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RESEARCH ARTICLE

A COMPARATIVE STUDY OF VARIOUS MODELS FOR ESTIMATING GLOBAL SOLAR RADIATION IN HEBRON CITY, PALESTINE

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ABSTRACT

Solar radiation is a primary driver for many physical, chemical, and biological processes on the earth's surface. Solar energy engineers, architects, agriculturists, hydrologists, etc. often require a reasonably accurate knowledge of the availability of the solar resource for their relevant applications at their local. In solar applications, one of the most important parameters needed is the long-term average daily global irradiation. For regions where no actual measured values are available, a common practice is to estimate average daily global solar radiation using appropriate empirical correlations based on the measured relevant data at those locations. These correlations estimate the values of global solar radiation for a region of interest from more readily available meteorological, climatological, and geographical parameters. The present study aimed to calibrate existing models and develop a new model for estimating global solar radiation data using available measured meteorological records such as precipitation or temperature. Fifteen empirical global radiation models based on meteorological variables were generated and validated using daily data in the period of January 2007 to December 2011 at Hebron city meteorological station in Palestine. Validation criteria included coefficient of determination, root mean square error, mean bias error, mean absolute bias error, mean percentage error, and mean absolute percentage error. The best result was derived from the model proposed, which uses extraterrestrial solar radiation, saturation vapor pressures, transformed rainfall data and daily minimum relative humidity as predictors. The new multiple regression relation giving accurate estimates of daily global solar radiation was suggested. It has a high coefficient of determination $R^2 = 0.94$. The results showed that the suggested model can estimate the global solar radiation with acceptable values of RMSE, MBE and MABE (2.38, 0.08, 1.75 MJ m^{-2} day^{-1}, respectively); and MPE and MAPE (-6.49%, 19.32%). Temperature based models provided less accurate results, of which the best one is the Bristow and Campbell model ($R^2 = 0.89$). The Hargreaves and Samani model is simple and are recommended to estimate the daily global radiation when only temperature data are available and when the coefficients cannot be determined. Based on overall results it was concluded that the meteorological based method provides reasonably accurate estimates of global solar radiation, for the site where coefficients of the model were developed.

INTRODUCTION

Estimation of global solar radiation is vital to solar energy system design everywhere where adequate observations are missing. Values of solar radiation are useful for determination of the maximum performances of solar heating and photovoltaic plants as well as for sizing air conditioning equipment in buildings or for determining their thermal loading. Other scientific fields such as agriculture or hydrology also demand global solar radiation estimations as they need knowledge of insolation levels for studying ecosystem fluxes of materials and energy.

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Since the global solar radiation reaching the earth's surface depends upon the local meteorological conditions, a study of solar radiation under local climatic conditions is essential (Alsamamra *et al*., 2009). For locations where measured values are not available, solar irradiance can be estimated using empirical models. The immediate short term to the long term solutions to address the problems of inadequate infrastructure in the area of solar energy data acquisitions have been the application of empirical models that rely on the correlation between the parameters obtained from measured meteorological data. In this regard, several empirical formulae have been developed to predict the global solar radiation using various variables. Parameters used as inputs in the relationships include astronomical factors (solar constant, world-sun distance, solar declination and hour angle); geographical factors (latitude, longitude and altitude); geometrical factors (surface azimuth, surface tilt angle, solar altitude, solar azimuth); physical factors (albedo, scattering of air molecules, water vapor content, scattering of dust and other atmospheric constituents); and meteorological factors (atmospheric pressure, cloudiness, temperature, sunshine duration, air temperature, soil temperature, relative humidity, evaporation, precipitation, number of rainy days, total perceptible water, etc.) (Alsamamra, 2013; Ruiz-Arias *et al*., 2010; Menges *et al*., 2006; Almorox *et al*., 2008 and Angstr¨om, 1924). However, the reliability and usability of these models depend largely on the strength of the correlation between the estimated and measured variables. Parameters that have been most frequently investigated are sunshine, cloud cover; temperature and/or precipitation variables. Solar radiation can be easily estimated from sunshine duration; the Angstrom-Prescott models are sunshine-based and have widely applied to estimate global solar radiation (Prescott, 1940; Hargreaves and Samani, 1982 and Annandale *et al*., 2002). However, sunshine and cloud observations are data that are not available at most of the meteorological stations. In this context, global solar radiation estimation models based on air temperature and precipitation are attractive and viable options. It is necessary to develop a precise solar radiation model which utilizes commonly available parameters such as maximum and minimum temperatures, precipitation and geographical location. These parameters are the only daily variables available at a great majority of meteorological stations. Some of these approaches make use of basic meteorological data only (Bristow and Campbell, 1984; Donatelli and Campbell, 1998; Goodin *et al*., 1999; Winslow *et al*., 2001; Mahmood and Hubbar, 2002; McCaskill, 1990; Hunt *et al*., 1990; Liu and Scott, 2001; Richardson and Reddy, 2004; Chen *et al*., 2006; Skeiker, 2009 and Wu *et al*., 2007).

Existing knowledge and aim of present work

Palestine located within the solar belt countries and considered as one of the highest solar potential energy, the climate conditions of the Palestinian Territories are predominantly very sunny; it has more than 3,000 sunshine hours per year. The solar radiation on a horizontal surface varies from 2.63 kWh/m^2 day in December to 8.4 kWh/m^2 day in June (Almorox *et al*., 2008). Palestinians, like other developing country people need a lot of energy for achievement of sustainable development. Nevertheless, many obstacles are facing them, namely; political, economical, social, and environmental problems. Palestinian people import all of its needs of petroleum from the Israeli market and also about 92% of electrical energy from the Israeli Electrical Corporation. The production of renewable energy contributes only 1.9% of the total energy during the year 2009. (Liu and Scott, 2001). In fact, Palestine is blessed with huge amounts of renewable energy resources, particularly solar and wind energies (Richardson and Reddy, 2004). The current tendency in Palestine is to use in future various solar energy applications in the overall mix of energy in Palestine, as well as identifying potential areas for utilizing future technologies and recommending future courses of action to encourage the commercial utilization of solar energy technologies. The duration of solar radiation and its energy that reaches the ground are becoming important spatial data.

Solar radiation research is significant not only for meteorologists but also for foresters, agronomists, geographers and others. Solar energy, on the other hand, is almost unlimited and it is considered to be the energy of the future. Solar radiation modeling has been used in agricultural and forested areas (McCaskill, 1990). Incoming solar radiation, through its influence on the energy and water balance at the earth's surface, affects such processes as air and soil heating, evapotranspiration, photosynthesis, winds, and snow melt (Chen *et al*., 2006). In contrast to the high cost of building and maintaining insolation monitoring stations, spatially based solar radiation models provide a cost-efficient means for characterizing the spatial and temporal variation of insolation. The solar flux model (Skeiker, 2009) simulates the influence of shadow patterns on direct insolation at discrete intervals through time. The prediction formulas are powerful tools that can be used to model and investigate various highly complex and nonlinear phenomena. Solar Radiation readings are usually very difficult if not impossible to correlate.

If algebraic correlations are developed in the standard manner the results are usually accompanied by a high degree of uncertainty. During the last few years, the solar radiation data has only been presented in tabular or graphical form. Application of such data for design calculations can be very difficult. Many parameters influence the amount of solar energy at a particular standing point of the Earth's surface; therefore, many solar radiation models were produced in the last few years (Wu *et al*., 2007). By using horizontal data, different mathematical models can be developed to predict the solar irradiance on various inclined surfaces. This work aimed to present an analysis of the relationship between daily global solar radiation and some Meteorological and geographical factors. The reason for this methodology comes from the fact that the air temperature and precipitation are the most worldwide measured meteorological parameters. The objectives of this work were to compare, calibrate and validate existing solar radiation models to estimate solar global radiation from observed meteorological data. It is a goal of this author to find a model in daily scale based on available meteorological variables without sunshine hours will provide a significant and new contribution to the approach.

MATERIALS AND METHODS

The meteorological data were obtained from the Palestinian meteorological office for Hebron city station covering the period from January 2007 to December 2011 on daily base. Hebron city is located in the southern part of Palestinian territories with a temperate Mediterranean climate. The following meteorological variables are currently recorded in daily database: actual global solar radiation (MJ m^{-2} day^{-1}), maximum relative humidity (%), minimum relative humidity (%), precipitation (mm), mean air temperature (◦C), maximum air temperature (◦C), minimum air temperature, and wind speed (km/h). Air temperature based estimation models and models used air temperature and other meteorological variables have been reported to estimate global solar radiation from measured meteorological variables. Daily total extraterrestrial radiation H_0 is often included in the relationships. H_0 values were calculated using standard geometric procedures.

Selected models

Empirical modeling is an essential and economical tool for the estimation of global solar radiation. A widely used method is based on empirical relations between solar radiation and measured meteorological variables. In the literature review, there are several empirical methods used to estimate global solar radiation. In this work, daily solar radiation was estimated using 14 solar radiation estimation models. These models were chosen as representative of the existing models that utilize extraterrestrial radiation and readily available meteorological data.

Solar radiation estimation using daily temperature

Air temperature based estimation models use maximum and minimum air temperature to estimate atmospheric transmissivity. These models assume that maximum temperature will decrease with reduced transmissivity, whilst minimum temperature will increase due to the cloud emissivity. Clear skies will increase maximum temperature due to higher short wave radiation, and minimum temperature will decrease due to higher transmissivity.

(Model 1) Hargreaves and Samani model were the first to suggest that global radiation could be evaluated from the difference between daily maximum and daily minimum temperature (Hargreaves and Samani, 1982).

(Model 2) Annandale model is the modified Hargreaves-Samani model developed by Annandale *et al*. (2002) includes a correction for altitudes.

(Model 3) Bristow and Campbell method describes daily solar radiation as an exponential asymptotic function of daily temperature range (Bristow and Campbell, 1984).

(Model 4) Donatelli and Campbell model is similar in structure to model 3 (Donatelli and Campbell, 1998).

(Model 5) Goodin model evaluated one form of model 3 (Goodin *et al*., 1999).

(Model 6) Winslow model developed a model for estimation of H with inputs of daily maximum and minimum air temperature, mean annual temperature, mean annual temperature range, site latitude and site elevation. The prediction equation is (Winslow *et al*., 2001).

(Model 7) Mahmood and Hubbard model used a different approach. In their model, transmissivity is a function of the day of the year, the daily range of temperature and the corrected clear sky solar irradiation is computed (Mahmood and Hubbar, 2002).

Solar radiation estimation using both temperature and other variables

In the estimation of solar radiation using temperature and other measured meteorological variables, the temperature based models were improved by adding other variables: precipitation, dew point temperature, relative humidity or averaged saturation deficit.

(Model 8) McCaskill related H and H_0 and rain information as (McCaskill, 1990).

(Model 9) Hunt model has shown that calculation of solar radiation using the basic daily meteorological data of temperature maximum, temperature minimum, and precipitation, along with radiation above the atmosphere, is quite feasible using a simple equation (Hunt *et al*., 1990).

(Model 10) Liu and Scott developed a model that included temperatures and rain information (Liu and Scott, 2001).

(Model 11) Richardson and Reddy model introduced a new solar radiation model (Richardson and Reddy, 2004).

(Model 12) Chen model using meteorological variables such as precipitation, air temperature, maximum temperature, minimum temperature to estimate the global solar radiation, when the sunshine hours are unavailable, developed a new correlation (Chen *et al*., 2006).

(Model 13) Skeiker model investigated the effect of geographical and meteorological parameters on the mean daily global solar radiation and found the following relationship (Skeiker, 2009).

(Model 14) Wu model introduced this model based on measured variables (Wu *et al*., 2007).

(Model 15) Proposed model of this study presents a new model for daily solar radiation (MJ m^{-2} day^{-1}). The new formula is a function of extraterrestrial solar radiation, saturation vapour pressures at temperature $T_{\min}$, saturation vapor pressures at temperature T_{max} ,transformed rainfall data R_T, and daily minimum relative humidity RH_{min}:

$$H = 0.7345H_0(1 - \exp(-0.2549(e_s(T_{min})/e_s(T_{max}))^{-2.6518}) \times (1 - 0.1233R_T - 0.00428RH_{min}) \quad (1)$$

The proposed new model requires measured maximum and minimum air temperatures, minimum relative humidity and precipitation data. As saturation vapour pressure is related to air temperature, it can be calculated from the air temperature. The relationship is expressed by (Hargreaves, 1994):

$$e_s(T_x) = 0.6108 \exp(17.27(T_x)/(T_x + 273.3)) \quad (2)$$

Statistical validation

Statistical criterion was used to check the performance of the models by comparing the calculated daily solar radiation with the measured daily solar radiation data. In this study, the accuracy of the estimated values was tested by calculating the R^2 (coefficient of determination), RMSE (Root Mean Square Error), MBE (Mean Bias Error), MABE (Mean Absolute Bias Error), MPE (Mean Percentage Error), and MAPE (Mean Absolute Percentage Error). These tests are defined by the relations (Meza and Varas, 2000):

$$R^2 = 1 - \left[\frac{\Sigma(H_{im} - H_{ic})^2}{\Sigma(H_{im} - H_{avgm})^2}\right], \quad (3)$$

$$RMSE = \left[\frac{1}{N_{obs}}\Sigma(H_{im} - H_{ic})^2\right]^{0.5} (MJm^{-2}day^{-1}), \quad (4)$$

$$MBE = \frac{1}{N_{obs}}\sum H_{im} - H_{ic}\ (MJm^{-2}day^{-1}), \quad (5)$$

$$MABE = \frac{1}{N_{obs}}\sum|H_{im} - H_{ic}|\ (MJm^{-2}day^{-1}), \quad (6)$$

$$MPE = \frac{100}{N_{obs}}\left(\sum\frac{H_{im}-H_{ic}}{H_{im}}\right)\%, \quad (7)$$

$$MAPE = \frac{100}{N_{obs}}\left(\sum\left|\frac{H_{im}-H_{ic}}{H_{im}}\right|\right)\%, \quad (8)$$

Here, N_{obs} is the number of data pairs, H_{im} is the measured solar radiation, H_{ic} is the calculated solar radiation and H_{avgm} is the mean measure radiation. A model is more efficient when R^2 is closer to 1. The RMSE provides information on the short-term performance of the correlations by allowing a term-by-term comparison of the deviation between the calculated and measured values. The values of the MBE represent the systematic error or bias, a positive value of MBE shows an over-estimate while a negative value an under-estimate by the model. The MABE gives the absolute value of bias error and it is a measure of the correlation goodness. The MPE is an overall measure of forecast bias, computed from the actual differences between a series of forecasts and actual data point observed; each difference is expressed as a percentage of each observed data point, then summed and averaged. The MAPE is an overall measure of forecast accuracy, computed from the absolute differences between a series of forecasts and actual observed data. The disadvantage associated with MBE and MPE is that errors of different signs may cancel each other, the smaller the value, the better the model performs, but some few values in the sum can produce a significant increase in the parameter. The MBE and MPE offering information regarding overestimation or underestimation of estimated data; low values of these mean errors are desirable, though it should be noted that overestimation of an individual data element will cancel underestimation in a separate observation.

RESULTS AND DISCUSSION

Empirical models to estimate solar radiation are a suitable tool. These models have the advantage of using meteorological data that are available. The models were validated by comparing calculated and measured solar radiation in Hebron city station. The statistical results of different models are given in Table 1. The first conclusion coming from Table 1 is that the estimation of global solar radiation can be performed with an acceptable accuracy using all the tested models. Obtained results show that estimation of solar radiation using temperature and precipitation data explained the highest portion of the solar radiation variance out of all the tested models. In general, temperature based models were less accurate in contrast to the meteorological based model. The temperature based models could be improved by adding other variables (Model 15), to the point where 94% of the solar radiation variance could be explained by adding successively the saturation vapour pressures at minimum and maximum temperatures, transformed rainfall data, and daily minimum relative humidity.

Table 1. Statistical results of different models. R^2, RMSE, MBE, MABE, MPE and MAPE computed in the comparison between observed and estimated daily solar radiation

Model	R^2	RMSE	MBE	MABE	MPE	MAPE
Model 1	0.89	3.10	-0.17	2.25	-16.44	27.51
Model 2	0.89	3.00	-0.19	2.23	-16.45	27.55
Model 3	0.89	2.76	0.05	1.95	-7.92	21.30
Model 4	0.89	2.79	-0.05	1.96	-9.66	21.84
Model 5	0.88	3.18	-0.43	2.27	-20.32	29.15
Model 6	0.88	2.97	0.03	2.09	-12.36	24.11
Model 7	0.86	2.86	-0.07	2.16	-13.55	25.52
Model 8	0.85	3.38	0.09	2.65	-13.72	32.43
Model 9	0.88	2.98	0.04	1.91	-8.75	22.64
Model 10	0.91	2.52	0.06	1.87	-8.41	20.31
Model 11	0.78	4.26	0.06	3.47	-15.04	32.93
Model 12	0.87	2.54	0.03	2.06	-8.83	23.30
Model 13	0.80	4.12	0.02	3.07	-15.57	30.52
Model 14	0.86	2.87	-0.07	2.04	-12.11	23.54
Model 15	0.94	2.38	0.08	1.75	-6.49	19.32

Model 15 is considered the best relation for estimating the global solar radiation intensity for the Hebron station with an acceptable error. The R^2, RMSE, MBE, MABE, MPE and MAPE values are 0.94, 2.38 MJ. $m^{-2}day^{-1}$, 0.08 MJ. $m^{-2}day^{-}$, 1.75 MJ. $m^{-2}day^{-1}$, -6.49% and 19.32%, respectively.

The regression analysis shows that in the models based on temperature data, the model 3 gives consistently a good estimate when applied to daily data. The model 3 had the best overall results for the R^2 and in general, it produced small residuals compared to the other temperature based models with overall RMSE of 2.76 MJ. m^{-2} day^{-1}. Model 1 performed better than the models 8, 11 and 13, considering the simplicity of the model and relative ease of deriving the coefficient compared to the other models, performed very well in the overall ranking. Generally, at locations where no solar radiation data (and no sunshine data) are available for site-specific estimation appears to be well suited (Donatelli *et al*., 2003).

The results demonstrated that most of the tested models used were able to adequately estimate daily global solar radiation from daily temperature and/or precipitation. Using meteorological variables such as precipitation, mean air temperature, maximum and minimum air temperature, relative humidity, and saturation deficit to estimate the solar global radiation could get good results at most conditions. The new proposed method (model 15) in this study to estimate global solar radiation from more and reliably measured meteorological data can be useful to provide radiation data which would otherwise be unavailable. This approach is applicable for estimating the daily global solar radiation on a horizontal surface at any site in Hebron city, Southern Palestine. Nevertheless, the inability of the model 15 to be extended to other locations without coefficient calibration is clearly evident. Although these calibrated or developed methods were based on the meteorological data of one specific station, we hope, they could be applicable in other locations which are climatically similar.

Conclusion

In the absence of global solar radiation data, reliable estimates can be made from easily available meteorological observations of temperature, precipitation and/or relative humidity along with extraterrestrial solar radiation using different models. In this study, using Hebron station (southern Palestine) as a case study, fourteen existing and one proposed models were calibrated and evaluated using the daily meteorological data from January 2007 to December 2011 for estimating global solar radiation. We propose an approach for selecting an optimal method, for estimating daily global solar radiation in Hebron city: when temperature, precipitation and relative humidity are available, use Model 15; when only temperature and precipitation are available, use Model 10; and when only temperature data are available, use Model 3. The models 15, 10 and 3 were slightly superior to Model 1, but are considerably more complicated to use than Model 1. The model 1 is simple and could estimate the solar global radiation with relatively high accuracy and recommended to estimate the daily global radiation when the solar radiation and sunshine hours are unavailable, when only temperature data are available and when the model coefficients cannot be determined directly from available data. Model 3 is the temperature based model that estimate the global radiation with relative accuracy, but they are more complex, and the model equations could be used when there are measured data for calibration of coefficients. When there are meteorological variables the estimation of solar radiation using temperature and precipitation data could estimate the daily solar radiation with higher accuracy than the temperature based models, these models are more complex and need calibration. The proposed Model 15 is recommended to estimate the global radiation in Hebron city. The validity of the global solar radiation regression relation needs to be tested and calibrated on other sites.

REFERENCES

Almorox, J., Benito, M. and Hontoria, C. 2008. Estimation of global solar radiation in Venezuela. INCI; 280: 289-33.

Alsamamra, H. 2013. Statistical Approach for Modeling of Daily Global Solar Radiation on Horizontal Surfaces Over Hebron City, Palestine. *J. Technol. Innov. Renew. Energy*; 1: 7-2.

Alsamamra, H., Ruiz-Arias, J., Pozo-Vazquez, D. and Tovar-Pescador, J. 2009. A comparative study of ordinary and residual kriging techniques for mapping solar radiation over southern Spain. *Agric Forest Meteorol*; 1343: 1357-3.

Angstr¨om, A. 1924. Solar and terrestrial radiation. *Q. J. Roy. Met. Soc*; 121:126-50.

Annandale, J., Jovanic, N., Benade, N. and Allen, R. 2002. Predicting crop water uptake under full and deficit irrigation. *Irrig. Sci*; 57: 65-21.

Bristow, K. and Campbell, G. 1984. On the relationship between incoming solar radiation and daily maximum and minimum temperature. *Agric. Forest Meteorol*; 159:166-31.

Chen, R., Kang, E., Lu, S., Yang, J., Ji, X., Zhang, Z. and Zhang, J. 2006. Application of adaptive Grey predictor based algorithm to boiler drum level control. *Energy Convers. Manage*; 2991:3007-47.

Donatelli, M. and G. S. Campbell, 1998. A simple model to estimate global solar radiation. Proceedings of the 5th European Society of Agronomy Congress, Nitra, (Slovak Republic), p.133.

Donatelli, M., Bellocchi, G. and Fontana, F. 2003. RadEst3.00: software to estimate daily radiation data from commonly available meteorological variables. *Eur. J. Agron*.; 363:367-18.

Goodin, D., Hutchinson, J., Vanderlip, R. and Knapp, M. 1999. Estimating solar irradiance for crop modeling using daily air temperature data. *Agron. J*.; 845: 851-91.

Hargreaves, G. and Samani, Z. 1982. Estimation of potential evapotranspiration. *J. Irrig. and Drain Engr*; 223:230-108.

Hargreaves, G. H. 1994. Simplified coefficients for estimating monthly solar radiation in North America and Europe. Utah State University (Logan, Utah), p. 9.

Hunt, L., Kuchar, L. and Swanton, C. 1990. Estimation of solar radiation for use in crop modeling. *Agric. Forest Meteorol*; 293: 300-91.

Liu, D. and Scott, B. 2001. Estimation of solar radiation in Australia from rainfall and temperature observations. *Agric. Forest Meteorol*; 41:59-106.

Mahmood, R. and Hubbar, G. 2002. Effect of time of temperature observation and estimation of daily solar radiation for the Northern Great Plains. *Agron. J*.; 723:733-94.

McCaskill, M. 1990. Prediction of solar radiation from rain day information using regionally stable coefficients. *Agric. Forest Meteorol*; 247: 255-51.

Menges, H., Ertekin, C. and Sonmete, H. 2006. Evaluation of global solar radiation models for Konya, Turkey. *Energy Convers. Manage*; 3149: 3158-47.

Meza, F. and Varas, E. 2000. Estimation of mean monthly solar global radiation as a function of temperature. *Agric. Forest Meteorol*; 231:241-100.

Prescott, J. 1940. Evaporation from water surface in relation to solar radiation. *Trans. R. Soc. Sci. Austr*; 114: 122-64.

Richardson, A. and Reddy, K. 2004. Assessment of solar radiation models and temporal averaging schemes in predicting radiation and cotton production. *Clim. Res*.; 85: 103- 27.

Ruiz-Arias, J., Alsamamra, H., Tovar-Pescador, J. and Pozo-Vazquez, D. 2010. Proposal of a regressive model for the hourly diffuse solar radiation under all sky conditions. *Energy Convers. Manage*; 881: 893-7.

Skeiker, K. 2009. Optimum tilt angle and orientation for solar collectors in Syria. *Energy Convers. Manage*; 2439:2448-50.

Winslow, J., Hunt, E. and Piper, S. 2001. A globally applicable model of daily solar radiation from air temperature and precipitation data. *Ecol. Modell*; 227:245- 143.

Wu, G., Liu, Y. and Wang, T. 2007. Methods and strategy for modeling daily global solar radiation with measured meteorological data- A case study in Nanchang station. China. *Energy Convers. Manage*; 2447:2452-48.

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