USING REMOTE SENSING AND BIG DATA TO ANALYSIS DIRECT SOLAR RADIATION IMPACTS ON THE SPREAD OF COVID-19 (CASE STUDIES: SIX STATES OF THE UNITED STATES)

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ABSTRACT:

The COVID-19 virus and its outbreak were among the most considered research areas in different science branches throughout last year. Meanwhile, some extensive studies have been conducted on the factors influential in increasing the infection rate. The present study examines the relationship between two sets of factors. Firstly, the rate of infection with the virus and the ways it spreads are considered. Secondly, one of the most important climatic factors (direct solar radiation and radiation duration) is studied. This study aims to examine the relationship between these factors and the infection rate with COVID-19 in the six selected U.S. states, including Arizona, California, Colorado, Nevada, New Mexico, and Utah, which receive the maximum radiation and whose population density is at a high level. In order to conduct this study, the analysis of big data and referring to the United States Geological Survey (USGS) have been implemented. This quantitative study is based on analyzing satellite data in the GIS and R software applications. Generally, the research comprises three phases. Firstly, it produces data. Secondly, it examines the satellite images. Finally, it explores and analyses data via sampling techniques and regression tests. The results of this study have revealed that direct solar radiation and density are significantly related to the spread of COVID-19. In the case of radiation duration, investigations show that this variable does not influence the spread of the COVID-19 virus.

1. INTRODUCTION

Last year, the COVID-19 virus and its outbreak were among the most researched topics in different science branches. Meanwhile, some extensive studies have been conducted on the factors influential in increasing the infection rate. There has been some research on different climatic factors and their impacts. This study aims to investigate the impact of the following factors on the spread of the COVID-19 virus: solar radiation and duration radiation, among the climatic-related indicators. Accordingly, in the research, various ways of the spread of the coronavirus in the geographic information system are explored and compared with solar radiation. A review of research related to these two areas indicates that in many cases, the amount of solar radiation is influential on the infection rate of COVID-19 (Isaia et al., 2021; Efstratiou and Tzoraki, 2021). However, we need a wide variety of research to prove the correlation between solar radiation and COVID-19. Further existing research investigation in this area highlights a lack of research types in which the effect of these factors is simultaneously studied on the spread rate of the disease. In order to accomplish this process, firstly, in the theoretical basics section, the impact of these factors on the infection rate with COVID-19 is studied through the existing literature. Secondly, the selected case studies objectively explore the spread of the virus and its potential to be impacted by these factors.

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2. LITERATURE REVIEW

Medical findings show that exposure to solar radiation can positively impact human health. Provision of a proper vitamin D level in the human body, improving hypertension, and providing mental health are some of the effects (Abraham et al., 2021; Juzeniene et al., 2011). Thus, avoiding it can contribute to the lack of vitamin D levels and decrease the body's immune system. This predisposes the body to more vulnerability and the potential of being affected by the epidemic and non-epidemic diseases such as Influenza (Moan et al., 2009; Seyer and Sanlidag, 2020). Furthermore, some studies have been undertaken regarding the contagious COVID-19 virus and the rate of infection and diseases associated with it. These studies are concentrated on the solar radiation impact, and the majority of them are focused on the ultraviolet radiation effect as the main vitamin-D producer in the human body. In some cases, the findings indicate an absence of a significant referable relationship between these factors (Seyer and Sanlidag, 2020; Yao et al., 2020). However, most cases demonstrate a significant indirect relationship and a considerable potential for the virus to receive impacts from ultraviolet radiation (Carleton et al., 2021). When the level of ultraviolet radiation is in a high range, more extended periods of exposure to the sun should be recommended to people by local meteorological or health authorities. Studies of Yudistira et al. (2020) confirm that although ultraviolet radiation can deactivate the COVID-19 virus, it loses its impact in areas with high air pollution. This is due to the transformation of this radiation into heat.

A few researchers have evaluated the impact of other solar radiation specifications on the rate of infection and diseases caused

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by COVID-19 (Srivastava, 2021). For instance,Asyary and Veruswati (2020) has emphasized the duration of solar radiation exposure and investigated statistical data related to infection, death, and recovery from COVID-19 in the city of Jakarta, Indonesia. They concluded that there is a significant relationship between the number of recovered cases and the duration of exposure to the sun. This means that exposure to the sun is associated with recovery from COVID-19. Similarly,Lansiaux et al. (2020) in France, the statistics of the average annual duration of solar radiation are considered. They found a significant relationship between this statistic and the COVID-19 death statistic. Thangariyal et al. (2020) in a study of 38 countries around the world, they found that a longer duration of solar radiation is highly influential in reducing the rate of infection and death associated with COVID-19.

In addition, another study by Ahmadi et al. (2020) has presented the relationship between average solar radiation (along with other climatic components) and the number of coronavirus patients in Iran. The findings of this study show a higher resistance to the virus. Consequently, a higher infection rate in areas with lower solar radiation levels is seen. A survey of 27 metropolitan areas in Brazil did not show a significant relationship between average solar radiation and the number of infected people with COVID-19 (Pedro et al., 2020). However, Rosario et al. (2020) found a significant relationship between these two factors in Rio de Janeiro.

Furthermore, other studies considered Brazil (Mendonça et al., 2020) and China (Byass, 2020); they proved that the increase in COVID-19 spread is related to the reduction of direct solar radiation level. Bäcker (2020) considered the importance of the Zenith angle on the absorption of solar radiation. This study investigated the impact of the daily average of this angle on the rate of infection and disease associated with COVID-19 and revealed that they are reversely proportional. Also, modeling of airborne viruses by Sagripanti and Lytle (2007) showed that diffused solar radiation causes a 50% reduction in the lethal impact of viruses. This study's findings emphasize that the virus's deactivation via solar radiation in the open air continues even in the shadows, on polluted air, or on partly cloudy days.

3. MATERIALS AND METHODS

3.1 Case Study

In order to identify the selected states for analysis, the solar radiation amounts of every state in the U.S. were initially determined for each month of the 2020 year. The results of the initial analysis of global data show that the average solar radiation in each state lies on a different spectrum. Moreover, generally in different states, the spread of the COVID-19 virus shows a significant relationship between radiation and the infection rate. It is important to note that confirmation of these hypotheses requires data examination and statistical tests. According to the initial analysis(Figure1), the solar radiation amount is high in Arizona, California, and New Mexico. In the states of New Jersey, New York, and Virginia, the solar radiation level is low. In both groups, the rate of infection with COVID-19 is high. Therefore, it seems that other factors influence the spread of COVID-19. Since this article focuses on the impact of solar radiation on the amount of COVID-19 spread, the states with maximum solar radiation and a relatively high infection rate with COVID-19 are examined in detail. In the selected states, solar radiation is relatively high. Arizona, California, Colorado, New Mexico, Nevada, and Utah are the nominating states. This helps to accurately investigate the impact of radiation on the spread of COVID-19 by undermining the effectiveness of the density factor. Therefore, the obtained results will be preferable for developing ideas and probable models of urban development.

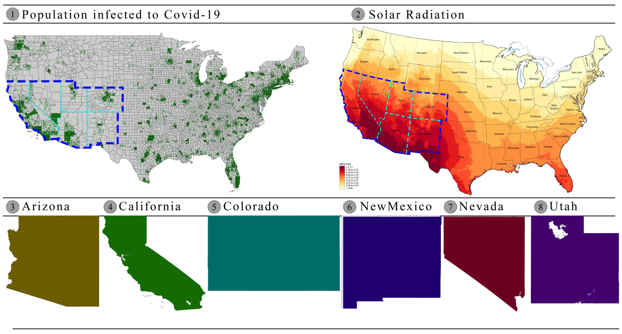

Figure 1. Case Study.

3.2 Data Description

This research uses big data and geographic information systems due to the profusion of its data and the multi-dimensional approach it has adopted. For analyzing solar radiation in GIS, we need digital elevation maps (DEM) from satellite Landsat 8 with 11 bands with spatial resolutions of 15 and 30 m, covering a large area. That is why it helps analyze solar radiation. In order to achieve the DEM of the selected states, the website of the United States Geological Survey has been used as a reference (Rydlund Jr and Densmore, 2012). It is a part of data related to solar radiation data for different states in the U.S. The data is examined over one year from December 2019, when the outbreak of the virus was intensified, until December 2 020. Since monthly data can be misleading due to the disease's incubation period, the data is analyzed seasonally. In this case, the cold and hot seasons provide a more comprehensive analysis. Another set of data related to the number of COVID-19 cases is studied in a similar period. This data is available on the Georgia COVID-19 Data Hub Content website according to each state (COVID, 19).

3.3 Pre-processing Data

After downloading Landsat 8, we need to preprocess the data due to having a series of errors, such as radiometric and geometric. In this case, radiometric calibration should be done on the atmosphere, and on satellite sensors. Use Radiometric Calibration to calibrate image data to radiance, and reflectance. So calculating Radiance should be done based on a formula Formula1 that $L\lambda$ means Radiance in units of W/(m2 * sr * m) and D_N equal Digital number. All of this data is contained in the metadata file.

$$L_\lambda = \frac{L_{max} - L_{min}}{Q_{max} - Q_{min}} * (D_N - Q_{min}) + L_{min} \qquad (1)$$

After that, Analysing Reflectance-TOA (Top of Atmosphere) should be done based on Radiance. The Reflectance defined the amount of reflection that is affected by the atmospheric layer which is calculated based on the formula Formula2.

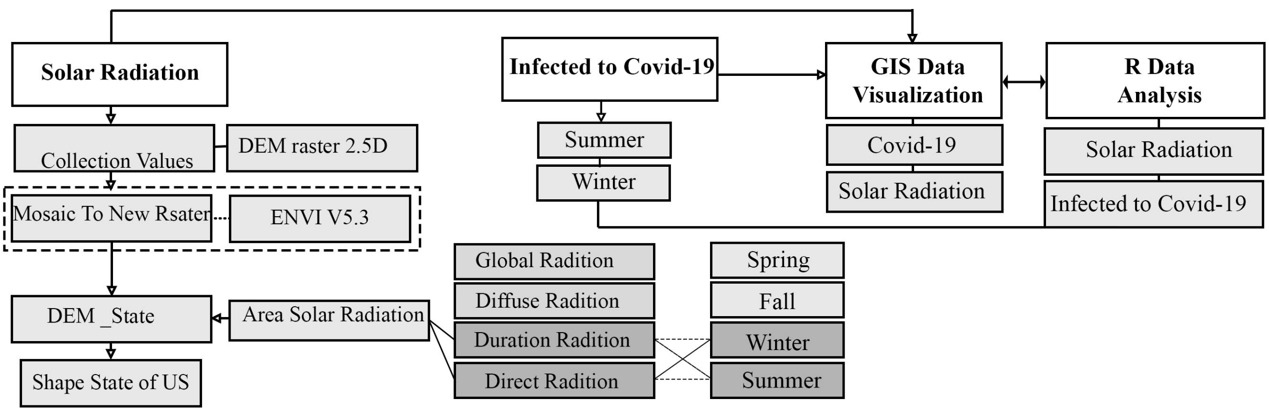

Figure 2. Research Framework.

$$\rho_\lambda = \frac{\pi L_\lambda d^2}{Esun_\lambda * Sin\theta} \quad (2)$$

In the Formula2, d means Earth-sun distance, in astronomical units, and $Esun_\lambda$ equals solar radiance in units of W/(m2*m) and θ means sun elevation in degrees.ENVI automatically calibrates radiation and reflectance using radiometric calibration tools. After calibration for every raster image, it was required to integrate them for each state mosaic by mosaic. This was due to separating DEM data based on 30 * 30 pixels. Due to the extensiveness of data, unification in Arcmap tools requires special hardware. Therefore, this was done in the ENVI V5.3 software environment, one of the most suitable tools for macro-scale image processing tasks. Then cut it according to the shape file of the state to remove the extra borders. Then, the raster file will be ready to be analyzed.

3.4 Processing Data

As stated before, the data collection method refers to the database of Big Data, and the method of data analysis is based on spatial analysis. The ArcMap software V10.8 from Esri's company was used for analyzing solar radiation by Area Solar Radiation Tools Veisi and Shakibamanesh (2022). In order to investigate the relationship between research variables, the correlation analysis method in the R software has been adopted. As illustrated in Figure2, the research comprises four general phases. Initially, it produces data via the achieved satellite data. The data in the second category is related to the spread of the COVID-19 disease in the U.S. states. This data has been obtained through the COVID-19 Information Center in the United States. In the phase of analysis and exploration, there have been some special considerations due to the complexity of data and its dependency on spatial data (solar radiation) and time data (Covid-19). Statistical and visual analysis have been used simultaneously. Therefore, in the third phase, data analysis is considered according to the GIS report of COVID-19 data. This offers an in-depth insight into COVID-19 spread in various seasons and solar radiation in different states. In the final phase, explorations have been conducted regarding the statistical level and data analysis to better understand the relationship between data in every state. The following is a brief report of the production process of prospective investigations.

3.5 Post-Processing Data

Solar radiation was analysed using GIS software. Using boundary cuts and Area Solar Radiation, each US state was analysed. Each state's direct solar radiation and duration were extracted. Using Arcmap's Point to Raster tool, convert the raster file to data. Each state receives a random data sample. The data is then statically analysed in R Studio. This research's hypotheses are: Solar light reduces COVID-19's spread. Second, solar radiation duration affects COVID-19's propagation.

4. RESULTS

After operating the satellite data collection and the initial data analysis, there was a requirement to collect the value of each data point in various parts of the state. These values needed to be adapted to the COVID-19 data. Each state individually had 40-100 million direct solar radiation data points in addition to the same amount of radiation duration data. This caused complications and limitations in examining data in the software environments. Therefore, the R software and various packages related to big data analysis were exploited for analyzing and investigating data.

4.1 Solar radiation in Winter

Table1 shows the extracted data from direct solar radiation in the summer season from the 21st of June until the 10th of September 2020 in the selected states. The initial study of data demonstrates that New Mexico State has the maximum solar radiation data with a median of 438888 kWh/m2 and a mean of 440401 kWh/m2. Moreover, compared with the other states, this state has higher minimum radiation. In California, the maximum radiation absorption amount is 559223, which is the highest recorded value compared with the other states. In the case of radiation amount in this state, median = 384369 kWh/m2 and mean = 389695 kWh/m2, which show lower values than New Mexico's. However, data from the California state has the maximum amount of 1st Qu. = 365025 kWh/m2 and also 3rd Qu. = 409183 kWh/m2. These show the lowest amount of recorded data related to the absorption of solar radiation.

Table2 presents the number of solar radiation hours during the summer season from the 21st of June until the 10th of September 2020. The report asserts that the maximum amount of the Min belongs to Nevada, with a Min. = 555.4 kWh/m2, and the maximum amount of the Max belongs to the Utah state, with a Max. = 1256.5 kWh/m2. However, the Colorado data is median = 1225.3 kWh/m2 and mean = 1196.8 kWh/m2; this emphasizes that generally, in this state, there are surfaces with a higher amount of radiation compared with the other selected states. Furthermore, in the New Mexico state, Median = 922.45, Mean

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state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	N. Data
Arizona	90594	395955	424105	419685	441399	536776	6371115
California	86410	365025	384369	389695	409183	559223	8388606
Colorado	164291	410198	426540	432513	451142	555929	6178683
Nevada	177110	407869	420983	419445	430945	539263	6465289
New Mexico	241318	424841	438888	440401	453458	546020	6797989
Utah	131247	406506	417224	420685	433330	542957	4962663

Table 1. Solar Direct Radiation in summer.

state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	N. Data
Arizona	312.6	1175.3	1204.1	1185.7	1218.8	1236	6371115
California	474.2	1141	1194	1171.4	1222.9	1249.1	8388606
Colorado	352.6	1174.8	1225.3	1196.8	1243.7	1254	6178683
Nevada	555.4	1163.4	1197.3	1182.4	1216.3	1253.1	6465289
New Mexico	27.65	904.14	922.45	909.86	932.22	940.98	6797989
Utah	350.8	1162.9	1206.5	1185	1229.9	1256.5	4962663

Table 2. Solar Duration Radiation in summer.

= 909.86, Min. = 27.65 kWh/m2 and Max. = 940.98 kWh/m2; this means the lowest amount of data for the received radiation duration among the selected states.

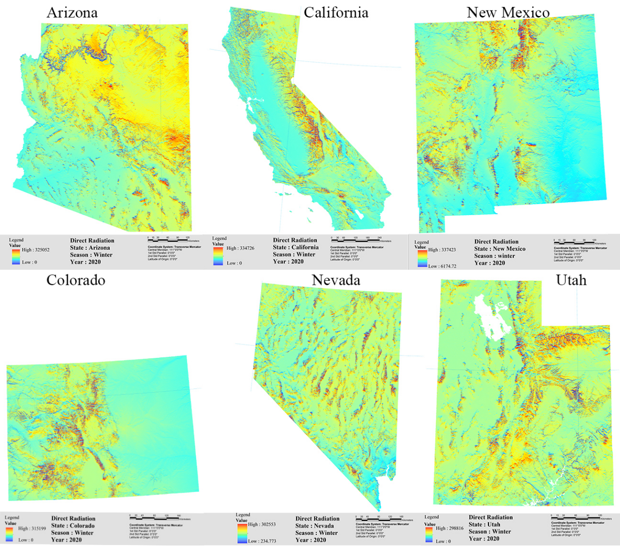

Figure 3. Solar Direct Radiation in Winter.

Analysis of geographic data via the GIS software is indicated in the Figure3. As presented in this figure, in addition to the radiation amount, the wideness of the spaces that receive more radiation is another factor to be considered in the calculations. In addition, due to the extraction of spatial data via point clouds, the statistical index can be assumed as an accurate approximation of the totality of the above pictures. The above satellite images show that considerable parts of the New Mexico, Arizona, and Colorado states have the lowest solar energy absorption. Moreover, the Utah and Nevada states have better conditions in terms of radiation absorption in the summer season. It is important to note that this data does not present an accurate perception according to the general data and color of the states. This is because these colors represent the amount of radiation in each state, comprising different solar radiation spectra, and therefore, they cannot correctly show the distinction between them.

After the initial study of the winter data shown in the Table3, a more explicit undressing of this data is achieved. This extracted solar radiation data is related to the period from 20th December 2019 until 19th March 2020 in the selected states. After reviewing the data related to each state, generally, it is perceived that in the New Mexico data, solar radiation is maximum with a median of 177871 kWh/m2 and a mean of 180293 kWh/m2. Besides, the minimum solar radiation in this state is higher than in other states. Minimum solar radiation belongs to the Arizona and California states, where there are similar numerical values of Median = 130115 kWh/m2 and Mean = 134173 kWh/m2. These two numerical values are less compared with the New Mexico state. The zero data, in this case, is related to outlier data or blind spot, where there has been no solar absorption; or it refers to the points located on the border of each state, where no data has been registered at the time of the creation of the GIS raster file. Therefore, the first quarter can obtain a better understanding of the minimum condition. Table4 shows the number of solar radiation hours during winter from 20th December 2019 until 10th March 2020 in the selected states. Maximum solar radiation hours in the New Mexico state are Median = 1212.4 kWh/m2 and Mean = 1199.2 kWh/m2. This shows that this state generally has more surface with more radiation than the other selected states. In the California state, where there is the lowest amount of data related to the received radiation time among the selected states, the Median = 865.3 kWh/m2 and the Mean = 839.8 kWh/m2.

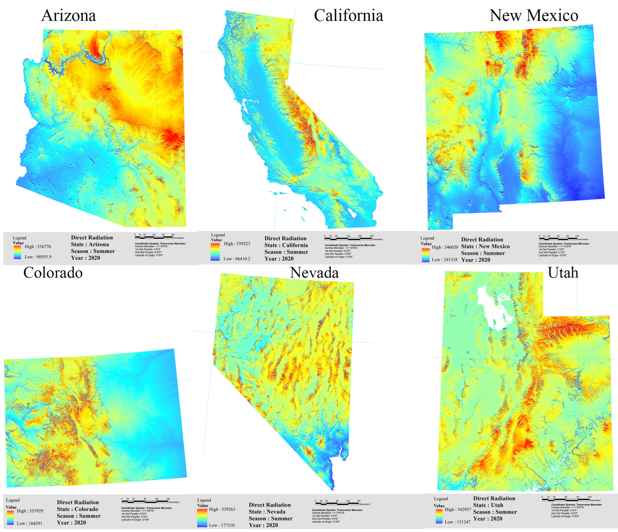

Figure 4. Solar Direct Radiation in summer.

state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	N. Data
Arizona	0	120142	130115	134173	146468	334726	6371115
California	0	120142	130115	134173	146468	334726	8719877
Colorado	0	132450	139471	145522	154680	315199	6178683
Nevada	234.8	136116.7	144018.3	144399.9	151574.1	302553.1	6465289
New Mexico	6175	170187	177871	180293	187894	337423	6797989
Utah	0	130502	136633	139671	148265	298816	4962663

Table 3. Solar Direct Radiation in Winter.

state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	N. Data
Arizona	0	888.8	914.9	896.3	927	941	6371115
California	0	814	865.3	839.8	892	912.2	8719877
Colorado	0	828.3	878	848	897.7	908.6	6178683
Nevada	2.028	837.77	870.009	854.062	888.274	921.231	6465289
New Mexico	581.8	1191.4	1212.4	1199.2	1223.7	1236	6797989
Utah	0	825.5	867.9	843.8	890.3	918.9	4962663

Table 4. Solar Duration Radiation in Winter.

4.2 Solar radiation in Summer

In the analysis of satellite data via the GIS tool, the level of changes in radiation has considerably reduced compared with the summer season. This analysis has considered the winter season from the 20th of December 2019 until the 10th of March 2020 in the selected states. Investigation of these two sets of data, namely satellite data and observed changes, shows that generally, in all the states, changes are relatively identical. Figure4 illustrates that the level of receiving energy in the summer season is close to the minimum and is more comprehensive than the level of the other selected states with radiation in the low spectrum.

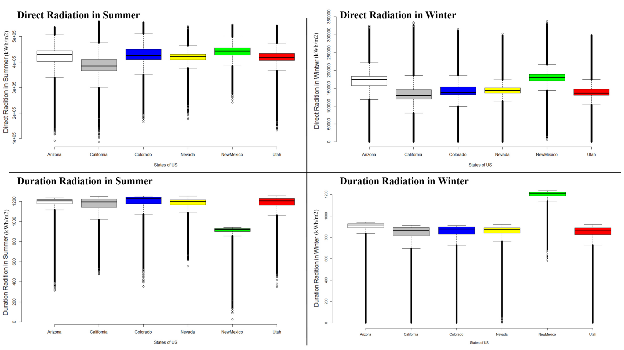

Figure 5. Boxplot for solar Radiation in summer and Winter.

In Figure5, a boxplot diagram is presented for receiving direct solar radiation in the summer and winter seasons. Data investigation shows that in these two seasons, the relationship between data and the domain of changes in solar radiation in each state has been preserved compared with the other states in the two different seasons. For instance, the state of New Mexico receives maximum solar radiation during the summer and winter seasons. Besides, in Figure5, the diagram of the duration of radiation in summer reveals that the minimum solar radiation duration belongs to the New Mexico state and the maximum solar radiation duration belongs to the Colorado state. The same relationship is reversed in the diagram of the winter radiation duration. In other words, the maximum radiation duration is in New Mexico state, and the minimum radiation duration is in Colorado state.

4.3 Covid-19 Data

Covid-19 data recorded at the World Health Center does not contain accurate spatial and temporal information. Therefore, it is essential to note that the investigations are restricted to some available evidence and proof. Data collected in each state is recorded in chronological order, but generally, the data can be studied through analytical environments and methods of spread. It is necessary to mention that the obtained data has been collected based on the official statistics available on the Georgia COVID-19 Data Hub Content website. The presented data in this database refers to the number of people who tested positive and negative for COVID-19 and recovered cases. In this research, the results associated with people who tested positive for COVID-19 have been considered. Moreover, this research uses Covid-19 data from the U.S. states from the 26th of January 2020 until the 23rd of August 2020. Thus, limitations of the research, specifically temporal limitations, confine the study to consider the relationships between variables in different quarters.

Table5 and Table6 show data related to infection with Covid-19. Summer season data is presented in the Table4 from the 21st of June 2020 until the 23rd of August 2020. Winter season data is presented in the Table5 from the 26th of January 2020 until the 29th of March 2020. According to the data of these two tables, the California state, with 60380 infected cases in summer and 142384 kWh/m2 infected cases in the winter, has the maximum number of infected cases with Covid-19. In contrast, New Mexico state, with 2079 cases in summer and 4168 cases in winter, has the minimum number of infected cases. Figure6 shows a general comparison of the rate of infection, which confirms the above observations.

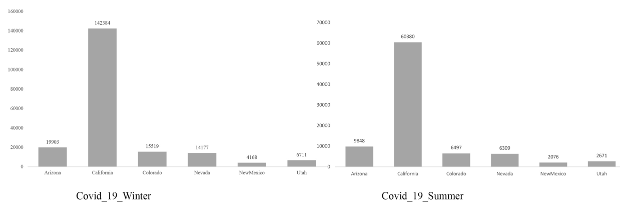

Figure 6. Bar plot diagram for infected by Covid-19 cases.

Figure7 shows a visual report of the spread of the COVID-19 virus in the various urban areas of the studied states. According to these investigations, not only do the course of scattering, and the virus spread depend on spatial data, but also this data in various seasons has decreased and increased considerably. In the following, the results obtained from the data are reported in detail. After extracting the data and performing its initial analysis, the data's behavior should be studied to select the method

state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Total Covid
Arizona	0	1	5	65.65	21.75	977	9848
California	0	1	10.5	104.1	59	3009	60380
Colorado	0	0	0	10.15	3	237	6497
Nevada	0	0	0	37.11	5	605	6309
New Mexico	0	0	1	6.291	3	126	2076
Utah	0	0	0	9.21	4	229	2671

Table 5. Covid-19 Infected Cases in summer.

state	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Total Covid
Arizona	0	0	4	133.6	29	3776	19903
California	0	1	11	245.49	83.75	16634	142384
Colorado	0	0	0	24.25	4	1314	15519
Nevada	0	0	0	83.39	6	3116	14177
New Mexico	0	0	1	12.63	5	517	4168
Utah	0	0	0	23.14	4	1029	6711

Table 6. Covid-19 Infected Cases in Winter.

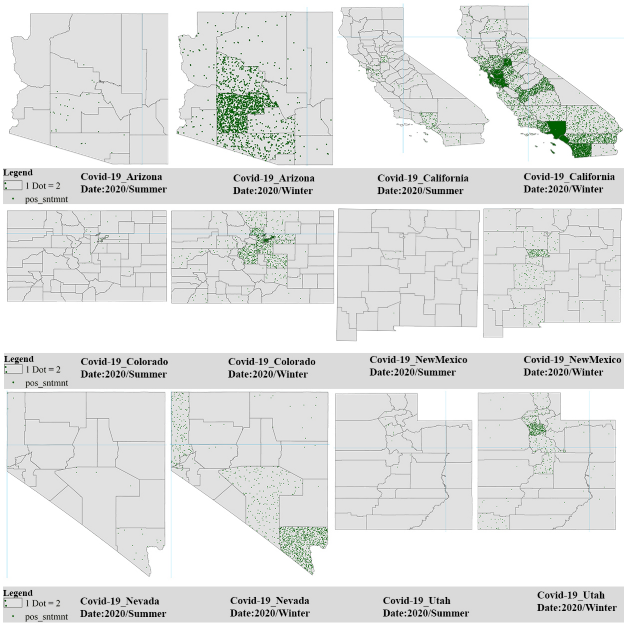

Figure 7. GIS Analysis for Covid-19 Infected Cases.

of examining the data. Since the solar radiation data ranges from 50 million to 100 million, reporting them as a QQ-Plot diagram in Figure5 to examine their behavior would adversely influence the clarity of the analysis. Hence, a histogram model has been used, and the authors have already developed a QQ-Plot study to confirm the following data. The obtained results of this model have been confirmed. Investigation of data indicated in Figures 8 and 9 refers to direct solar radiation and radiation duration. It is understood that data behavior in both solar direct radiation and radiation duration shows a skewness towards the right side. The diagrams and their data do not have a normal state. Therefore, to investigate the totality of data, a non-linear analysis should be conducted.

In the following, the behavior of data associated with COVID-19 infection in the selected states is studied. The investigation results show that Covid-19 infection data is recorded based on time. Data behavior is a function of time and the state of the registered data. Therefore, data behavior is a time series function and needs to be measured via non-linear algorithms. In the following, the relationship between research variables is studied, and the data adaptation level via quantile =.05 is examined for the entire dataset. This is done to provide a better idea of the relationship between the data. This tool has been used for the purpose of sampling from the statistical population in order to explore the population significantly. In addition, Covid-19 infection data in the summer season reveals a normal state with some skewness to the left. However, according to the diagrams, winter data has some skewness towards the right, showing a non-linear state of data. Generally, it is claimed that for predicting the relationship between data, the type of regression should be non-linear.

5. DISCUSSION

Examining the research hypotheses demonstrates a wide range of spatial and temporal variation in research data. While considering the solar radiation spatial data on the one hand and the spread of the COVID-19 virus, on the other hand, it seems that they are significantly related. Nevertheless, examining data via statistical tests offers a better understanding of whether data is authentic or rejected. Because the data has been normalized via quantal sampling, the ANOVA and the regression tests can be used to investigate the relationships between the research variables and explore the hypotheses. In the following, the research hypotheses are examined.

The impact of direct solar radiation on COVID-19 in the six states with maximum solar radiation is illustrated in Table6. In this hypothesis testing, the probability value (p-value) is equal to the minimum value of the significance level (significance level=0.05) or the probability of the type-1 error that causes the rejection of the null hypothesis. The reported data of the six selected states are from two different seasons: summer and winter. As indicated in Table6, during the summer season, this data in the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah, respectively, shows a P-value of 0.05, 0.00, 0.02, 0.01, 0.01, and 0.03. All of the data shows values less than 0.05, except for the state of Arizona, where the P-value is at the level of 0.05. Furthermore, the P-values in the winter season are respectively 0.00044, 7.644e-06, 7.321e-05, 8.918e-05, 0.0004448, and 7.553e-05 kWh/m2. Since the P-values are less than 0.05 with a confidence level of 95%, the null hypothesis is rejected. Instead, the authors' hypothesis is confirmed, stating the impact of direct solar radiation variable on COVID-19 among various groups of the statistical population of the research.

Another study on the six mentioned states investigated solar radiation duration in each state in the summer and winter seasons.

Model	–	Sum of Squares	df	Mean Square	F	p-value
Arizona:Summer Direct Radiation	Regression	2.4416e+10	1	2.4416e+10	4.3342	0.05111
	Residuals	1.0703e+11	19	5.6333e+09	-	-
California: Summer Direct Radiation	Regression	4.0359e+10	1	4.0359e+10	8.3149	0.009516
	Residuals	9.2223e+10	19	4.8538e+09	-	-
Colorado: Summer Direct Radiation	Regression	2.4400e+10	1	2.4400e+10	6.3223	0.02109
	Residuals	7.3329e+10	19	3.8594e+09	-	-
Nevada: Summer Direct Radiation	Regression	2.0396e+10	1	2.0396e+10	6.8077	0.01725
	Residuals	5.6925e+10	19	2.9961e+09	-	-
New Mexico: Summer Direct Radiation	Regression	1.6424e+10	1	1.6424e+10	8.0137	0.01068
	Residuals	3.8940e+10	19	2.0495e+09	-	-
Utah: Summer Direct Radiation	Regression	2.2275e+10	1	2.2275e+10	5.1787	0.03463
	Residuals	8.1723e+10	19	4.3012e+09	-	-
Arizona: Winter Direct Radiation	Regression	2.8131e+10	1	2.8131e+10	17.925	0.00044
	Residuals	2.9819e+10	19	1.5694e+09	-	-
California: Winter Direct Radiation	Regression	4.3243e+10	1	4.3243e+10	36.918	7.644e-06
	Residuals	2.2255e+10	19	1.1713e+09	-	-
Utah: Summer Direct Radiation	Regression	2.2275e+10	1	2.2275e+10	5.1787	0.03463
	Residuals	8.1723e+10	19	4.3012e+09	-	-
Colorado: Winter Direct Radiation	Regression	3.2117e+10	1	3.2117e+10	25.371	7.321e-05
	Residuals	2.4052e+10	19	1.2659e+09	-	-
Nevada: Winter Direct Radiation	Regression	2.7726e+10	1	2.7726e+10	24.488	8.918e-05
	Residuals	2.1512e+10	19	1.1322e+09	-	-
New Mexico: Winter Direct Radiation	Regression	2.8008e+10	1	2.8008e+10	17.962	0.0004448
	Residuals	2.9626e+10	19	1.5592e+09	-	-
Utah: Winter Direct Radiation	Regression	2.8348e+10	1	2.8348e+10	25.23	7.553e-05
	Residuals	2.1349e+10	19	1.1236e+09	-	-

Table 7. Analysis Regression for predictions relationship between variable by the ANOVA test.

An analysis operated by the ANOVA and the regression test has been done to investigate a significant relationship between solar radiation duration data in each state and the spread of COVID-19. This analysis found the following P-values: According to the findings of this analysis, the P-values in summer for the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah are respectively 0.4769, 0.4064, 0.5188, 0.3474, 0.6084, and 0.4757; the P-values in winter for the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah are respectively 0.622, 0.5545, 0.599, 0.5524, 0.01068 and 0.5334. The null hypothesis is confirmed since the P-value is greater than 0.05. This emphasizes that the radiation duration variable does not have a significant relationship with the spread of COVID-19.

According to the Figure3 and Figure4 and also the data presented in the Table3 and Table4, the following fact is understood; in the states where solar radiation has a greater intensity, which means the angle between the solar radiation and the horizon is more comprehensive, the rate of infection with COVID-19 is higher compared with the colder regions (Shahzad et al., 2020). This can be due to various reasons, such as: sterilizing spaces via solar radiation and social distancing associated with state laws or cultural structures. Since the research emphasizes solar radiation, these subjects have not been investigated. The concluding results of this research reveal the conclusive impact of solar radiation on the spread of COVID-19 in the selected states, which have the maximum radiation in the U.S.

Nowadays, the transition from the COVID-19 pandemic period and its positive and negative impacts can be followed by valuable managerial and developmental experience. Discussions about the negative impacts of the virus sound obvious. However, in the case of the positive impacts still, there is a space for investigation and discussion. Some of the positive impacts are the spectacular reduction of air pollution in some cities around the world due to urban quarantine (Alauddin et al., 2021); management experiences as a result of quarantines (Collivignarelli et al., 2021)and the complications existing in some cities around the world. In order to develop the results of this article, the usage of geographic information data, visual and developmental functioning, and urban development have been considered. Therefore, the results can contribute to better management of such pandemics via presenting efficient models for applying and developing management and surveillance. This is efficient for crisis management and the development and planning of cities (Sarwar et al., 2020).

6. CONCLUSION

The study's results clearly show the significant impact of solar radiation on the rate of COVID-19 spread. The results are entirely confirmed in the summer and winter. Hence, the results of this study can be a practical step toward further studies in the climatic and morphological fields associated with the infection rate of Covid-19. Further studies related to the function and spread of the virus throughout society can lead to further behavioral, climatic, and social investigations. This contributes to the prediction of the spread of the virus and the time of the highest infection rate; eventually, preparations for quarantine or preventive implementations can be more applicable.

Moreover, a review of data related to the number of days or sunny hours in the six states of Arizona, California, Colorado, Nevada, New Mexico, and Utah in the two seasons of summer and winter has been conducted. Consequently, it is found that if the intensity of solar radiation is low in a city, meaning that solar radiation is inclined in that region, the impact of solar radiation is less, even though the radiation duration is high. This is in comparison with areas close to the equator. In the first place, this conclusion, alongside the other factors, can be considered for prioritizing treatment and vaccination in various regions of large countries. In the second place, it can be considered from the viewpoint of urban planning and design. In this case, organizing current urban forms and constructing prospective cities according to local conditions in each area with the purpose of maximum usage of light and solar energy are considered.

Other variables, such as population density, wind, temperature, and humidity, among others, may significantly influence the incidence of COVID-19 infection and can vary widely across states. Due to time, budget, and data limitations, we can not pay for all of them. Moreover, this study focused on solar radiation in the six US states in winter and summer because the difference in sunlight in these two seasons is very different.

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