar radiation measurement is not yet available because they cannot afford the equipment and

measurement technology. Hence, it is vital to create methods for evaluating solar radiation based on more promptly accessible meteorological data. Within the design and execution examination of solar energy projects, particularly within the design and measure assurance of solar PV as a future alternative energy source, exact forecast of Diffuse Solar Radiation (DSR) is essential. Careful thought of DSR can way better assess the productivity of the solar system (Shukla *et al.*, 2015b; 2016a; Jamil *et al.*, 2016).

In addition, in several regions of the world, there is no or very little measurement of diffuse solar radiation. Because of their wide application in other places, they can measure total horizontal irradiance and other standard meteorological variables, such as sunshine duration,

temperature and relative humidity. In the field of meteorology and agriculture, given global solar radiation data and some meteorological parameters, the diffusion component can be obtained through various correlations. Recently, extensive research has been conducted in many parts of the world to estimate DSR using the most widely available data. Many authors have proposed empirical formulas to use the clearness index (Kt: The ratio of global solar radiation to extraterrestrial solar radiation) (Shukla *et al.*, 2016b; 2015c; 2016c), or use the fraction of hours of sunshine (Shukla *et al.*, 2016d, e) to forecast the monthly average on a horizontal surface of DSR, or in combination (Shukla *et al.*, 2016f; Duffie and Beckman, 2006; Karatasou *et al.*, 2003). A model for predicting daily DSR using sunshine fraction (the ratio of sunshine duration to the maximum possible sunshine time), clarity index and haze factor is also proposed (Al-Mohamad, 2004). Facts have proved that the model that uses both the clarity index and the sunshine score is the best choice for estimating DSR.

The utilization of solar energy will facilitate scale back the demand for standard energy. Therefore, owing to this, solar power is taken into account to be the proper resolution to the energy crisis facing the globe nowadays (Diez-Mediavilla *et al.*, 2005; Tarhan and Sari, 2005; Aras *et al.*, 2006). During this method, radiation information should be established for places of interest that is sometimes a requirement for the institution and commission of star facilities. In any case, it's not possible to form careful observations of native environmental condition. This can be the case for several developing countries (such as Saudi Arabia). Though these countries could have high radiation potential, they lack comfortable radiation info results in fewer energy plans to be explored and enforced (Noorian *et al.*, 2008; De Miguel *et al.*, 2001).

The quality of radiation is typically outlined in step with its composition, specifically incident and diffuse solar radiation. Among these elements, the number of diffuse radiation is usually unsure, as a result of additionally to location parameters; it's chiefly littered with several native geographic factors and climatically characteristics. Most accessible information bases are equipped with data on world radiation and need info on diffuse radiation. This can be because of the sometimes higher value of putting in a meteorological workplace to examine elements. Therefore, empirical models are sometimes wont to measure diffuse radiation. The written kind proposes a range of various models to estimate the common monthly average radiation, that uses input factors (such as world radiation and daytime) and different climatically factors (such as humidness, pressure, precipitation and temperature) to estimate. Among these, world radiation and sunshine amount are imperative factors used at intervals the advancement of experimental models for diffuse radiation

(Khorasanizadeh and Mohammadi, 2016; Aras *et al.*, 2006; Boland *et al.*, 2001).

The base target of this study is to find the foremost correct empirical from the literature for forecasting monthly average daily of DSR on a surface for Al-Baha, Abha, port and metropolis locations across the Saudi Arabia. Several empirical models are collected from the literature. For this purpose, twenty-five years from 1990 to 2014 of domestically measured information were obtained a {part of} the Meteorological and Environmental Protection Agency (MEPA) in Saudi Arabia and another part of the station in Al-Baha University. This information is divided into 2 information sets such every dataset contains twenty-five years of pyranometer data measurements. The first dataset is employed for determinative the coefficients of 19 empirical radiation models, whereas the second dataset is employed for testing the accuracy of those models exploitation varied indicators within the same chosen locations throughout the amount time from 2015 to 2018. The most effective acting model is additionally compared against nineteen models found at intervals the literature that were developed exploitation measured information from climates kind of like the climate of the Saudi Arabia.

Literature Overview of Present Research

The models accessible among the literature were developed victimization several purposeful forms, sort of predictors and for varied time resolutions. The first kind to induce the diffuse radiation was a second degree polynomial as operate of clearness index (Boland *et al.*, 2008). Their correlation is taken under consideration one among the pioneering works among the among the radiation analysis. Their reasonably correlation has been used by many researchers over the years by calibrating the coefficients. This can be discovered in a very sort of comparable approaches in varied analysis works projected for diversified locations (Yao *et al.*, 2017; Oliveira *et al.*, 2002; Tarhan and Sari, 2005; Jacovides *et al.*, 2006; Liu and Jordan, 1960). Such classical practices square measure extended by El-Sebaili *et al.* (2010); Bashahu (2003); El Mghouchi *et al.* (2016); Jin *et al.* (2004), where fraction was correlative with sunshine quantity, whereas others researchers correlative correlation fraction with the sky-clearness index like (Ulgen and Hepbasli, 2003; Dervishi and Mahdavi, 2012; Khahro *et al.*, 2015). Different meteorological factors have collectively been deployed to determine to determine radiation models (Li *et al.*, 2012a; Cao *et al.*, 2017).

In later associate degree extended time, varied analysts have investigated the probability of assorted relationships for estimation of diffuse radiation. Assessed four existing empiric relationships to calculate the worldwide, diffuse and bar radiation for Tetuan city, Morocco and pictured the appropriateness of show supported the factual examination

(Jamil and Akhtar, 2015). Inferred a diffuse radiation show with useful frame comparative to Liu and Jordan show utilizing the measured knowledge of seventy-eight locations in China, MBE and RMSE were went to factually analyze the appliance of models to a lower place the areas thought-about, a pair of trendy models connecting diffuse fraction with sky-clearness list (first and third-order polynomial) were created and compared with sixteen accessible models from writing (El-Sebaii and Trabea, 2003; Tapakis *et al.*, 2016).

The created models were found to possess superior execution for the venue thought-about. Compared eight diffuse radiation models utilizing measured knowledge of worldwide radiation for Austrian capital, Austria, they expressed that standardization of the models can somewhat move forward the execution of the models (Wattan and Janjai, 2016). Derived the horizontal diffuse radiation victimization the accessible models from literature, they developed nine new diffuse radiation models correlating diffuse fraction and diffusion coefficient with relative sunshine quantity and sky-clearness index (Ulgen and Hepbasli, 2009). Investigated worldwide, beam and diffuse sun powered radiation estimation for Aligarh, Asian nation and projected show for diffuse division in terms of sky-clearness record with an unused set of regression coefficients (Kaygusuz, 1999; Bakirci, 2012). Models were projected by Paulescu and Blaga (2016) connecting diffuse constant and diffuse division with sky-clearness index and relative sunshine quantity. Examined execution of fourteen radiation models at a pair of locales within the tropics for foreseeing hourly diffuse sky irradiation on inclined surfaces unit of measurement found in (Magarreiro *et al.*, 2014). Projected eight new models beneath four different categories to survey diffuse radiation; and talked regarding their application and appropriateness in three major areas in Turkey. They too urged utilize of created models for areas beneath comparable climatic conditions (Li *et al.*, 2011). Measured knowledge for Trabzon, Turkey and created seven experimental models to gauges diffuse radiation supported air parameters. Comparative technique was taken once by Li *et al.* (2012b); Safaripour and Mehrabian (2011), administrative body projected vi new models supported the cruel values of sun-based radiation obtained out of 10 models accessible within the writing to assess the monthly average daily radiation for Erzurum, Turkey. Compared the appliance the appliance radiation models on Azorean region for the assessment of the potential of other energy technologies in (Marques Filho *et al.*, 2016; Despotovic *et al.*, 2016). Counseled pair of correlations for estimation of diffuse radiation, projected models were compared with eight existing models from literature (Khorasanizadeh *et al.*, 2014). Assessed and compared existing diffuse radiation models for 267 different sites all over the world; classified and stratified the models for quality of estimation (Ekren, 2013 Bakirci, 2015; Boland *et al.*, 2013). Analyzed the

radiation knowledge of assorted destinations for a few of states within the world, encourage, they performed categorization of empiric models utilized in estimation of diffuse radiation and examined their applications (Khalil and Shaffie, 2013). Created and evaluated models for estimation of diffuse radiation supported climatically components for Turkey (Khalil, 2007; Bortolini *et al.*, 2013). Displayed models for diffuse radiation and jointly examined assessed hourly direct ancient radiation (Bailek *et al.*, 2018). Experimental relationships for diffuse radiation from worldwide radiation and sunshine length, performed comparative examination of radiation for Cairo, Egypt utilizing whole totally different models for level and slanted surfaces (Boukelia *et al.*, 2014). Created 10 experimental models connecting the diffuse division and so the relative sunshine quantity knowledge at areas for country, they what is more created generalized relationships for estimation of diffuse star irradiance in different locales of country (Abal *et al.*, 2017). ten models for hourly diffuse light-weight and assessed their execution, every in their distinctive and regionally balanced forms, against knowledge recorded at 5 locales from a subtropical temperate zone within the southern a section of South America, they elaborate that the multi-variable models outflank the sole variable models in terms of scattering (Jafari and Javaran, 2012). Created twelve relationships between diffuse radiation with single input variable within the shape of sky-clearness index and relative sunshine length for Kerman, Iran, supported measurable take a glance at it fully was inferred that the foremost superb show encompasses an instantaneous type connecting diffusion coefficient with sky-clearness index (Khatib *et al.*, 2011). Experimental models supported a combination of sky-clearness index and relative sunshine quantity, have rarely been investigated in writing, as a result of it were a touch style of case ponders square measure elaborate, propose such a gathering of sky-clearness index and sunshine quantity went to went to radiation models for country (Al-Hamdani *et al.*, 1989). Created demonstrate connecting sky-clearness index, relative sunshine quantity, or a combination of every, it fully was finished that the gathering of sky-clearness index and sunshine quantity provides higher precise comes regarding within the estimation of diffuse radiation, relationships were created within the frame of diffuse fraction and diffusion constant as a chunk of relative sunshine quantity and sky-clearness index and a combination of them (Khorasanizadeh and Mohammadi, 2016). Created diffuse division models supported sky-clearness and sunshine length and a combination of them beneath three categories for Tabass, Iran, interrogation polynomial show with a pair of input factors was urged to perform the leading among the created models (Jiang, 2009a; Mubiru and Banda, 2007; Khorasanizadeh *et al.*, 2014). Established simple technique victimization neural network-based

technique for diffuse radiation, diffuse radiation was sculptural victimization international radiation and different earth science parameters by utilizing neural-network technique (Lou *et al.*, 2016; Soares *et al.*, 2004). Performed estimation of worldwide energy for 5 sites in Asian nation victimization linear, nonlinear, ANN and logic models for shrewd and finished that ANN-based model best estimates the diffuse radiation (Khorasanizadeh *et al.*, 2016; Jiang, 2009b).

They finished that prime accuracy are going to be achieved by the mixtures of two or three most relevant inputs. It's apparent from literature that empirical models supported international radiation and sunshine quantity unit of measurement among the foremost common forms exploited. It's discovered kind the literature that although several studies square measure targeted on the event and analysis of diffuse radiation models. Further, the comparison of models for estimation of diffuse radiation among the shape diffuse fraction and diffusion constant of single variable and a couple of variable input for wet subtropical climate has not been mentioned in literature. It's of express interest to believe the models for estimation of diffuse radiation as single variable input and two-variable input and compare the performance of such models.

Geography and Climate of Selected Locations in Saudi Arabia

Saudi Arabia may be a nation arranged in Southwest Asia and incorporates roughly four-fifths of the Middle Eastern Peninsula between scopes 16° and 33° N and between longitudes 34° and 56° E. Saudi Arabia contains the world's biggest persistent sand desert, Al-Rub Al-Khali (the Purge Quarter). The desert spring locale of Al-Ahsa involves much of the Eastern Area as appeared in Fig. 1. KSA is well put for capitalizing solar energy with the average daily solar radiation level coming to 6 kWh/m^2 and 80-90% of clear sky days over the year. The annual solar radiation level comes to over 2400 kWh/m^2 as appeared in Fig. 2 (Božnar *et al.*, 2017). KSA climate is for the most part hot and dry, in spite of the fact that evenings are cool and ices happen in winter. The humidity along the coasts is high. The temperature amid the summer is tall, coming to well over 45°C , with by and large cold evenings. Extraordinary temperatures well underneath $^{\circ}\text{C}$ are frequent in winter. The average monthly temperatures watched in KSA over the final century extended between a low of 15.5°C from December to February to 30°C from May to September (Božnar *et al.*, 2017).



Fig. 1: Geographic map of Saudi Arabia

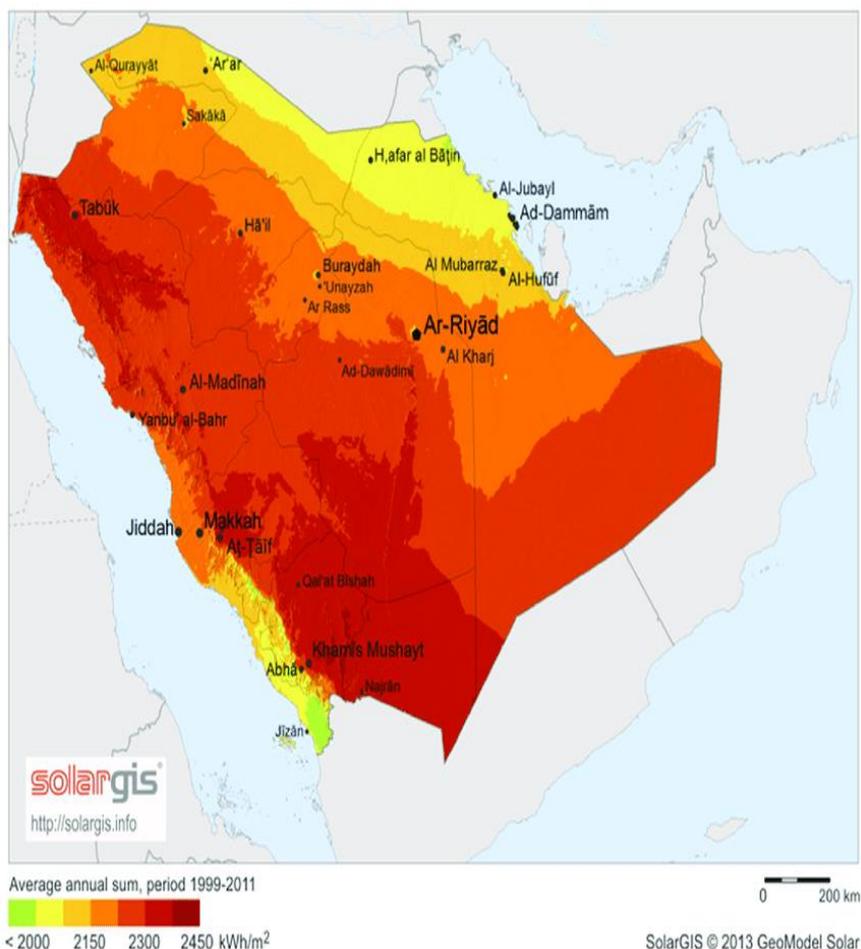


Fig. 2: Solar radiation map of Saudi Arabia

Table 1: Information of the selected locations in the present study

Locations	Al-Baha	Abha	Jeddah	Taif
Latitude (°N)	20.02	18.13	21.32	21.16
Longitude (°E)	41.20	42.30	39.11	40.24
Elevation (m)	2470	2200	12	1879
The period of data	1990-2014	1990-2014	1990-2014	1990-2014
Mean T (°C)	23.4	24.7	29.2	25.4

The topographical areas in Saudi Arabia are exceedingly favorable for solar energy speculation due to its nearness to the European Union and as a portion of one of the Sunbelt countries (Şenkal and Kuleli, 2009). The geological dispersion of the chosen areas within the present research is illustrated within the map displayed in Fig. 1 and the solar radiation map of Saudi Arabia displayed in Fig. 2. The assist data almost the chosen area subtle elements is given in Table 1.

Al-Baha city is separated topographically into three verifiable parts: Sarah, which contains the tall Hejaz mountains portrayed by calm environment and wealthy plant spread due to commonly tall annually precipitation,

Tihama which is the swamp, ocean shore a front region westbound of the Hejaz depicted by irritating and the damp air and essentially no precipitation standard and the eastern inclines delineated by a rise of 1,550 to 1,900 m over ocean level with cool winters, bubbling summers and little plant spread. The most noteworthy city within the space, both in individuals and the zone is Baljurashi the coming about one is Al-Mandaq. In Tehama, there are two basic metropolitan systems: Qilwah and Al-Mikhwah (Şenkal and Kuleli, 2009).

Abha is organized within the southern zone of Asir at a rising of around 2,270 m over ocean level. Abha lies on the western edge of Mount Al-Hijaz close Jabal Sawda,

the foremost raised best Saudi Arabia. With regard to Asir Mountains as a noteworthy portion of the Sarawat, the scene is notwithstanding coordinated by the Sarawat Mountains. The environment of Abha is semi-dry and it is impacted by city's tall stature. The city's air is customarily smooth, dependably, getting recognizably cooler amid the "low-sun" season (Khalil *et al.*, 2019).

Jeddah was a critical city of Hejaz Vilayet, the Kingdom of Hejaz and other commonplace political substances as appeared by Hijazi history books. Jeddah joins a dry environment beneath Koppen's climate diversion arranges, with a tropical temperature run. Jeddah holds its warm temperature in winter. Summer temperatures are unfathomably irritating. Summers are besides amazingly sweltering, with dew concentrates. Precipitation in Jeddah is by and large deficiently and routinely happens in November and December (Khalil *et al.*, 2019; Şenkal and Kuleli, 2009).

Taif lies south east of Jeddah and the Heavenly City of Mecca. Taif is organized within the mountains above Makkah and Jeddah. Within the winter the temperature can discover a workable pace as three degrees and as tall as eighteen degrees. In spring and harvest time, it a few of the time deluges and the environment are tender with a small infection wind. Taif's rise gives it a distant cooler and lovelier air than either Jeddah or Makkah and without the ungainly clamminess of the past (Božnar *et al.*, 2017).

Materials and Methods

Numerical expression of the estimation relationship of diffuse solar radiation can be classified in to three categories as takes after; the primary, diffuse solar radiation from sunshine duration, the moment, connection between diffuse solar radiation and clearness index and the third, relationship combining clearness index and sunshine duration. Where; we utilized (G), is the monthly mean daily global solar radiation, ($K_t = G/G_o$) is the clearness index, G_o is the extraterrestrial solar radiation (was calculated from (Klein, 1977), (D) is the monthly mean daily diffuse solar radiation, (S) is the monthly mean daily number of hours of observed bright sunshine and (S_o) is the monthly mean daily number of hours of sunshine between sunrise and sunset.

The linear relationships connecting (D/G) and (S/S_o) which have the forms:

$$D/G = 0.791 - 0.635(S/S_o) \quad (1)$$

$$D/G = 0.79 - 0.59(S/S_o) \quad (2)$$

$$D/G = 0.697 - 0.577(S/S_o) \quad (3)$$

$$D/G = 0.754 - 0.651(S/S_o) \quad (4)$$

$$D/G = 0.163 + 0.478(S/S_o) - 0.655(S/S_o)^2 \quad (5)$$

$$D/G = 0.31 + 0.0078(S/S_o) - 0.314(S/S_o)^2 \quad (6)$$

$$D/G = -2.313 + 7.393(S/S_o) - 5.314(S/S_o)^2 \quad (7)$$

$$D/G = 1.135 - 2.126(S/S_o) + 1.717(S/S_o)^2 - 0.585(S/S_o)^3 \quad (8)$$

$$D/G = -0.5928 + 4.604(S/S_o) - 6.857(S/S_o)^2 + 3.068(S/S_o)^3 \quad (9)$$

The second relationships between diffuse solar radiation and clearness index:

$$D/G = 1.00 - 1.13(K_t) \quad (10)$$

$$D/G = 1.017 - 1.159(K_t) \quad (11)$$

$$D/G = 0.958 - 0.982(K_t) \quad (12)$$

$$D/G = 3.49 - 9.03(K_t) + 6.22(K_t)^2 \quad (13)$$

$$D/G = 1.39 - 4.027(K_t) + 5.531(K_t)^2 - 3.018(K_t)^3 \quad (14)$$

The third, correlation combining clearness index and sunshine duration:

$$D/G = 0.89 - 0.74(K_t) - 0.18(S/S_o) \quad (15)$$

$$D/G = 0.93 - 0.59(S/S_o) - 0.16(K_t) \quad (16)$$

$$D/G = 0.80 - 0.07(S/S_o) - 0.75(K_t) \quad (17)$$

$$D/G = 0.879 - 0.575(K_t) - 0.323(S/S_o) \quad (18)$$

$$D/G = 1.194 - 0.838(K_t) - 0.446(S/S_o) \quad (19)$$

Equation (3, 8, 12, 18 and 19) suggested by Gopinathan (1988) are based on data from six locations in the South African region. Equation (1, 4 and 12) we developed by (Iqbal, 1979), Eq. (4) by Lewis (1983), Eq. (18) by Page (1961) and Eq. (14) by Liu and Jorden (1960), Eq. (9) by the (Sabzpooshani and Mohammadi, 2014), the Mohammed model Eq. (15) Mohammadi *et al.* (2016), Ibrahim model Eq. (2) (Ibrahim, 1985), Trabea model Eq. (16) (Trabea, 1999), Elminir model Eq. (17) (Elminir *et al.*, 2007), Boukelia models Eq. (6, 7 and 13) (Boukelia *et al.*, 2014).

Computation Techniques

A few relationships, which have a place to the distinctive categories said within the over section, are accessible for computing diffuse solar radiation values. The coefficients of these relationships are for the most part diverse for geographic and climatic districts. Among the over relationships Pag's and Liu and Jordin's models are most broadly utilized. The model proposed by Gopinathan could be a more recent one and its appropriateness needs to be tested assist in other locales.

In the present research, the results mentioned in the above section are used with the following correlations to express the dependence of diffuse radiation on various parameters and dividing models of Eq. (20-26) are case 1, models of Eq. (27-32) are case 2 and models of Eq. (33-38) are case 3:

Case 1

$$D/G = a + b(S/S_o) \quad (20)$$

$$D/G = a + b(S/S_o) + c(S/S_o)^2 \quad (21)$$

$$D/G = a + b(S/S_o) + c(S/S_o)^2 + d(S/S_o)^3 \quad (22)$$

$$D/G = a + b \log(S/S_o) \quad (23)$$

$$D/G = a + b \exp(S/S_o) \quad (24)$$

$$D/G = a + \exp b(S/S_o) \quad (25)$$

$$D/G = a + b \log(S/S_o) + c(S/S_o) \quad (26)$$

Case 2

$$D/G = a + b(K_t) \quad (27)$$

$$D/G = a + b(K_t) + c(K_t)^2 \quad (28)$$

$$D/G = a + b(K_t) + c(K_t)^2 + d(K_t)^3 \quad (29)$$

$$D/G = a + b \log(K_t) \quad (30)$$

$$D/G = a + b \exp(K_t) \quad (31)$$

$$D/G = a + \exp b(K_t) \quad (32)$$

Case 3

$$D/G = a + b K_t + c(S/S_o) \quad (33)$$

$$D/G = a + b K_t + c(k_t)^2 + d(S/S_o) + e(S/S_o)^2 \quad (34)$$

$$D/G = a + b K_t + c(k_t)^2 + d(k_t)^3 + e(S/S_o) + f(S/S_o)^2 + g(S/S_o)^3 \quad (35)$$

$$D/G = a + b \log(K_t) + c \log(S/S_o) \quad (36)$$

$$D/G = a + b \exp(K_t) + c \exp(S/S_o) \quad (37)$$

$$D/G = a + \exp(b K_t) + \exp(c S/S_o) \quad (38)$$

where, a, b, c, d, e, f and g are regression coefficients that depend on the site. The measured values of global solar radiation and diffuse solar radiation obtained with Epply Pyranometer, together with the corresponding sunshine duration values for the different selected locations in Saudi Arabia are used in linear, multilinear and polynomial regression analysis to obtained values of the regression coefficients of Eq. (20-38), the values of regression coefficients are listed in Table 1.

Statistical Analysis

Created models under every class were assessed with the assistance of factual instruments. Probably the most generally acknowledged and mainstream measurable instruments are utilized to assess the presentation of the created models for assessment of diffuse sun oriented radiation. Following are the measurable devices depicted beneath: Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Mean Percentage Error (MPE), Uncertainty at 95% (U_{95}) and t -statistics (t -stats) (Ruiz-Arias *et al.*, 2010; Furlan *et al.*, 2012; Li *et al.*, 2012b; Lemos *et al.*, 2017). These are described below.

Mean Bias Error (MBE)

Mean bias error to assess the precision of the forecast data from the models depicted above, this test gives data on the long-term execution of a model. A low MBE value is wanted. A negative value gives the average amount of underestimation within the calculated value. So, one disadvantage of MBE is that overestimation of an individual observation may cancel underestimation in an isolated observation. We can be obtained the values of MBE as follow:

$$MBE = \frac{1}{n} \sum_{i=1}^n (G_{di.calc.} - G_{di.meas.}) \quad (39)$$

The subscript (i) refer to the i th value of the daily solar irradiation, (n) is the number of the daily diffuse solar

irradiation data. The subscripts “*calc.*” and “*meas.*” refer to the calculated and measured daily diffuse solar irradiation values, separately (Kambezidis *et al.*, 2017; Bouzid and Ghellai, 2015).

Root Mean Square Error (RMSE)

RMSE is used to converse with the execution of show by setting up a correlation among estimated and anticipated qualities. The model with more minute worth is considered to have best execution when contrasted with exhibit having more prominent estimation of RMSE. RMSE persistently have a positive worth and in a perfect world is zero for glorify gauges. Numerically RMSE is depicted as (Li *et al.*, 2011; El-Sebaï *et al.*, 2010):

$$RMSE = \left[\frac{1}{n} \sum_{i=1}^n \left\{ (G_{di,calc.} - G_{di,meas.}) * 2 \right\} \right]^{1/2} \quad (40)$$

Mean Percentage Error (MPE)

It is described as the measure of extent of the error of values in terms of percentage of the observed or measured value (Kambezidis *et al.*, 2017):

$$MPE\% = \frac{1}{n} \sum_{i=1}^n \left\{ \frac{G_{di,meas.} - G_{di,calc.}}{G_{di,meas.}} \right\} * 100 \quad (41)$$

The *t*-state

Model verification can also be done by applying *t* statistical error. The values close to zero in all models are the models with the best performance. It was proposed by stone (Li *et al.*, 2012b) and the mathematical equation is described in terms of MBE and RMSE as (Bailek *et al.*, 2017; Shamshirband *et al.*, 2016; Behar *et al.*, 2015):

$$t - state = \left\{ (n-1)(MBE)^2 / (RMSE)^2 - (MBE)^2 \right\}^{1/2} \quad (42)$$

The smaller values of *t*-statistic the better the performance of modeling.

The Correlation Coefficient (*R*²)

In statistics literature, it is the proportion of variability in a data set that is accounted for by a statistical model, where the variability is measured quantitatively as the sum of square deviations. Most often it is defined notationally as (Zell *et al.*, 2015):

$$R = \sum_{i=1}^n \frac{(G_{di,calc.} - G_{d,calc.})(G_{di,meas.} - G_{d,meas.})}{\left\{ (G_{di,calc.} - G_{d,calc.}) * 2 (G_{di,meas.} - G_{d,meas.}) * 2 \right\} * 1/2} \quad (43)$$

where, *G_{di,calc.}* and *G_{di,meas.}* are the calculate and measure diffuse solar radiation respectively. A high value of *R*² is alluring as this appears a lower unexplained variety. *R*² may be a measurement that gives a few data almost the

goodness-of-fit of a model. In regression, the *R*² coefficient of assurance may be a factual measure of how well the regression line approximates the real information points. An *R*² of 1.0 clear that the regression line impeccably fits the information, which is never substantial in any solar radiation estimation model.

Uncertainty at 95% (*U*₉₅)

The expanded uncertainty in the 95% confidence interval is used to represent the data of the model deviation. This can be expressed mathematically using the formula described by Hepbasli and Alsuhaibani (2011):

$$U_{95} = 1.96 (SD^2 + RMSE^2)^{1/2} \quad (44)$$

Among them, SD is the percentage standard deviation (W/m²) of the difference between the predicted value and the measured value. In the above formula, 1.96 is the coverage factor corresponding to the 95% confidence interval.

Global Performance Index (GPI)

The Global Performance Index (GPI) is called statistical indicator. The values of the statistical indicator have to be compelled to be scale down between zeros to one assist the median value is subtracted from the scaled value of the individual statistical indicator. Finally using the appropriate weight factor for individual statistical indicator GPI is obtained. Mathematical expression for *GPI_i* of the *i*th model is defined as:

$$GPI_i = \sum_{j=1}^{10} \alpha_j (\tilde{Y}_j - Y_{ij}) \quad (45)$$

where, *α_j* equals -1 for the correlation coefficient (*R*) only, while for others indicators is equal to 1, *Y_j* is the median of scaled values of indicator *j*, *Y_{ij}* is the scaled value of indicator *j* for model *i*. Higher value of GPI represents better accuracy of the model (Abreu *et al.*, 2019).

Results and Discussion

The evaluations of the developed models from each case are assessed and compared the results of 19 models presented within the literature. In order to achieve this objective, using measured data covering the period time from 1990 to 2014 for the different four selected locations over Saudi Arabia. From the analysis of the combined data for selected locations in the present study, relationships are obtained to express the diffuse radiation from various parameters. The obtained values of the regression coefficients of the Eq. (20-38), with the Standard Error Estimate (S.E) and the correlation coefficient (*R*) are listed in Table 2. From this table, we may noticed that, Eq. (23, 28, 30 and 38) have the highest values of correlation

coefficients, while the lowest values of the correlation coefficients obtained from Eq. (20, 22, 31 and 36). The values of correlation coefficient in other equations lie between highest and lowest values.

Table 3, shows a comparison between all models using the considered statistical indicators. The results of this table reveal that there are some models that can be excluded from the discussion due to either high of t-test ($t\text{-test} > 2$) or low of correlation coefficient magnitudes, three models for case 1, two models for case 2 and one model for case 3 at Al-Baha and Jeddah locations, while 2 models for case 1, three models for case 2 and two models for case 3 at Abha and Taif locations during the period time in the present research. The comes about obtained in this study demonstrate that the sunshine based models are for the most part more precise than models based on the clearness index at the selected locations. Agreeing to the results, the most excellent exhibitions are generally obtained by the quadratic regression models. As given in Table 3, indicating that Eq. (22) achieved the largest GPI and the lowest overall statistical errors at the locations of presented study.

Table 4 shows the comparison of the statistical performance of different case models with the (U_{95}) uncertainty index and (R) correlation coefficient during the selected time period during this study. It can be seen from the table that case (1) provides the minimum value of U_{95} and the maximum value of R. Therefore, compared with case (2), the model based on SD data are shows better performance and (3) for the overall position selected in this study. On the other hand, case (3) provides a higher correlation than case (2). The minimum value U_{95} of the case (3) is lower than the

minimum value U_{95} of the case (2). Therefore, it is clear that during this period of time, case (3) showed better performance than case (2).

The values of Mean Bias Error (MBE) at the different selected locations during the period time in the present research are show in Fig. 3. The figure indicate that, the MBE underestimation of the diffuse solar radiation is notated numbers of Eq. 8, 10, 8 and 9 for Al-Baha, Abha, Jeddah and Taif respectively and the other numbers of models for the selected locations are overestimation of the diffuse solar radiation. The values of MBE obtained for each of the developed models is fairly small and for most of the models is observed to be quit close to zero. The lowest values of MBE at selected locations in the present study appear for models 22 (closest to zero). Therefore, this is the best model in terms of MBE test indicator. The models presented here are compared with the statistical error. These models have reasonable values estimations errors. Consequently, the model developed in this study can be reliably used to estimate monthly average daily diffuse solar radiation in the different selected locations in the present research and elsewhere with similar climatic conditions.

Figure 4, shows the values of U_{95} uncertainty indicator at the selected locations during the period time in the present research. The figure clear that, the values of U_{95} for all models at the selected locations in the present study are nearest them. The highest values of U_{95} are appears in case 2 for models 28, 29, 30 and 31, while the minimum values of U_{95} occur for model 22. In addition, the U_{95} values are similar approximately in cases 1 and 3 with exception models 25 and 36. Therefore the model 22 is considering the best statistical error in this study.

Table 2: The values of different regression coefficients, standard error and correlation coefficient

Models	The values of regression coefficients							Standard Error (S.E)	Correlation coefficient (R)
	a	b	c	d	e	f	g		
20	0.642	-0.391	-	-	-	-	-	0.021	0.752
21	0.721	-0.462	0.061	-	-	-	-	0.041	0.862
22	0.215	2.123	-3.547	5.142	-	-	-	0.035	0.789
23	0.213	-0.462	-	-	-	-	-	0.028	0.953
24	0.592	-0.285	-	-	-	-	-	0.033	0.867
25	-0.407	-0.756	-	-	-	-	-	0.027	0.912
26	-0.208	2.191	-1.905	-	-	-	-	0.024	0.793
27	0.851	-0.723	-	-	-	-	-	0.045	0.886
28	0.465	0.291	-1.121	-	-	-	-	0.027	0.942
29	0.681	-0.642	0.000	0.000	-	-	-	0.034	0.842
30	0.206	-0.375	-	-	-	-	-	0.038	0.934
31	1.121	-0.252	-	-	-	-	-	0.037	0.776
32	-0.311	-0.639	-	-	-	-	-	0.029	0.827
33	0.425	0.721	-0.116	-	-	-	-	0.044	0.896
34	-3.219	5.918	-3.617	0.481	-0.627	-	-	0.038	0.917
35	9.816	-16.115	35.205	-41.105	-5.125	5.203	-2.119	0.027	0.875
36	0.165	0.514	-0.432	-	-	-	-	0.043	0.745
37	0.125	0.318	-0.291	-	-	-	-	0.026	0.835
38	-0.891	-0.211	-1.327	-	-	-	-	0.035	0.925

Table 3: The statistical test indicators of all models for estimating the DSR on a horizontal surface at selected locations in the present research

Al-Baha							Abha						
Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI	Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI
20	0.065	0.859	-0.024	2.215	1.112	0.312	20	-0.045	0.752	0.052	2.122	1.235	0.289
21	-0.015	0.913	-0.019	2.124	2.314	0.218	21	-0.025	0.856	-0.032	2.162	2.114	-0.315
22	-0.012	0.825	-0.034	2.542	1.032	0.354	22	0.018	0.698	-0.054	2.511	1.115	0.388
23	-0.029	0.962	-0.018	2.635	2.112	0.132	23	-0.051	0.924	0.027	2.532	1.515	0.145
24	0.085	0.873	-0.022	2.812	1.524	0.125	24	0.049	0.836	-0.036	2.745	1.385	-0.168
25	0.049	0.945	-0.026	3.112	2.214	-0.089	25	0.066	0.914	-0.061	3.458	2.065	0.065
26	0.034	1.045	-0.019	2.589	1.235	0.154	26	0.052	1.134	-0.045	2.457	1.323	0.124
27	-0.041	1.032	0.013	2.547	1.324	0.231	27	-0.084	1.214	0.021	2.523	2.116	0.247
28	-0.025	1.011	-0.027	3.524	2.098	0.247	28	0.047	1.089	0.033	3.567	1.578	0.289
29	-0.039	0.987	-0.016	3.652	1.624	-0.124	29	-0.025	0.875	-0.062	3.524	2.032	0.158
30	-0.066	0.892	-0.015	3.952	1.457	-0.213	30	-0.085	0.932	-0.037	3.824	1.487	-0.263
31	-0.084	1.325	-0.024	3.214	2.118	-0.165	31	-0.037	1.258	-0.042	3.264	2.156	-0.178
32	0.042	1.421	0.027	2.586	1.324	-0.157	32	-0.069	1.354	0.051	2.475	1.411	-0.124
33	0.037	1.245	0.014	2.214	1.265	0.123	33	0.045	1.285	0.045	2.289	1.324	0.168
34	0.029	0.958	-0.013	2.268	1.119	0.245	34	-0.057	0.962	-0.029	2.221	1.245	0.245
35	0.035	0.936	0.016	2.345	1.147	0.147	35	0.077	0.915	0.032	2.312	2.113	-0.128
36	0.025	1.102	0.012	3.812	2.054	0.135	36	-0.048	1.137	0.028	3.724	1.415	0.167
37	0.031	0.893	0.015	2.145	1.246	0.245	37	0.026	0.941	0.018	2.245	2.214	0.282
38	0.041	0.924	0.023	2.243	1.298	0.329	38	0.062	0.962	0.042	2.286	1.166	-0.311
Jeddah							Taif						
Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI	Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI
20	0.028	0.825	0.052	2.265	1.214	0.314	20	-0.057	0.724	0.047	2.185	1.261	0.262
21	-0.029	0.935	-0.027	2.19	2.084	0.289	21	0.041	0.814	0.066	2.127	2.034	-0.345
22	0.011	0.768	-0.045	2.578	1.054	0.335	22	0.016	0.712	-0.024	2.475	1.114	0.362
23	0.055	0.962	0.025	2.514	1.514	0.166	23	0.037	0.854	-0.045	2.475	1.345	-0.125
24	-0.064	0.892	-0.037	2.754	2.125	-0.147	24	0.025	0.745	0.081	2.615	2.144	0.185
25	0.078	0.978	-0.045	3.215	1.625	0.064	25	-0.089	0.658	-0.064	3.315	1.475	0.027
26	0.056	1.124	-0.013	2.451	2.055	0.127	26	0.041	1.245	0.027	2.512	1.365	-0.145
27	0.091	1.068	0.018	2.359	1.411	-0.247	27	-0.047	1.145	0.063	2.471	1.192	0.289
28	0.042	1.032	-0.042	3.568	1.485	0.189	28	-0.024	1.062	-0.058	3.326	2.065	-0.231
29	-0.074	0.955	0.028	3.647	2.032	0.163	29	0.033	0.821	-0.078	3.586	2.111	0.121
30	-0.034	0.842	-0.018	3.758	1.324	-0.254	30	-0.062	0.965	0.082	3.625	1.421	0.289
31	-0.067	1.354	-0.033	3.326	2.122	-0.114	31	0.029	1.178	-0.055	3.324	2.218	-0.134
32	-0.032	1.468	-0.015	2.452	1.254	-0.132	32	-0.044	1.247	-0.024	2.274	1.475	0.189
33	0.056	1.289	0.024	2.324	1.145	-0.162	33	0.037	1.365	0.069	2.124	1.245	-0.131
34	-0.071	0.911	-0.027	2.154	1.189	0.289	34	-0.082	0.825	-0.032	2.324	1.362	0.277
35	0.047	0.945	0.031	2.268	1.162	0.165	35	-0.051	0.962	0.041	2.411	2.175	0.165
36	0.034	1.124	-0.025	2.715	2.219	-0.144	36	0.038	1.265	-0.061	3.528	1.415	-0.114
37	-0.029	0.868	0.037	2.214	1.278	0.231	37	-0.029	0.985	0.027	2.289	1.234	0.252
38	0.035	0.965	0.016	2.312	1.224	0.324	38	0.042	0.945	0.031	2.225	2.035	-0.305

Table 4: Comparison of the statistical performance of the different cases of models to (U₉₅) uncertainty indicator and (R) correlation coefficient

Al-Baha		Case 1	Case 2	Case 3	Abha		Case 1	Case 2	Case 3
U ₉₅	Min.	2.1240	2.547	2.1450	U ₉₅	Min.	2.1220	2.4750	2.2210
	Max.	3.1120	3.652	3.8120		Max.	3.4580	3.8240	3.7240
R	Min.	0.8800	0.860	0.8300	R	Min.	0.9100	0.8700	0.8900
	Max.	0.9700	0.980	0.9600		Max.	0.9500	0.9400	0.9600
Jeddah		Case 1	Case 2	Case 3	Taif		Case 1	Case 2	Case 3
U ₉₅	Min.	2.1900	2.359	2.1540	U ₉₅	Min.	2.1270	2.2740	2.1240
	Max.	3.2150	3.758	3.7150		Max.	3.3150	3.6250	3.5280
R	Min.	0.9200	0.900	0.8900	R	Min.	0.8500	0.8400	0.8600
	Max.	0.9800	0.970	0.8500		Max.	0.9800	0.9600	0.9400

The test of the leading models to the four chosen areas in Saudi Arabia: Al-Baha, Abha, Jeddah and Taif amid the period time from 2015 to 2018 within the show ponder are appear in Table 5. The leading performing show (22) and the 19 comparative models from the writing were

moreover evaluated for the areas of Al-Baha, Abha, Jeddah and Taif in arrange to illustrate the pertinence of the models over a more extensive locale. In Table 5, the come about of different measurable pointers for these models are displayed.

Table 5: The test of the best models to the four selected sites in Saudi Arabia: Al-Baha, Abha, Jedda and Taif

Al-Baha							Abha						
Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI	Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI
Eq. (22)	0.031	0.624	-0.018	1.234	1.112	0.536	Eq. (22)	-0.042	0.7290	0.015	1.258	1.235	0.624
Eq. (1)	-0.014	0.851	-0.025	2.325	2.354	0.235	Eq. (1)	-0.031	0.8890	-0.033	2.195	2.158	-0.332
Eq. (2)	-0.013	0.869	-0.039	2.564	1.156	0.324	Eq. (2)	0.045	0.8540	-0.051	2.534	1.247	0.345
Eq. (3)	-0.025	0.751	-0.024	2.689	2.134	0.147	Eq. (3)	-0.068	0.9630	0.025	2.547	1.532	0.191
Eq. (4)	0.061	0.821	-0.027	2.825	1.589	0.168	Eq. (4)	0.042	0.8870	-0.032	2.762	1.361	-0.184
Eq. (5)	0.041	0.985	-0.021	3.137	2.247	-0.068	Eq. (5)	0.065	0.9740	-0.067	3.447	2.021	0.092
Eq. (6)	0.036	1.124	-0.034	2.541	1.281	0.171	Eq. (6)	0.058	1.1540	-0.049	2.485	1.378	0.165
Eq. (7)	-0.057	1.068	0.024	2.516	1.315	0.262	Eq. (7)	-0.077	1.2240	0.026	2.595	2.147	0.287
Eq. (8)	-0.061	1.065	-0.068	3.568	2.134	0.289	Eq. (8)	0.034	1.0620	0.038	3.524	1.527	0.264
Eq. (9)	-0.045	0.947	-0.057	3.618	1.524	-0.192	Eq. (9)	-0.039	0.8370	-0.068	3.561	2.015	0.159
Eq. (10)	-0.061	0.832	-0.027	3.923	1.414	-0.265	Eq. (10)	-0.081	0.9650	-0.032	3.874	1.434	-0.217
Eq. (11)	-0.057	1.247	-0.023	3.265	2.168	-0.247	Eq. (11)	-0.032	1.2270	-0.049	3.231	2.147	-0.137
Eq. (12)	0.049	1.314	0.022	2.537	1.384	-0.198	Eq. (12)	-0.061	1.3140	0.055	2.445	1.456	-0.185
Eq. (13)	0.051	1.115	0.019	2.289	1.237	0.167	Eq. (13)	0.049	1.2420	0.041	2.262	1.387	0.137
Eq. (14)	0.038	0.914	-0.035	2.228	1.191	0.282	Eq. (14)	-0.053	0.9470	-0.025	2.282	1.224	0.269
Eq. (15)	0.051	0.964	0.027	2.367	1.167	0.195	Eq. (15)	0.071	0.9950	0.037	2.347	2.189	-0.145
Eq. (16)	0.044	1.215	0.027	3.834	2.092	0.188	Eq. (16)	-0.042	1.1258	0.024	3.764	1.491	0.182
Eq. (17)	0.036	0.828	0.034	2.247	1.275	0.227	Eq. (17)	0.038	0.9360	0.027	2.291	2.265	0.253
Eq. (18)	0.062	0.922	0.037	2.189	2.124	-0.321	Eq. (18)	0.047	0.8620	0.037	2.145	2.287	0.265
Eq. (19)	0.072	0.752	0.029	2.262	1.252	0.367	Eq. (19)	0.068	0.9240	0.048	2.227	1.452	-0.345
Jeddah							Taif						
Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI	Models	MBE	RMSE	MPE	U ₉₅	t-test	GPI
Eq. (22)	0.022	0.814	0.059	1.057	1.214	0.716	Eq. (22)	-0.051	0.7150	0.042	1.118	1.254	0.681
Eq. (1)	-0.035	0.964	-0.022	2.185	2.095	0.265	Eq. (1)	0.049	0.8620	0.061	2.152	2.076	-0.324
Eq. (2)	0.028	0.864	-0.047	2.562	1.312	0.389	Eq. (2)	0.015	0.7840	-0.029	2.435	1.154	0.331
Eq. (3)	0.051	0.945	0.027	2.545	1.587	0.189	Eq. (3)	0.031	0.8740	-0.048	2.427	1.382	-0.162
Eq. (4)	-0.068	0.887	-0.032	2.732	2.162	-0.165	Eq. (4)	0.027	0.7950	0.086	2.634	2.128	0.174
Eq. (5)	0.072	0.963	-0.048	3.245	1.684	0.097	Eq. (5)	-0.081	0.8450	-0.067	3.347	1.454	0.068
Eq. (6)	0.051	1.157	-0.019	2.468	2.087	0.178	Eq. (6)	0.048	1.2140	0.024	2.524	1.341	-0.184
Eq. (7)	0.087	1.097	0.015	2.374	1.465	-0.262	Eq. (7)	-0.043	1.1320	0.068	2.435	1.163	0.262
Eq. (8)	0.049	1.075	-0.047	3.591	1.462	0.268	Eq. (8)	-0.029	1.0940	-0.052	3.374	2.034	-0.257
Eq. (9)	-0.077	0.924	0.024	3.645	2.065	0.197	Eq. (9)	0.037	0.8680	-0.074	3.545	2.164	0.181
Eq. (10)	-0.039	0.887	-0.013	3.724	1.357	-0.278	Eq. (10)	-0.064	0.9740	0.088	3.639	1.447	0.264
Eq. (11)	-0.062	1.332	-0.039	3.338	2.134	-0.168	Eq. (11)	0.025	1.1320	-0.057	3.381	2.238	-0.174
Eq. (12)	-0.038	1.414	-0.018	2.427	1.241	-0.175	Eq. (12)	-0.042	1.2210	-0.028	2.224	1.427	0.165
Eq. (13)	0.051	1.242	0.027	2.391	1.162	-0.124	Eq. (13)	0.031	1.3150	0.061	2.175	1.268	-0.147
Eq. (14)	-0.062	0.953	-0.024	2.189	1.174	0.245	Eq. (14)	-0.088	0.8860	-0.037	2.362	1.341	0.252
Eq. (15)	0.042	0.938	0.038	2.237	1.135	0.138	Eq. (15)	-0.056	0.9480	0.049	2.447	2.139	0.187
Eq. (16)	0.039	1.145	-0.029	2.718	2.252	-0.185	Eq. (16)	0.034	1.2320	-0.066	3.562	1.481	-0.162
Eq. (17)	-0.034	0.891	0.032	2.265	1.225	0.273	Eq. (17)	-0.026	0.9450	0.025	2.278	1.262	0.247
Eq. (18)	0.039	0.937	0.024	2.345	1.269	0.365	Eq. (18)	0.047	0.9620	0.034	2.241	2.091	-0.351
Eq. (19)	0.027	0.862	0.024	3.124	2.321	0.245	Eq. (19)	-0.037	0.0851	0.042	1.189	2.142	0.285

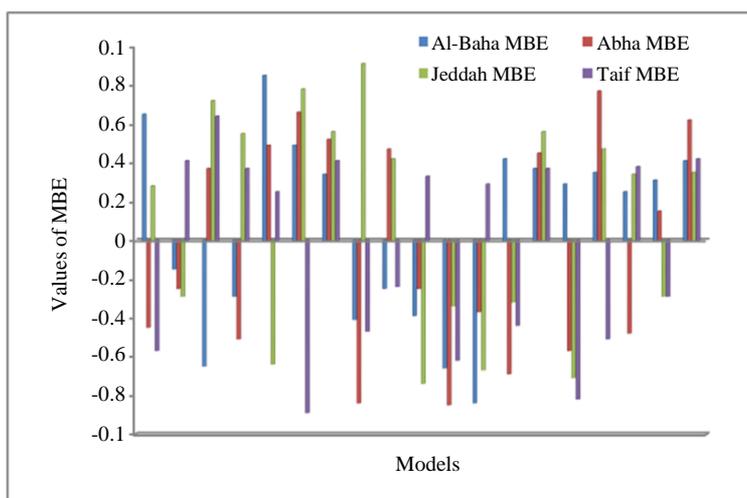


Fig. 3: The values of MBE at the selected locations during the period time in the present research

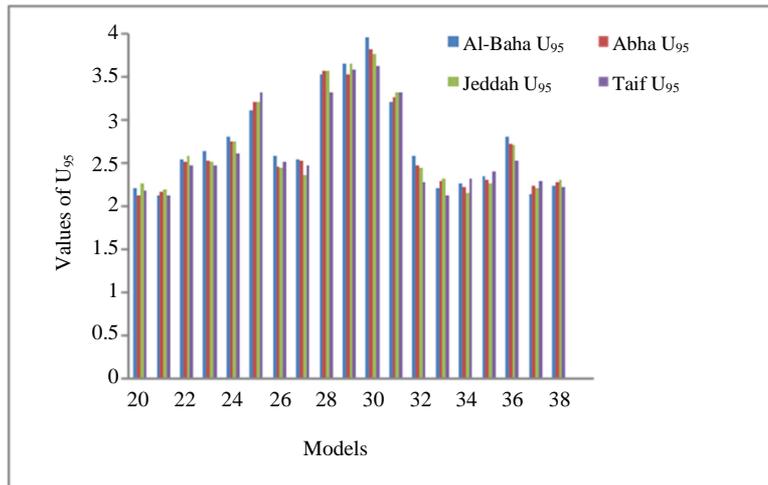


Fig. 4: The values of U_{95} uncertainty indicator at the selected locations during the period time in the present research

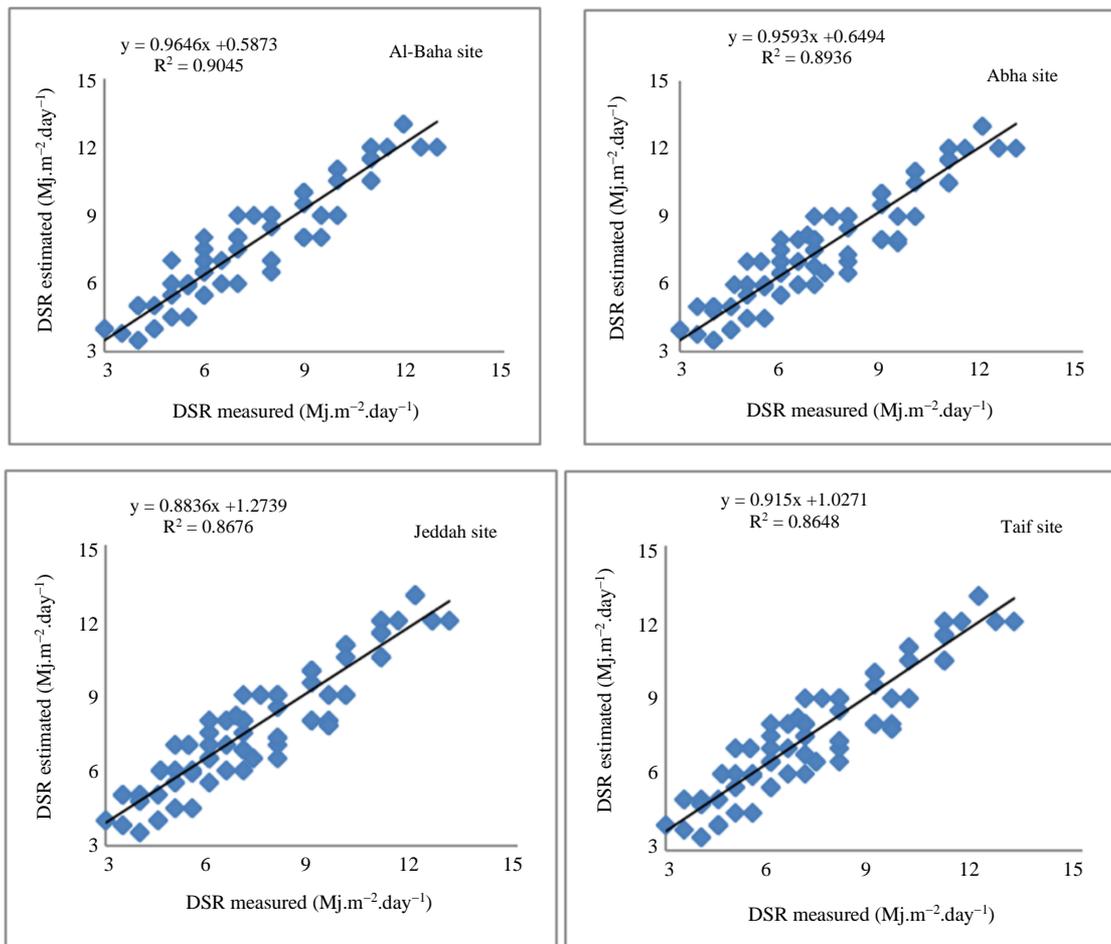


Fig. 5: The correlation coefficients between DSR measured and estimated values at the selected locations during the period time from 2015 to 2018 in the present research

It is clearly seen that the 22 show has the finest real values among all designated models for the four areas, it to boot justified by the foremost hoisted esteem of GPI. In

extension, the RMSE values of Al-Baha, Abha, Jeddah and Taif are 0.624, 0.729, 0.814 and 0.715 independently. All sites have higher values of Global Performance Indicator

(GPI). It is obvious from the results that the past models of the Saudi Arabia appear low accuracy levels within the four considered locales. This ascribed to the fragmented data used in developing these models. Figure 5, shows the correlation coefficients between DSR measured and estimated values at the selected locations during the period time from 2015 to 2018 in the present research. From this figure, we cleared that, there is a strong correlation coefficient of the new model when compared with the measured data of the DSR. R is equal 95, 94, 93 and 93% of DSR for Al-Baha, Abha, Jeddah and Taif respectively.

Conclusion

Confirmation of diffuse solar radiation is basic for sun oriented frameworks plan and change. In this setting, nineteen proposed connections for diffuse sun powered radiation component are overviewed and their execution compared to measured illumination of four chosen areas utilizing different measurable parameters such as MBE, MPE, RMSE, t-statistic and GPI. The created relationships are connected to compute the month-to-month normal day by day diffuse illumination of Al-Baha, Abha, Jeddah and Taif locations. The diffuse component of worldwide radiation is connected with the daylight hour division, the relative clearness record and with a combination of them. Advance, the execution of these models was too assessed against a set of nineteen models displayed inside the writing. The proposed demonstrate uncovered precise comes about in comparison to these existing models with the most reduced measurable blunders. Agreeing to these comes about the demonstrate 22 gives most noteworthy esteem of GPI. In this way, it is concluded that the cubic condition demonstrates of diffuse division (i.e., $D/G = 0.215 + 2.123 (S/S_0) - 3.547(S/S_0)^2 + 5.142 (S/S_0)^3$) is chosen as the foremost exact show which has been specified within the previous talk. This show is generalized condition for the Saudi Arabia locale and is able to appraise the month to month normal every day diffuse illumination on a level surface for any destinations in comparative conditions of climate, within the nonappearance of the measured one.

In extension, this appear can be utilized by investigators or engineers in terms of area assurance and techno-economic execution appraisal of sun-oriented vitality applications particularly those depending on photovoltaic technologies.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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