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# Developing an Empirical Equation for Solar Ultraviolet Radiation Estimation for the Production of Vitamin D Photosynthesis for Selected Provinces in Iraq

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**Abstract:** Ultraviolet radiation is dangerous to humans. In a relatively short time, it has the potential to induce diseases such as skin cancer, cataracts, and autoimmune disease weakening. On the other hand, the human body produces vitamin D in part because of the UV radiation from the sun. The kidneys and liver convert the necessary vitamin D production in the epidermis to hydroxyvitamin D by the kidneys and liver. The solar ultraviolet radiation for vitamin D photosynthesis (DUV) measured by UV sensors board on the Al-Mustansiriyah solar radiation station. The present paper focuses on supposing an empirical equation to estimate DUV using numerous atmospheric characteristics under clear skies. such as ultraviolet index, aerosol optical depth, total ozone column, solar zenith angle and air mass as an input of the developed models for Mosul, Baghdad and Basra also the results shows that the daily variation of UVI for area of Mosul, Baghdad and Basra, where the highest values appear in summer months which ranged between (10-13), Whereas the lowest values shown during winter season with a range (1.6 - 5 ) and the maximum UVI lies shown in June month was (13.2) in Basra, while the minimum UVI appear in December month was (1.6) in Mosul. The data is used in present paper for the year 2021. The statically evaluation result shows that the estimated DUV by RMSE of 55.96, MBE of 5.84, MAPE of 10.27, MBE of 5.84, and the R of 0.99.

**Keywords:** Aerosol Optical Depth; Baghdad; Human Health; Ultraviolet Index; Vitamin D.

## 1. Introduction

The Sun emit solar energy with different wavelengths reaching the earth surface with different radiation spectra, including the range between (100-400) nm, is called ultraviolet radiation that represents 3% of the solar radiation reaching as its properties can be obtained ground base and satellites sensor measurements [1]. Ultraviolet radiation is classified into three categories according to wavelength: UVA ranges from (315-400) nm, which has a high wavelength, so its energy is low, UVB varies (280-315) nm and UVC ranges from (100-240) nm, which is a short wavelength with higher energy [2]. Where UVA and even UVB are affected by depletion processes by ozone, clouds and air masses during propagation into the atmosphere at this wavelength.

(O<sub>3</sub> and SO<sub>2</sub> are UVB absorbents) whereas (NO<sub>2</sub> is UVA absorbent [3]. The quality of exposure to ultraviolet radiation in terms of time and quantity of exposure is the dividing line between its negative and positive effects. Augmented exposure increases negative effects due to increased access to UVA, and UVB Radiation [4]. Exposure to direct sunlight is an essential source of vitamin D, which is beneficial for humans, especially UVB [5], therefore exposure to sunlight remains necessary to produce Vitamin D which can be stored in the body. One of the most important benefits of Vitamin D is that it is considered an inhibitor for the growth of cancer cells, blood pressure diseases, immune diseases, and skeletal health [6]. It is also considered a nutrient because it contributes to calcium absorption. Several cases of cancer, heart diseases and bone fragility are caused by low levels of vitamin D. [7]. All of this is controlled by a balanced exposure to sunlight. Lack of sufficient exposure to solar radiation causes this deficiency, but exposure depends on skin color, age of the person, use of sunscreen, geographical location, cultural background of countries, the season of exposure, time of day, and air pollution [8]. Air pollution has an effect on the effectiveness of Vitamin D absorption as well as the amount of UV arriving [9], and even an increase in PM<sub>10</sub> and O<sub>3</sub> increases this harmful effect, while an increase in the green belt reduces it [10, 11, 12]. Aerosols have a significant impact on the radiation budget, and these sources are either of human origin resulting from the burning of biomass [13, 14]. Or of marine origin and are considered non-absorbent or dust, as well as mineral ones with absorbent non-absorbent components that give an opportunity to increase the AOD, which is meant by the amount of blocking sunlight, and they are considered a separate source [15, 16]. It is important to sediment dust because the interaction of its particles with solar radiation leads to different heating rates [17, 18]. Effectiveness in terms of smoke and dust storms, it is necessary to find an indicator based on UV, and this is the context used always. It is inferred from the carbon smoke above the vast lands such as deserts, snowy areas and clouds [19]. The measure of the amount of radiation reduction due to Rayleigh scattering by aerosols relative to the Rayleigh scattering of net radiation at different wavelengths defined as aerosol index (AI). [20], Also, AI and AOD are related by a high correlation value and the probability of a linear relationship between them depending on the height of the aerosol layer and particle type [21, 22]. The main aim of the present work includes three empirical equations in order to estimate the dose of UV inquired to generate Vitamin D employing AOD, UVI, SZA, and air mass as an input for each of the cities of Mosul, Baghdad and Basra.

## 2. Study Area

Iraq is located between latitudes 29.5°-37.5° north and longitudes 38.45°-48.45° east in southwest Asia. It also includes the eastern part of the Arab world. Iraq is bordered to the south by Saudi Arabia and Kuwait, and to the east by Iran, Turkey, Syria, and Jordan. (shown Figure 1). The proximity or distance of Iraq from water bodies has a significant impact on Iraq's climate, which is significantly affected by low-pressure systems coming from the Mediterranean and Red Sea regions during certain seasons of the year [23]. The climate of Iraq is generally cold and humid in winter and hot and dry in summer, with temperatures ranging between 21-25 °C degrees in winter and between 40-48 °C degrees during summer. [24], compared to the northern regions of the country, in general, the total cumulative annual rainfall in Iraq does not exceed 200 mm, most of which falls during the winter and spring. Either rainfall is absent or rare in the summer [13, 14]. The following stations were chosen for this study: Mosul, Baghdad and Basra due to their representing various Iraqi locations and climates and the economic and administrative status of the various regions of Iraq. Mosul is the second largest city in population after Baghdad, and a major administrative and commercial center in the country. Basra, with a population of 1,500,000, is an important center for the Iraqi economy due to the presence of oil wells [25, 26].

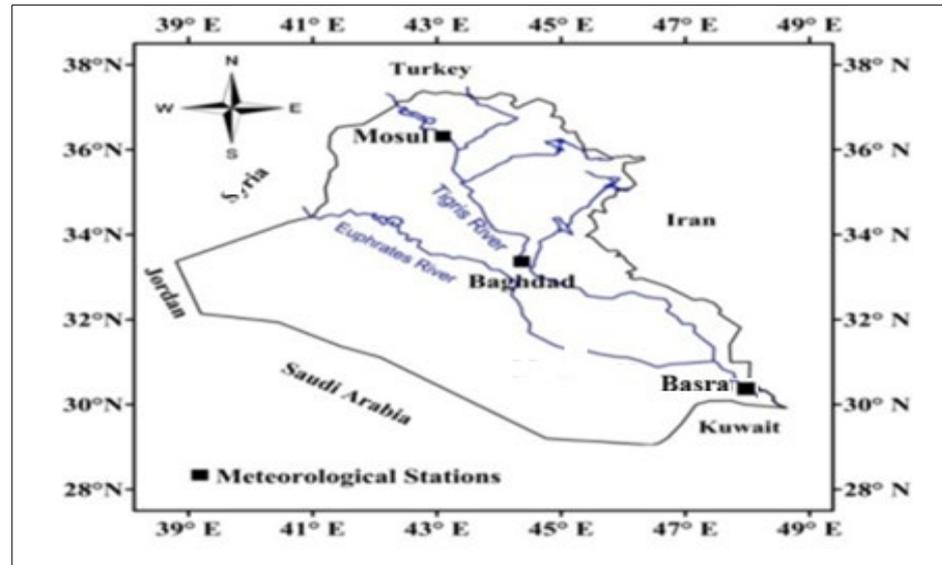


Figure 1. Iraqi Map and study area.

### 3. Acquisition of Ultraviolet Index Data

This research investigates the daily ultraviolet radiation index for 2021 which was obtained by the European Space Agency. The UV Index is calculated from the absorption of the global ozone field at local solar noon, or when the Sun is highest in the sky. For UV dose, this calculation is supplemented by the daily variation in the Sun's position above the horizon. Ozone records and Global Clear-Sky UV Index data are available (<https://www.temis.nl/>). The daily value DUV was computed by multiplying the UV irradiation spectrum by the spectral response of Vitamin D across all wavelengths. The sensors of MODIS Terra (Geovanni Nasa Data Portal) employ different wavelengths such as 340, 380, 440, 500, 670, 870, 940 and 1020 Nanometers in order to estimate direct solar radiation, which can yield aerosol optical depth (AOD) and Total ozone column values at these wavelengths [27].

### 4. Methodology

Modeling and validation are the two aspects of the technique. The specifics are as follows. DUV data, atmospheric characteristics (AOD, UVI, O<sub>3</sub>, SZA, and air mass) from 2021 were utilized for modeling, since five atmospheric factors impacted the DUV. The relations between the DUV and all parameters were explored initially, and the relationships between these parameters were then used as a guide for creating the model. Based on statistical criteria to verify the results of the accurate model using four statistical criteria: R, MAPE, MBE and RMSE. As for Root mean square error (RMSE), Mean Absolute Error (MAE), Mean Base Error (MBE), and Mean Absolute Percentage Error (MAPE) were represented mathematically by equations (1-4) respectively as the following:

$$R = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y})^2} \quad (2)$$

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}| \quad (3)$$

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - \hat{y}}{y_i} \right| \quad (4)$$

Where:  $y_i$  measured value,  $\bar{y}$  mean value,  $\hat{y}$  estimated value.

## 5. Results and Discussion

Daily DUV means UVI and AOD were acquired from the archive of the TEMIS and Geovanni respectively whereas the Solar zenith angle and Air mass have been calculated. The employed data depend on daily basis for the year 2021 over the stations of Mosul for latitude and longitude (36.32 °N, 43.15 °E), Baghdad (33.22 °N, 44.23 °E) and Basra (30.51 °N, 47.81 °E) which represents the north, middle and southern Iraqi parts respectively. Figure 2, shows the daily variation of UVI for area of Mosul, Baghdad and Basra, where the highest values appear in summer months which ranged between (10-13), Whereas the lowest values shown during winter season with a range (1.6 - 5) and the maximum UVI lies shown in June month was (13.2) in Basra, while the minimum UVI appear in December month was (1.6) in Mosul. This large variability between summer and winter seasons due to the high arid during summer and most cloudy weather in winter season and additionally to solar declination angles during the year.

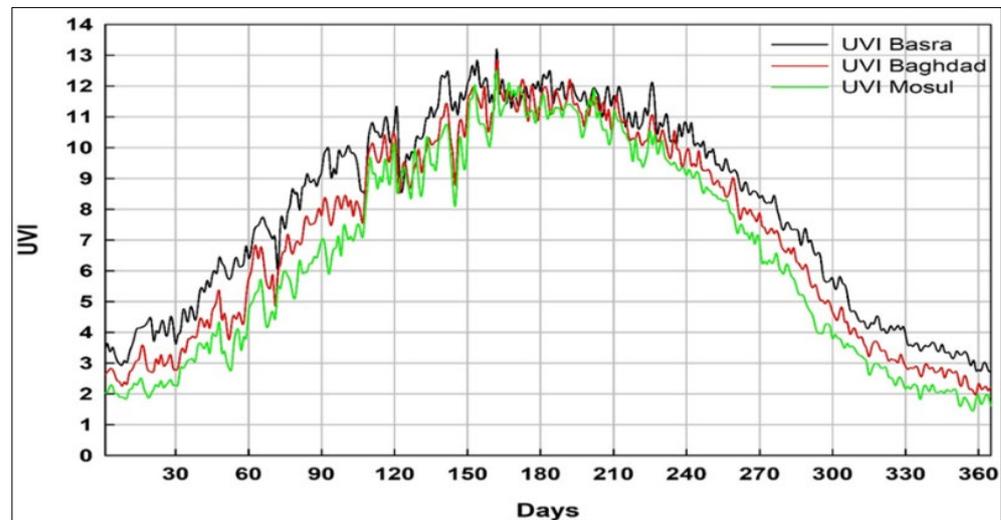


Figure 2. UV index at local noon in Mosul, Baghdad and Basra during the year 2021.

DUV have been presented and employed in present paper for each model in multi-linear regression employing IBM SPSS Statistics 23 according to the following equations:

$$DUV = a_0 + a_1UVI + a_2AOD + a_3SZA + a_4Ma \quad (5)$$

DUV: UV irradiation required for vitamin D photosynthesis (MW/m<sup>2</sup>)

UVI: ultraviolet index

AOD: aerosol optical depth

SZA: Solar zenith angle

Ma: air mass

$a_0$ ,  $a_1$ ,  $a_2$ ,  $a_3$  and  $a_4$  are the model's empirical coefficients.

The following coefficient values are given by the statistical employed software:

$a_0=115.493$ ,  $a_1= 17.164$ ,  $a_2= 529.489$ ,  $a_3= 2.366$  and  $a_4= 276.443$  for Mosul model:

$$DUV = 115.493 + 17.164UVI + 529.489SZA + 276.443Ma \quad (6)$$

$a_0= 127.581$ ,  $a_1= 20.653$ ,  $a_2= 608.740$ ,  $a_3= 2.063$  and  $a_4= - 265.541$  for Baghdad model:

$$DUV = 127.581UVI + 608.740AOD + 2.063SZA - 265.541Ma \quad (7)$$

$a_0= 88.804$ ,  $a_1= 27.269$ ,  $a_2=349.851$ ,  $a_3= 1.345$  and  $a_4= 223.915$  for Basra model:

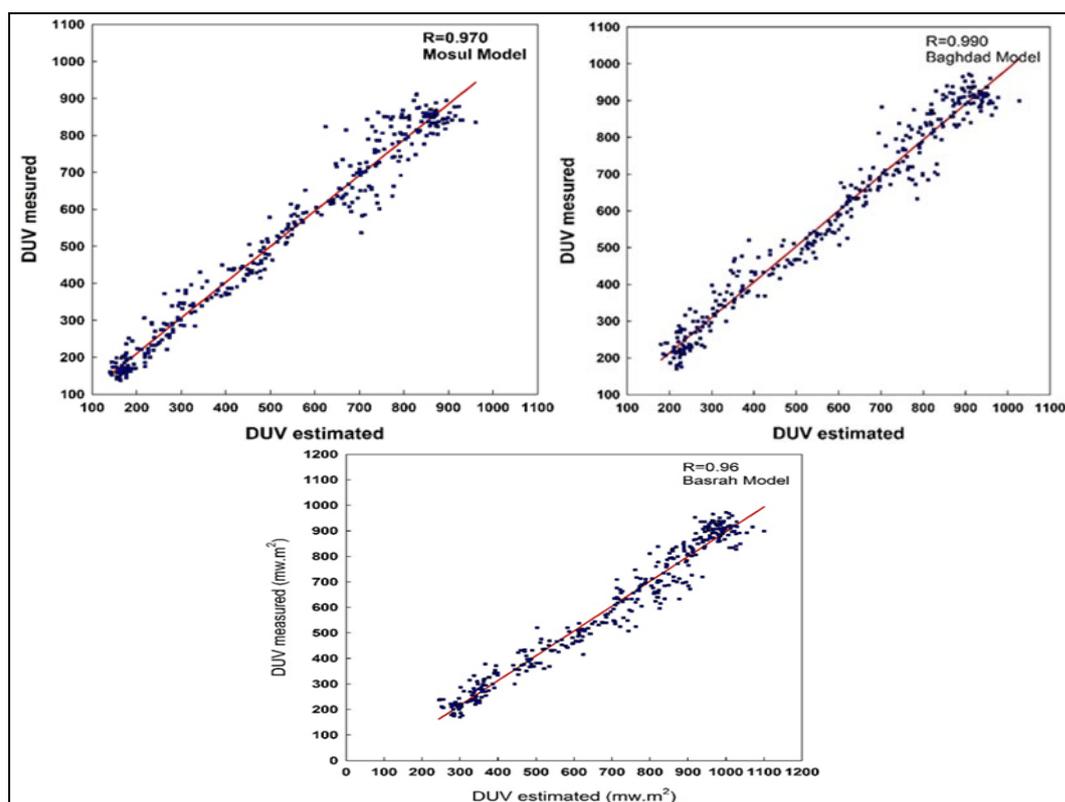
$$DUV = 88.804 + 27.269UVI + 349.851AOD + 1.345SZA + 223.915Ma \quad (8)$$

From Table 1, the correlation coefficient for Baghdad is 0.99. According to the statistical criteria considered (MAE, MAPE, RMSE and MBE) shows the highest accuracy among the proposed empirical equations while the Basra empirical equation shows the lowest accuracy according to the statics considered.

**Table 1.** Statistical parameters of the proposed models.

Statistical Criteria	Mosul Station	Baghdad Station	Basra Station
MAE	44.63	41.82	106.81
MAPE	9.52	10.27	17.26
RMSE	56.84	55.96	122.44
R	0.97	0.990	0.96
MBE	7.12	5.84	10.6

Figure 3, shows that the model can estimate properly for low DUV values. The model underestimates DUV value at high DUV values. This might be due to the complicated interactions of UVI, AOD, SZA, and air mass. However, the overall result reveals that the DUV expected by the Baghdad model approved with the data with an RMSE of 55.96% and an MBE of 5.84%. This demonstrates that the empirical model developed in this study may be utilized to estimate daily DUV at this location. In order to estimate the DUV at a given day, the data of UVI, AOD, SZA at the given day and the coefficients are required as inputs. Then the DUV can be calculated from the model. However, to estimate the DUV at any various climate region, the factors change.



**Figure 3.** The comparison between the DUV from the model (Estimated DUV) and from the measurement (measured DUV) for the model of Mosul, Baghdad and Basra.

## 6. Conclusions

In present work, the UV index, Aerosols optical depth, total ozone column data obtained from Ozone Monitoring Instrument for the year 2021 were employed in order to develop empirical equations to estimate DUV for Mosul, Baghdad and Basra. The evolution of the pervious mentioned models shows powerful performance; the linear correlations of the data range from 0.96 to 0.99 for Basra and Baghdad respectively. Finally, according to the statically criteria indicate that Baghdad model superior to the other proposed models which achieved the following statics evolution values the RMSE of 55.96, MBE of 5.84, MAPE of 10.27, MBE of 5.84, and finally a R of 0.99.

**Supplementary Materials:** None

**Author Contributions:** Zahraa N. Al-Montaser write the paper, Ali M. Al-Salihi make the experiments Noor S. Al-Timime plot the graphs and Nagham T. Ibraheem prepared the draft.

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**Data Availability Statement:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

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**Conflicts of Interest:** No interest

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