PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

MONITORAMENTO E CÁLCULO DAS EMISSÕES DE DIÓXIDO DE CARBONO EM BAGDÁ E SEU EFEITO NO AUMENTO DAS TEMPERATURAS DE 2003-2018 USANDO DADOS DE SENSORIAMENTO REMOTO

MONITORING AND CALCULATING THE CARBON DIOXIDE EMISSIONS IN BAGHDAD AND ITS EFFECT ON INCREASING TEMPERATURES FROM 2003-2018 USING REMOTE SENSING DATA

مراقبة وحساب انبعاث غاز الكاربون في مدينة بغداد واثره في ارتفاع درجات الحرارة من الفترة 2003-2018 باستخدام بيانات التحسس النائي

JASIM, Mazin Shakir[1*]; MASHEE, Fouad Kadhum[2]

[1] Computer Science Department, Almamon University College, Baghdad, Iraq.

[2] Remote Sensing Unit, College of Science, College of Science, University of Baghdad, Baghdad, Iraq

** Corresponding author*
e-mail: mazin.s.jasim@almamonuc.edu.iq

Received 22 June 2020; received in revised form 09 August 2020; accepted 18 August 2020

RESUMO

A cidade de Bagdá testemunhou uma expansão urbana e industrial com aumento da população, especialmente a partir de 2003. As fontes de poluição do ar se multiplicaram pelo aumento do número de veículos e geradores de energia elétrica causando a emissão de grandes quantidades de gases de hidrocarbonetos, incluindo o dióxido de carbono, CO_2. A emissão desses gases na atmosfera, e em grandes quantidades, certamente terá um papel em contribuir para o aquecimento global. Portanto, terá efeitos negativos proeminentes em influenciar a elevação das temperaturas na cidade. A pesquisa teve como objetivo mostrar o aspecto aplicado das técnicas de sensoriamento remoto e sistemas de informação geográfica na estimativa do CO_2 e sua relação com o balanço térmico para a cidade de Bagdá por meio de quinze estações distribuídas pela cidade. Dados de sensoriamento remoto adotados do *US Geological* e do *European Center*, além de dados de CO_2 para a sonda atmosférica infravermelha (AIRS) de Giovanni para o período prolongado (2003-2018) foram usados. Processamento e análise estatística foram realizados nos dados usando o software GIS 10.6 e Origin 2018. As taxas mensais de CO_2 apresentaram oscilações sazonais entre inverno e verão, sendo o maior valor de CO_2 em julho e o menor valor em fevereiro. A tecnologia *Inverse Distance Weighting* (IDW) foi usada para representar a distribuição espacial das concentrações de CO_2 na cidade. As regiões residenciais e industriais experimentaram concentrações mais altas se comparadas às regiões agrícolas. O coeficiente de correlação de Pearson foi usado para descobrir a relação entre o dióxido de carbono e as temperaturas. O coeficiente de correlação mostrou uma alta relação positiva entre concentrações aumentadas de gás e altas temperaturas para todas as estações de estudo durante todo o período de estudo. Pode-se concluir que a concentração de dióxido de carbono difere localmente nas regiões de Bagdá, como residenciais, comerciais, de trânsito, industriais e rurais, bem como durante os meses do ano.

Palavras-chave: *AIRS, ECMWF, concentração de CO_2, Técnicas de Sensoriamento Remoto.*

ABSTRACT

The city of Baghdad has witnessed an urban and industrial expansion with an increase in population, especially since 2003. Air pollution sources have multiplied by the increase in the number of vehicles and electricity generators, causing the emission of large quantities of hydrocarbon gases, including carbon dioxide, CO_2. The discharge of such gases into the atmosphere and large amounts, will surely have a role in contributing to global warming. Therefore, it will have prominent adverse effects in influencing the rise in temperatures in the city. The research aimed to show the applied aspect of remote sensing and geographic information systems techniques in estimating the CO_2 and its relationship to thermal balance for Baghdad city through fifteen stations distributed throughout the city. Remote sensing data adopted from US Geological and the European Centre, in addition to CO_2 data for the Atmospheric Infrared sounder (AIRS) from Giovanni for the extended period (2003-2018), were used. Processing and statistical analysis were performed on data using GIS 10.6 and Origin 2018 software. The monthly rates of CO_2 showed seasonal fluctuations between winter and summer, where the highest value of CO_2 in July and the lowest value in February. Inverse Distance Weighting (IDW) technology was used to represent the spatial distribution of CO_2 concentrations in the city. Residential and industrial regions experienced higher levels compared to agricultural areas. Pearson correlation coefficient was used to find out the relationship between carbon dioxide and temperatures. The correlation coefficient showed a high positive relationship between increased gas concentrations and high temperatures for all study stations over the entire study period. It can be concluded the concentration of carbon dioxide differs locally in regions of Baghdad, such as residential, commercial, traffic, industrial, and rural areas, as well as during the months of the year.

Keywords: *AIRS, ECMWF, CO_2 concentrations, Remote Sensing Techniques.*

الملخص

شهدت مدينة بغداد توسعاً حضرياً وصناعياً مع زيادة في عدد السكان خاصة منذ عام 2003. حيث تضاعفت مصادر تلوث الهواء بزيادة عدد المركبات ومولدات الكهرباء ، مما تسبب في انبعاث كميات كبيرة من الغازات الهيدروكربونية بما في ذلك الكربون ثاني أكسيد ، CO_2. إن انبعاث مثل هذه الغازات في الغلاف الجوي ، وبكميات كبيرة ، سيكون له بالتأكيد دورهام في المساهمة في الاحتباس الحراري. وبالتالي سيكون لها آثار سلبية بارزة في التأثير على ارتفاع درجات الحرارة في المدينة. يهدف البحث الى اظهار الجانب التطبيقي لتقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية في تقدير غاز ثاني اكسيد الكربون وعلاقته بالتوازن الحراري لمدينة بغداد من خلال خمس عشرة محطة موزعة في عموم المدينة. تم استخدام بيانات الاستشعار عن بعد متمثلة بالمركز الجيولوجي الأمريكي والمركز الأوروبي ، بالإضافة إلى بيانات CO_2 لمسبار الأشعة تحت الحمراء للغلاف الجوي (AIRS) من جيوفاني للفترة الممتدة (2003-2018). تم إجراء المعالجة والتحليل الإحصائي للبيانات باستخدام برنامج GIS 10.6 و Origin 2018. أظهرت المعدلات الشهرية لثاني أكسيد الكربون تقلبات موسمية بين الشتاء والصيف ، حيث بلغت أعلى قيمة لثاني أكسيد الكربون في يوليو وأدنى قيمة في فبراير. تم استخدام تقنية معكوس المسافة الموزون (IDW) لتمثيل التوزيع المكاني لتراكيز ثاني أكسيد الكربون في المدينة. شهدت المناطق السكنية والصناعية مستويات أعلى مقارنة بالمناطق الزراعية. تم استخدام معامل ارتباط بيرسون لمعرفة العلاقة بين ثاني أكسيد الكربون ودرجات الحرارة. أظهر معامل الارتباط علاقة موجبة عالية بين زيادة تركيزات الغاز وارتفاع درجات الحرارة لجميع محطات الدراسة خلال فترة الدراسة بأكملها. وعليه يمكن الاستنتاج ان تركيز ثاني اكسيد الكربون يختلف محليا في مناطق بغداد مثل المناطق السكنية والتجارية والمرورية والصناعية والريفية وكذلك خلال اشهر السنة.

الكلمات المفتاحية: *متحسس AIRS, المركز الاوربي للتنبؤات الجوية, تراكيز غاز ثاني اوكسيد الكاربون ,تقنيات الاستشعار عن بعد*

1. INTRODUCTION:

The role of carbon dioxide in the atmosphere and its effect on global temperature is central to the contemporary debate on global warming caused by human activities. Carbon dioxide is a colorless and tasteless gas. It is formed naturally through breathing processes and the natural decomposition of dead bodies and the earth's crust rocks. Also, it can be found in volcanoes. About 40% of the gas released from the volcanoes during the eruption is carbon dioxide; that is, the volcanoes release between 130 and 230 million tons of carbon dioxide into the atmosphere every year (Al-jaf and Al-Taai, 2019).

The seas and oceans contain large amounts of it, as the total of exchanges with the atmosphere annually, up to 100 billion. It also created due to human activities through the burning of fossil fuels, burning, and deforestation and changes in the land-use patterns and other industrial processes. However, carbon dioxide emissions from human activities are about 135 times higher than volcanic emissions (Falkowski *et al.,* 2000). The presence of carbon dioxide in the atmosphere and at high concentrations works to trap heat and prevent it from penetrating through the absorption of infrared radiation. The higher concentration, the higher in temperature, and more climatic and environmental changes, this phenomenon is known as global warming (Al-Bayati and Al-Salihi, 2019).

Global warming is a natural phenomenon that occurs in any region. However, when there is an exacerbation of this phenomenon from its natural limits, it becomes an environmental problem. The increase in the proportions of some gases in the atmosphere, where the most important of which is carbon dioxide, leads to the temperature rise. The global temperature has increased by about 0.7°C over the past century due to an increase in carbon dioxide (Weinbauer *et al.,* 2011).

Recent readings show a 30% increase in the concentration of carbon dioxide in the atmosphere since the readings began in 1958. The level of this gas in its first measurement reached 315 parts per million, while its concentration exceeded the barrier of 400 parts per million for the first time in 2013. In contrast, the carbon dioxide rate in the atmosphere was about 280 parts per million before the year 1800 (Hashim and Sultan, 2010). Global warming has affected the climate of Iraq, especially in Baghdad, with a significant and noticeable effect on the temperature; according to Iraq meteorological organization, the temperatures in Baghdad have increased significantly in their rates. As a result of the change in the rates of greenhouse gases resulting from industrial activities, means of transportation, the widespread prevalence and use of diesel generators, and an increase in the population (Al-ramahi, 2020). This increase in temperature affected various natural and environmental phenomena in Iraq by increasing the amount of evaporation from the Tigris and Euphrates water, and this leads to serious ecological problems including drought, desertification and the problem of sand dune encroachment (Hassoon, 2015; AL-Hassany and Hindi, 2016)

This study aimed to monitor carbon dioxide emissions in Baghdad and its impact on increasing temperatures seeking to control it and contribute to reducing global warming by using the Inverse Distance Weighting (IDW) technology provided by the GIS program *(*Al Naqeeb *et al.,* 2020).

2. MATERIALS AND METHODS:

2.1. Study area

Baghdad is the administrative capital of Iraq, and it is considered the largest city in terms of population. According to 2015 statistics, its population reached 8.405.172 million people with a population density of 11614 people per km². The Tigris River divides it into two parts: Karkh and Rusafa, including 288 residential areas. It is located between latitudes (33.10°N) and (32.04 °N) and longitude (44.77°E) and (43.29°E), at an altitude of 34 meters above sea level (Jasim *et al.*, 2020).

Baghdad is one of the urban areas with explicit human activity and, after 2003, witnessed significant changes in the areas of land use, random population density, urban and industrial expansion. Also, the increased vehicles and electricity generators led to a diversity of pollution sources, which enhances the increase in carbon dioxide. The climate of Baghdad is characterized by the continental characteristic of being hot dry in summer and cold rainy in winter, according to the Köppen classification, where the highest temperatures in the world were recorded in recent years. Temperatures vary between summer and winter, as the highest monthly average was in July when it reached (36.2) °C. It also recorded the lowest decrease in January, where the monthly average was (10.7) °C (AL-Hassany and Hindi, 2016).

The current study included estimating carbon dioxide gas through fifteen selected stations throughout Baghdad, and these stations were represented by some residential, traffic, and industrial areas, including two stations in the agricultural areas for comparison, as shown in Figure 1 and Table 1.

2.2. Data collected

This study used remote sensing data, represented by the United States Geological Survey (USGS). One satellite image of the Sentinel-2 satellite was used (acquisition time: 13 April 2019 approximately CCT 10:37 a.m.) with spectral beams (MID IR NER-IR, GREEN) to help to implement returns and projections according to the World Geodetic System1984. This was done for the study area maps and to positioning the spatial locations of the stations chosen on them.

Besides, data from the European Centre for Medium-Range Weather Forecasts (ECMWF) represented by the monthly average of temperature were used. Also, data of a monthly average of carbon dioxide taken from the atmospheric infrared sounder (AIRS) from Giovanni of NASA with an accuracy of $2^{o} \times 2.5^{o}$, where the spectral coverage of AIRS sensor at (3.74 μm to 4.61 μm), (6.20 μm to 8.22 μm), and (8.8 μm to 15.4 μm) were taken (Thomas *et al.,* 2011).

The annual, monthly rates for February and July were used for the period from (2003-2018) and for each station depending on the GPS locations of these stations and in the form of coordinates (x, y). The Pearson test was chosen from several statistical tests for regression analysis and knowledge of the relationship between temperature variables and carbon dioxide concentrations using the Origin 2018 statistical program. The study area was divided into residential, industrial, and agricultural. Spatial distribution maps of carbon dioxide concentration with temperature were performed using a GIS program. The inverse distance weighted method was used to plot the spatial differences of carbon dioxide and temperature according to the selected areas.

2.3. Spatial and statistical analysis

Spatial analysis is one of the necessary techniques to represent the spatial distribution of carbon dioxide concentrations and its relationship to temperature changes to know spatial differences between one part and another in the selected areas, among the geostatistical techniques (Muthanna *et al.*, 2018).

The Inverse Distance Weighting (IDW)

technology provided by the ArcGIS 10.6 program was used to produce spatial distribution maps of carbon dioxide concentrations and temperature in the city. This method depends on the spatial correlation of the data measured at specific points in the region to calculate the required data at points where measurements are not available (Al Ramahi and Al Bahadly, 2020; Ghazal *et al.*, 2012).

The data of each known point affects more whenever it is close to the unknown points or does not contain measurements. Its effect decreases whenever you move away from it so that each known location has a specific weight included in the calculation. It expects or predicts unknown values depending on their proximity or distance from the source. This technique is characterized by accurate estimates such that the Mean error, Mean Prediction Error, Root-mean-square error. The standard average mistake is close to zero. There are many statistical measures that can be used to find the correlation relationship between two variables (AL Naqeeb *et al.*, 2020; Hadi and Mashee, 2017).

The Pearson correlation coefficient provided by Origin 2018 was used to detect the relationship between gas concentration and temperature. It is a statistical measure to measure the strength of the relationship between two variables and is expressed as a value between (+1 and -1). The number (+1) indicates a strong positive correlation between the two variables, which means that a positive change will follow any positive change in one of the variables in the other variable. The number (-1) indicates a robust negative correlation between the two variables, which means that a negative change will follow any positive change in one of the variables in the other variable. While zero indicates no relationship between the two variables or that there is no clear relationship between the changes (Gelfand *et al.*, 2010).

3. RESULTS AND DISCUSSION:

3.1. Spatial distribution and temporal trends of carbon dioxide means

Figure 2 illustrates the Time Series, Area-Averaged of Carbon Dioxide in PPM, 2 x 2.5 deg. [AIRS AIRX3C2M v005] over 2003-Jan - 2018-Dec, Region (43.4762 °E, 32.9919 °N, 44.3221 °E, 33.783 °N) plotting by Origin 2018. Figures 3 and 4 illustrate the spatial distribution of the monthly average of carbon dioxide concentrations in Baghdad for the period (2003-2018) and for February and July months using the Inverse Distance Weighting (IDW) technology provided by ArcGIS (Chen and Liu, 2012). The monthly rates of carbon dioxide concentrations showed a spatial difference in most parts of a region with variations in the spatial area patterns for each season. They depend on different seasonal fluctuations and weather conditions.

The increase of the population and the significant emissions of fuel burned from many vehicles and electric power generators are one of the factors to the growth of carbon dioxide levels. The agricultural degradation and the change of thousands of dunums of agricultural and open areas to residential, industrial, and commercial áreas have also contributed to this increase in the CO_2 levels.

The highest values of carbon dioxide concentrations were found in July, where the average gas concentration was 379.80 ppm in 2003, with a continuous increase to 406.35 ppm in 2018. In contrast, in February, the lowest values were where the average gas concentration was 376.35 ppm in 2003, with a continuous increase to 410.79 ppm in 2018 (Al-Timimi and Al-Jiboori, 2013). These differences between July and February are due to several reasons. The most important is the low consumption of gas from plants in the summer, where photosynthesis is less in the summer than the spring months, and, thus, the use of carbon dioxide decreases. Also, increasing electrical energy consumption for cooling leads to an increase in the quantities of fuel burned, so the percentage of gas in the atmosphere also increases. While the growing season of plants and trees begins in Baghdad in February, photosynthesis in the plant is at its highest value, thus increasing the consumption of carbon dioxide and reducing the amount of gas in the atmosphere (Al Jiboori *et al.*, 2016). The concentration of carbon dioxide differs in residential, commercial, traffic, industrial, and rural areas. It can be observed a significant increase in the concentration of carbon dioxide in industrial and traffic-congested areas with cars compared to stations in agricultural and open áreas. The rate of concentration of carbon dioxide in regions of Al-Taji and Al-Rashid was relatively low compared to the stations of Al-Shu'ala, New Baghdad, Karrada, and Sadr City. These cities witnessed a relatively high value due to industrial activity, as these areas are considered industrial and traffic-related areas, with cars and high population density. Dora station recorded the most elevated concentrations over time due to the presence of an electric power station that consumes large quantities of fuel for energy production apart from the bulldozing of agricultural lands, especially during recent years, where turned these areas to residential lands or factories. Due to the proliferation of brick production plants in the Al-Bawi region, east of Baghdad, high carbon dioxide concentrations have also been seen (Worrell *et al.*, 2001). An increase in the levels of carbon dioxide will lead to negative consequences to the atmosphere, as it affects various natural and environmental phenomena of the city of Baghdad. The most important of which is the high temperatures, where Baghdad recorded the most elevated temperatures in the world during recent years. Other negative consequences are drought, desertification, and an imbalance in precipitation, as the city has suffered from persistent floods due to torrential rains (Solomon *et al.*, 2009).

3.2. Spatial distribution and temporal trends of temperature means

Figure 5 illustrates the Time Series, Area-Averaged of temperature in ° C, 0.125 x 0.125 deg. [ERA-interim] over 2003-Jan - 2018-Dec, Region (43.4762 °E, 32.9919°N, 44.3221°E, 33.783°N) plotting by Origin 2018. Figures 6 and 7 illustrate the spatial distribution of the monthly average of carbon dioxide concentrations in Baghdad for the period (2003-2018) and for February and July months using the Inverse Distance Weighting (IDW) technology provided by ArcGIS (Chen and Liu, 2012). It can be observed that the spatial distribution of the monthly average temperatures showed a spatial difference in most parts of the region. The highest monthly average temperature was during July, while the lowest monthly rate was in February.

By analyzing trends for the entire period, the increase was apparent, as the average temperature of the city of Baghdad increased by (1.73) degrees Celsius since the monthly average for July was 36.4°C from the year 2003 with a continuous increase to 38.45° C in 2018. At the same time, the monthly rate was in February 13.2°C from 2003, with a constant rise to 15.27 °C in 2018 (Fenner *et al.*, 2014). This increase is due to several reasons, the most important of which is the increase in the area of land use according to the urban expansion in terms of built areas or those that entered into human activity, especially after 2003, where many green and agricultural fields were subjected to significant deterioration. Hence, the urban character became prevalent in the city, especially in recent years, in addition to increasing the concentrations of carbon dioxide gas as the molecules of this gas have a great ability to absorb infrared radiation and thus work to trap heat in the lower layers and prevent them from penetrating into outer space, which leads to an increase in temperature (Salman *et al.*, 2018).

The lowest temperature was found along the Tigris River from the far north of the study area to the far south and southwest. This was due to the nature of the wet soil and the presence of agricultural lands at the Al-Taji and Al-Rashid regions. The highest temperature was in the center of Baghdad because of the low vegetation cover in urban areas at the Karrada and New Baghdad and Sadr City once these areas are considered to be of high population density, with vehicles and generators widespread. Dora and Al-Bawi region stations recorded the most elevated temperatures, as they are deemed industrial areas. Accordingly, there are multiple sources of pollution, which enhances the carbon level in them (Al-Timimi and Al-Khudhairy 2018).

3.3. Carbon dioxide concentrations and temperature: the assumed correlation

By studying the spatial distribution of carbon dioxide, it could be seen that carbon dioxide is continuously increasing due to the increased combustion of fossil fuels, oil, gas, transportation, aviation, and electricity generation. Another factor that plays a vital role in this increase is the increase in population density. The stations of the study area were divided into three types of residential, industrial, and agricultural, according to the presence of these stations in the Baghdad regions. Pearson correlation coefficient was used to find out the relationship between carbon dioxide concentrations and temperatures by taking annual averages of February and July along the study period (Shakun *et al.*, 2012).

The correlation coefficient showed a high positive relationship between increased gas concentrations and high temperatures for all study stations over entire study period. The highest value of the correlation coefficient between gas concentrations and temperatures in residential areas of Baghdad, as it reached (0.92) in July while it was (0.89) in February. As for the stations in the industrial regions was (0.83) in July and (0.82) in February, especially in Dora region, and this is due to the bulldozing of its agricultural lands and its transformation into factories and residential lands (French *et al.*, 2009). Al-Bawi region has witnessed high correlation values over time, especially in recent years. The proliferation of factories causes this, mainly since those plants emit a lot of gas, including carbon dioxide, which affects raising gas levels in the neighboring regions like New Baghdad, Karrada and Sadr City.

Stations in the agricultural areas at Al-Taji and Al-Rashid have witnessed different correlation values where dioxide decreases during the winter and the beginning of the plant growth season as plants withdraw carbon dioxide from the atmosphere through photosynthesis. Therefore the value of carbon dioxide in the cold months is less than the warm summer months were (0.80) in February and (0.91) in July (Rehan and Nehdi, 2005). Fig (8) shows a scatter plot of correlation coefficients between temperature and carbon dioxide concentrations for February and July over the period (2003-2018). Table 2 shows the values of Pearson's r coefficient correlation, Adj. R-Square, Standard Error, and T-Value between carbon dioxide concentrations and temperature and for the same period.

4. CONCLUSIONS:

1. The concentration of carbon dioxide differs locally based on Baghdad areas such as residential, commercial, traffic, industrial, and rural areas, as well as changes during the months of the year.
2. Stations in agricultural regions at Al-Taji and Al-Rashid have witnessed different correlation values where dioxide decreases during the winter and the beginning of the plant growth season as plants withdraw carbon dioxide from the atmosphere through photosynthesis. Therefore the value of carbon dioxide in the cold months is less than the warm summer months were (0.80) in February and (0.91) in July.
3. Human activity increases carbon dioxide concentrations - which is estimated at 38.7 parts per million -. This is a relatively significant increase related to other ground cover changes, such as agricultural land, abandonment land, and arid land. During the winter, the water level increased due to rainfall leading to low nutrients concentrations.
4. The continuous increase in the concentration of carbon dioxide has negative results about the atmosphere as it affects the several natural and environmental phenomena of the city of Baghdad. The most important of which are high temperatures, drought, desertification, and the imbalance in the amount of precipitation, as the city has suffered from continuous flooding, especially in recent years.
5. The correlation coefficient showed a high positive relationship between increased gas concentrations and high temperatures for all study stations over the entire study period. The highest value of the correlation coefficient between gas concentrations and temperatures in residential areas of Baghdad, as it reached (0.92) in July while it was (0.89) in February.

5. REFERENCES:

1. AIRS (Atmospheric Infrared Sounder). onboard NASA's Aqua Satellite . [Online] Available at: https://giovanni.gsfc.nasa.gov
2. Al Jiboori, M. H., Hassan, A. S., and Hashim, B. M. (2016). Evaluation of Industrial CO_2 Emissions from Cement Production and Transportation Sector in Iraq Using IPCC Methods. *Diyala Journal for pure science*, 12(4-part 2), 58-69.
3. Al Naqeeb, N.A., Mashee, F.K. and Al Hassany, J. S. (2020). Estimation the factors affecting on growth of algae in um el-naaj lake by using remote sensing techniques. *Periódico Tchê Química, 17* (35), 227-238.
4. Al Ramahi, F. K. M., and Al Bahadly, Z. K. I. (2020). The Spatial Analysis for Bassia eriophora (Schrad.) Asch. Plant Distributed in all IRAQ by Using RS and GIS Techniques. *Baghdad Science Journal*, *17*(1), 126-135.
5. Al-Bayati, R. M., and Al-Salihi, A. M. (2019). Monitoring carbon dioxide from (AIRS) over Iraq during 2003-2016. In *AIP Conference Proceedings* (Vol. 2144, No. 1, p. 030007). AIP Publishing LLC.
6. AL-Hassany, J. S., and Hindi, M. T. (2016). A Study of Epiphytic and Epipelic Algae in Al-Dora Site/Tigris River in Bagdad Province-Iraq. *Baghdad Science Journal*, *13*(4), 721-733.
7. Al-jaf, S. J., and Al-Taai, O. T. (2019). Impact of carbon dioxide concentrations on atmospheric temperature changes over Iraq and some neighboring countries. *Plant Archives*, *19*(2), 1450-1456.
8. Al-ramahi, F.K.M. (2020). Spatial analysis

of radon concentration distrusted at Baghdad city using remote sensing techniques and geographic information systems. *Iraqi Journal of Agricultural Sciences*, 51(Special Issue), 21-32.

9. Al-Timimi, Y. K., and Al-Jiboori, M. H. (2013). Assessment of spatial and temporal drought in Iraq during the period 1980-2010. *Int. J. Energ. Environ*, 4(2), 291-302.
10. Al-Timimi, Y. K., and Al-Khudhairy, A. A. (2018). Spatial and Temporal Analysis of Maximum Temperature over Iraq. *Al-Mustansiriyah Journal of Science*, 29(1), 1-8.
11. Chen, F. W., and Liu, C. W. (2012). Estimation of the spatial rainfall distribution using inverse distance weighting (IDW) in the middle of Taiwan. *Paddy and Water Environment*, *10*(3), 209-222..
12. ECMWF (European Centre for Medium-Range Weather Forecasts). ERA-interim model. [Online] Available at: http://apps.ecmwf.int
13. Falkowski, P., Scholes, R. J., Boyle, E. E. A., Canadell, J., Canfield, D., Elser, J., Gruber, N., Hibbard, K., Högberg, P. , Linder, S., Mackenzie, F. T., Moore III, B., Pedersen, T. , Rosenthal, Y. , Seitzinger, S., Smetacek, V., and Steffen, W. (2000). The global carbon cycle: a test of our knowledge of earth as a system. *science*, *290*(5490), 291-296.
14. Fenner, D., Meier, F., Scherer, D., and Polze, A. (2014). Spatial and temporal air temperature variability in Berlin, Germany, during the years 2001–2010. *Urban Climate*, 10, 308-331.
15. French, S., Levy-Booth, D., Samarajeewa, A., Shannon, K. E., Smith, J., and Trevors, J. T. (2009). Elevated temperatures and carbon dioxide concentrations: effects on selected microbial activities in temperate agricultural soils. *World Journal of Microbiology and Biotechnology*, *25*(11), 1887-1900.
16. Gelfand, A. E., Diggle, P., Guttorp, P., and Fuentes, M. (Eds.). (2010). *Handbook of spatial statistics* (pp12-23). CRC press.
17. Ghazal, N. K., Shaban, A. H., Mashi, F. K., and Raihan, A. M. (2012). Change Detection Study Of Al Razaza Lake Region Utilizing Remote Sensing And GIS Technique. *Iraqi Journal of Science*, *53*(5), 950-957.
18. Hadi, G. S., and Mashee, F. K. (2017). Study the Wet Region in Anbar Province by Use Remote Sensing (RS) and Geographic Information System (GIS) Techniques. *Iraqi Journal of Science*, 58(3A), 1333-1344.
19. Hashim, M.B., and Sultan, M. A. (2010). Using remote sensing data and GIS to evaluate air pollution and their relationship with land cover and land use in Baghdad City. *Iranian Journal of Earth Sciences*, *2*(1), 20-24.
20. Hassoon, A. F. (2015). Assessment of air pollution elements concentrations in Baghdad city from periods (May-December) 2010. *International journal of energy and environment*, *6*(2), 191
21. Jasim, O., Ali, A. R. B., and Hashim Hamed, N. (2020). Urban expansion of Baghdad city and its impact on the formation of Thermal Island based upon Multi-Temporal Analysis of satellite images. *MSandE*, *737*(1), 012215.
22. Muthanna, M. A., Mashee,F .K., and Fadhil, M. (2018). Assessment of Irrigation Water Quality for Dabdaba for Mation by Using GIS Techniques in Karbala Province. *Indian Journal of Natural Sciences*, I9(50), 14677-14684.
23. Rehan, R., and Nehdi, M. (2005). Carbon dioxide emissions and climate change: policy implications for the cement industry. *Environmental Science and Policy*, *8*(2), 105-114.
24. Salman, S. A., Shahid, S., Ismail, T., Ahmed, K., and Wang, X. J. (2018). Selection of climate models for projection of spatiotemporal changes in temperature of Iraq with uncertainties. *Atmospheric Research*, 213, 509-522.
25. Shakun, J. D., Clark, P. U., He, F., Marcott, S. A., Mix, A. C., Liu, Z., ... and Bard, E. (2012). Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. *Nature*, 484(7392), 49-54.
26. Solomon, S., Plattner, G. K., Knutti, R., and Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the national academy of sciences*, 106(6), 1704-1709.

27. Thomas, H. E., Watson, I. M., Carn, S. A., Prata, A. J., and Realmuto, V. J. (2011). A comparison of AIRS, MODIS and OMI sulphur dioxide retrievals in volcanic clouds. *Geomatics, Natural Hazards and Risk*, *2*(3), 217-232.

28. USGS (United States Geological Survey), (2017). Landsat — A Global Land-Imaging Mission.[Online] Available at: http://glovis.usgs.gov

29. Weinbauer, M. G., Mari, X., and Gattuso, J. P. (2011). Effect of ocean acidification on the diversity and activity of heterotrophic marine microorganisms. *Ocean acidification. Oxford University Press, Oxford*, 83-98.

30. Worrell, E., Price, L., Martin, N., Hendriks, C., and Meida, L. O. (2001). Carbon dioxide emissions from the global cement industry. *Annual review of energy and the environment*, 26(1), 303-329.

Table 1. *Location of study area stations and its types, names, global coordinate system (λ, φ), and Universal Transverse Mercator (UTM) coordinate (x, y).*

Stations	Longitude (Eº)	Latitude (Nº)	UTM Easting	UTM Northing	Station type
Adhamiyah	33.368	44.358	440276.74	3692268.71	**Residential (Re)**
Al-Taji	33.428	44.309	435762.50	3698950.10	**Agricultural (Ag)**
Al-Shu'ala	33.368	44.259	431066.89	3692329.84	**Residential, Traffic (Re, Tr)**
Al-A'amiriya	33.295	44.288	433709.47	3684217.56	**Residential (Re)**
Baghdad airport	33.29	44.215	426908.49	3683711.96	**Residential, Traffic (Re, Tr)**
Sha'ab	33.422	44.402	444404.38	3698231.30	**Residential (Re)**
Sadr City	33.398	44.466	450340.83	3695538.06	**Residential (Re)**
Karrada	33.342	44.4	444167.33	3689362.82	**Residential (Re)**
Al-Jadriya	33.282	44.393	443477.24	3682714.50	**Residential, Agricultural (Re, Ag)**
Mansour	33.329	44.342	438760.99	3687954.09	**Residential (Re)**
Al-Bawi region	33.401	44.536	456852.00	3695839.46	**Industrial (In)**
New Baghdad	33.32	44.486	452158.08	3686880.97	**Residential, Industrial (Re, In)**
Dora	33.255	44.48	451563.72	3679677.38	**Residential, Industrial (Re, In)**
Al-Rashid	33.214	44.389	443060.68	3675177.72	**Agricultural (Ag)**
Hayy Al-Jihad	33.253	44.321	436751.70	3679540.62	**Residential (Re)**

Table 2. *Statistical summary of the study area stations.*

	Stations types	Pearson's r	Adj. R-Square	Standard Error	T-Value
February	agricultural	0.80914	0.79551	0.00384	2.14449
	industrial	0.82321	0.81058	0.00388	2.33883
	residential	0.89663	0.78995	0.00447	1.09056
July	agricultural	0.90031	0.90461	0.00694	1.03030
	industrial	0.83841	0.82687	0.00951	1.68395
	residential	0.92738	0.9222	0.00662	1.58674

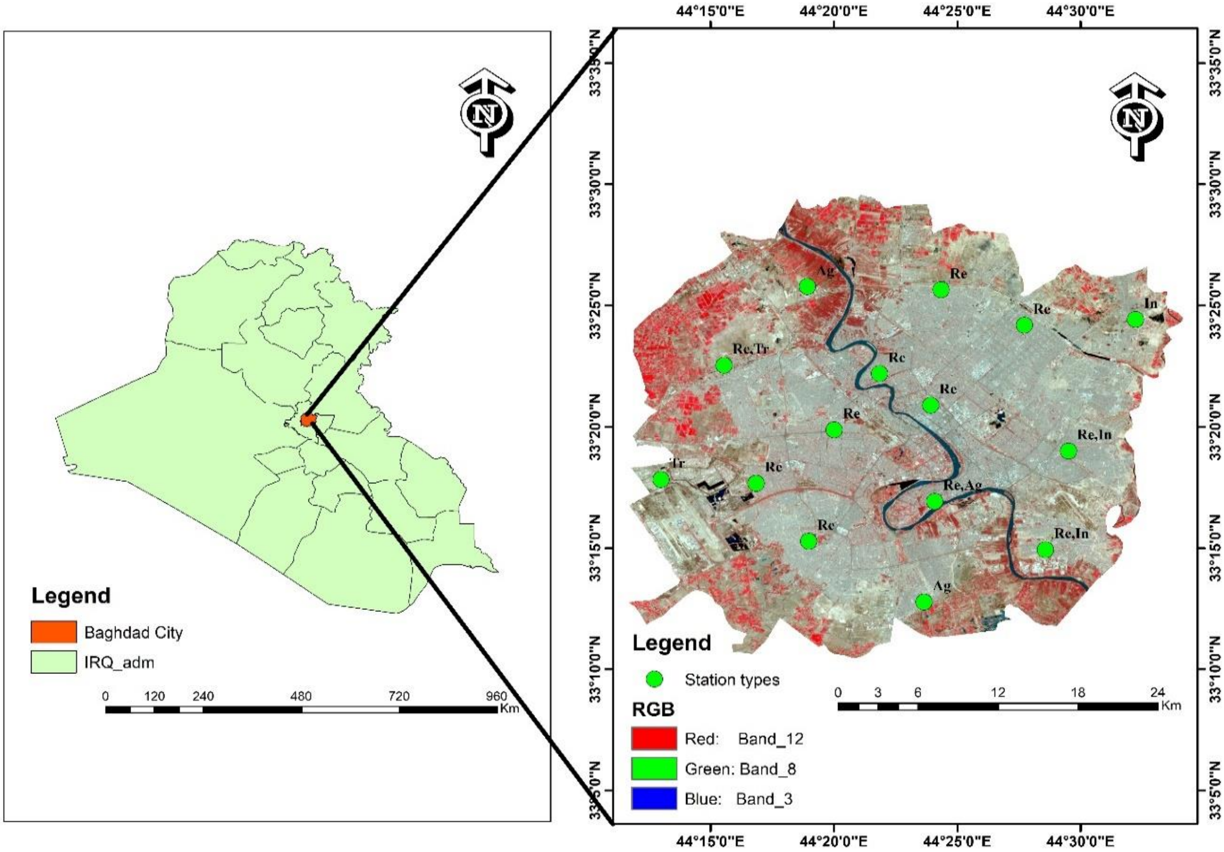

Figure 1. *Boundaries of study area of Sentinel-2 satellite with spectral beams (MID IR NER-IR, GREEN) and distribution of stations, include fifteen stations (●) plotting by ArcGIS.*

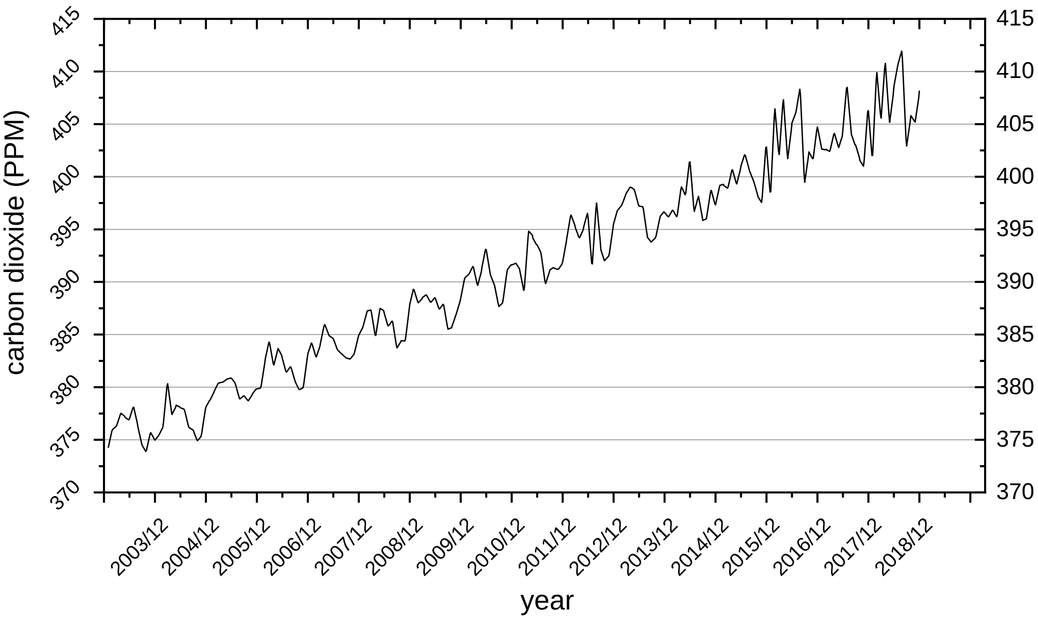

Figure 2. *Analyzing trends of the monthly average of Carbon Dioxide over 2003-Jan - 2018-Dec for Baghdad city*

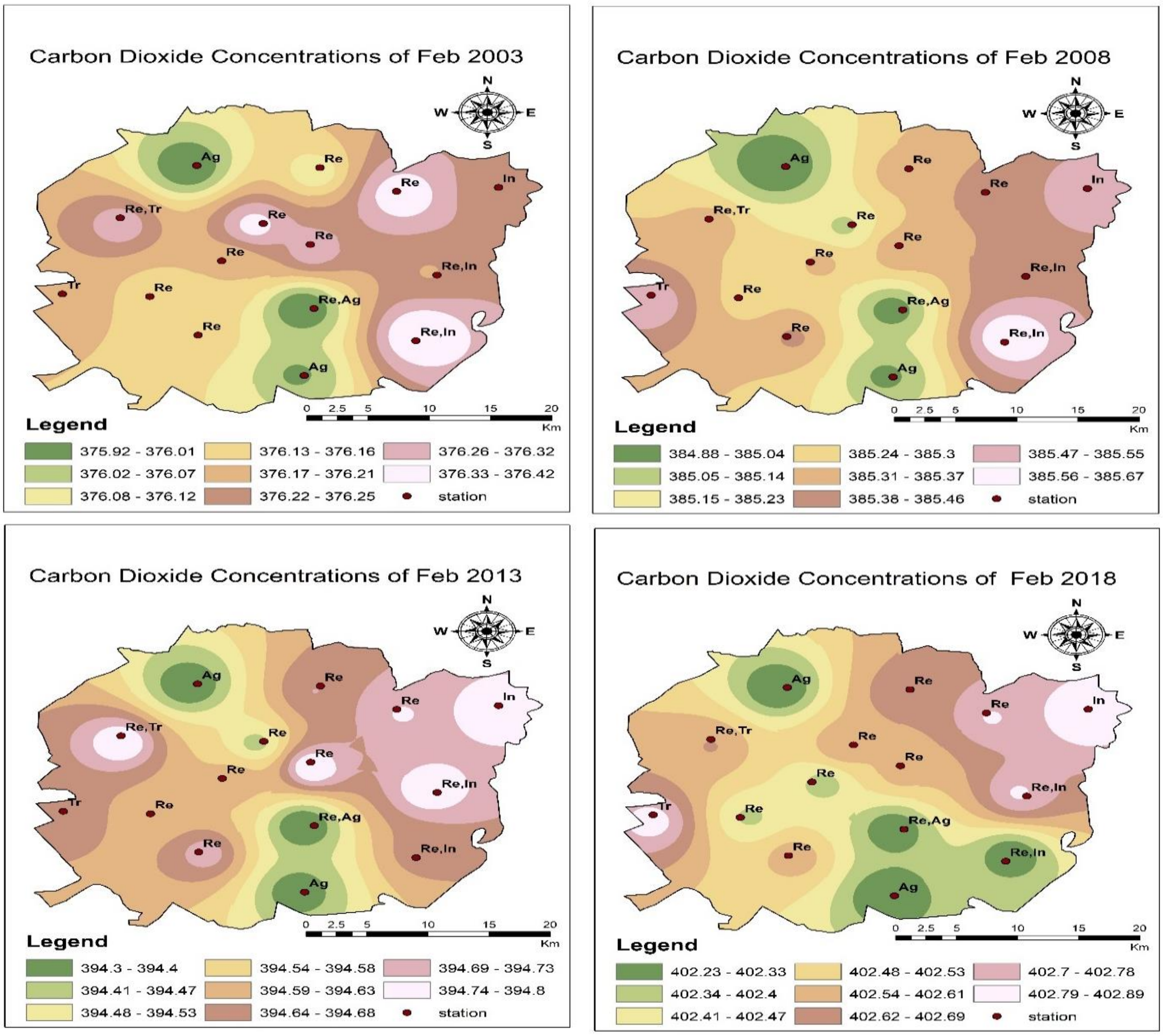

Figure 3. *Spatial analysis map of monthly average carbon dioxide concentrations in (PPM) for the February (2003, 2008, 2013 and 2018) years representation by Inverse Distance Weighting (IDW) technology*

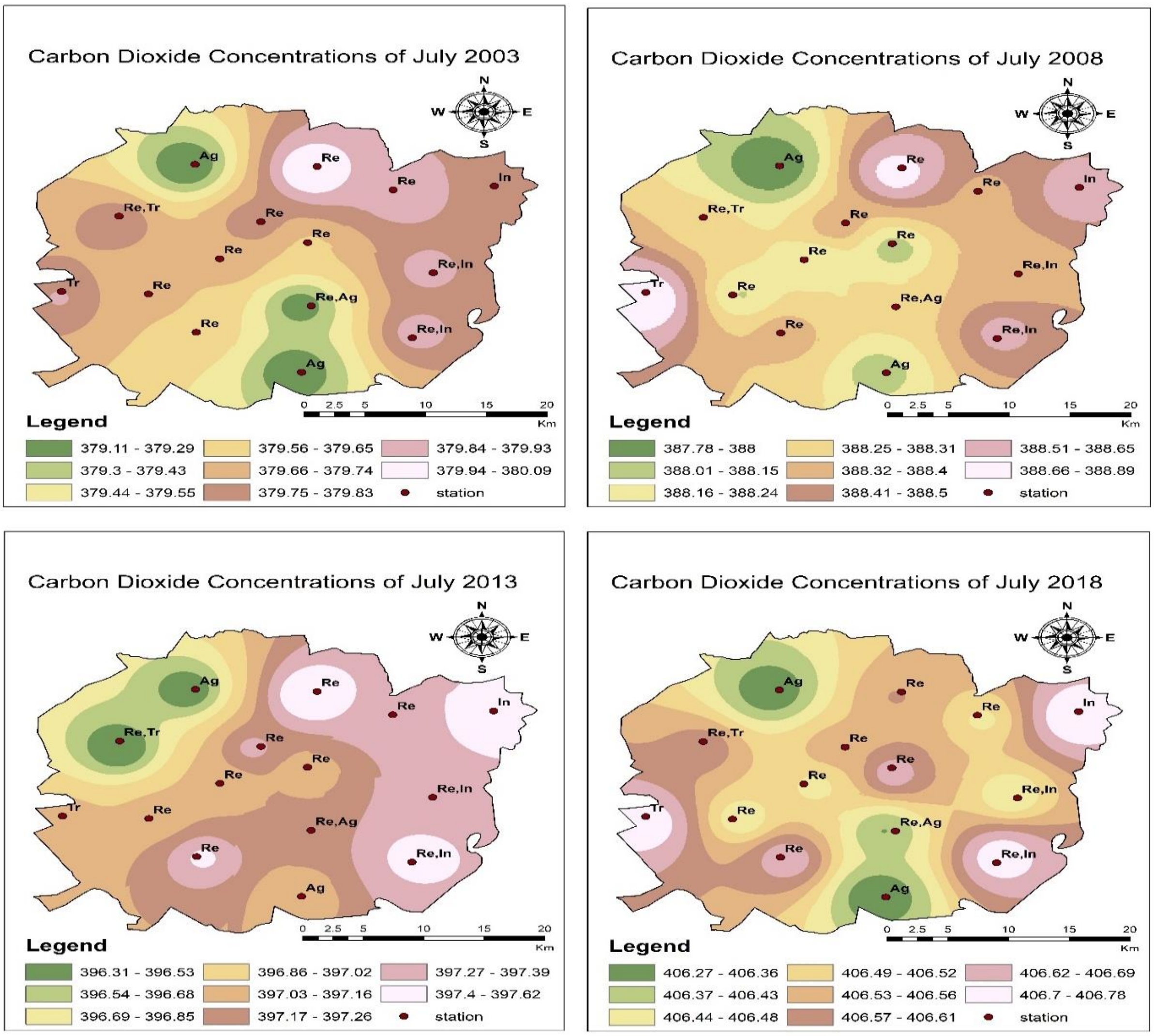

Figure 4. *Spatial analysis map of monthly average carbon dioxide concentrations in (PPM) for the July (2003, 2008, 2013 and 2018) years representation by Inverse Distance Weighting (IDW) technology*

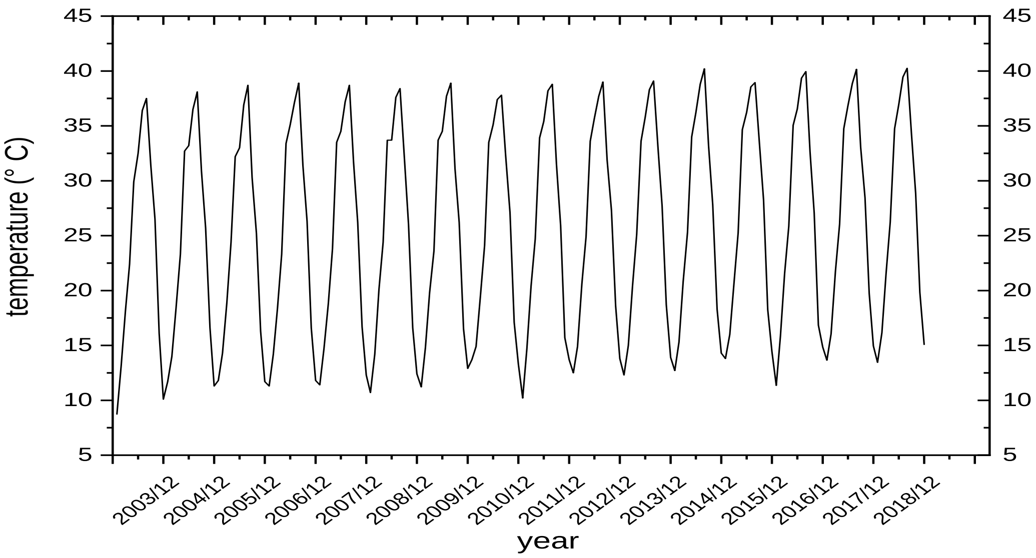

Figure 5. *Analyzing trends of the monthly average of Carbon Dioxide over 2003-Jan - 2018-Dec for Baghdad city*

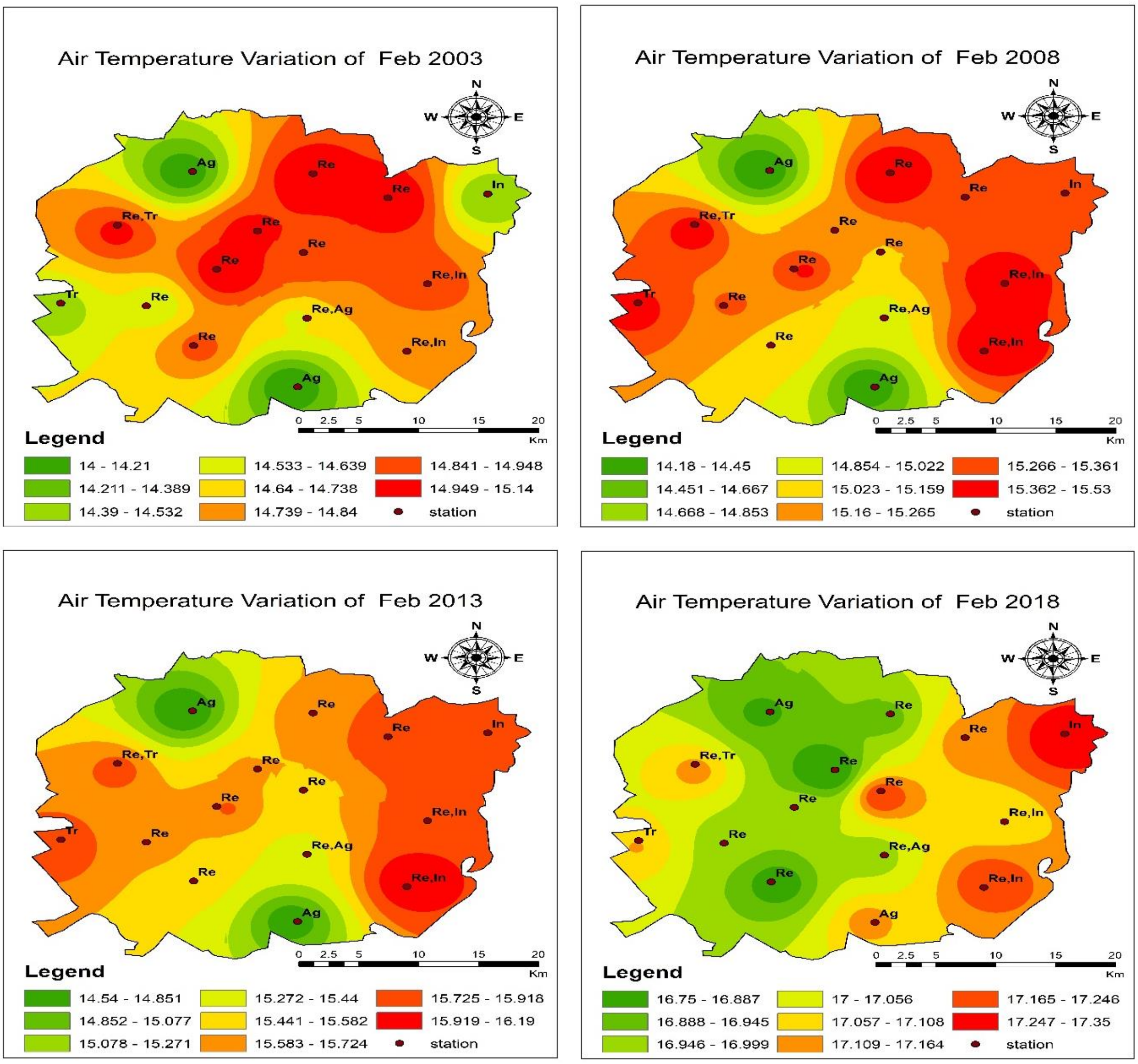

Figure 6. *Spatial analysis map of monthly average temperature in (°C) for the February (2003, 2008, 2013 and 2018) years representation by Inverse Distance Weighting (IDW) technology.*

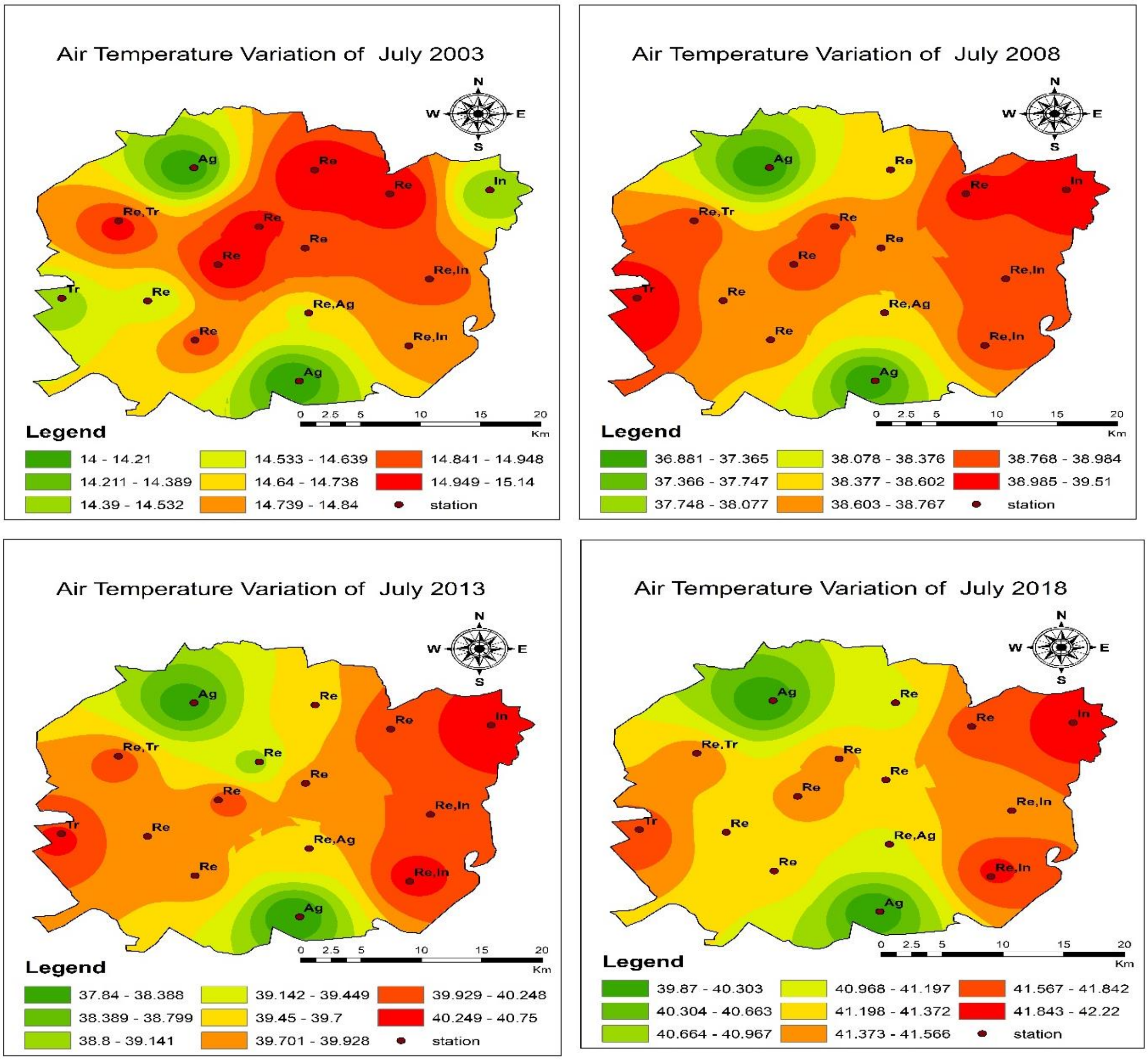

Figure 7. *Spatial analysis map of monthly average temperature in (°C) for the July (2003, 2008, 2013 and 2018) years representation by Inverse Distance Weighting (IDW) technology.*

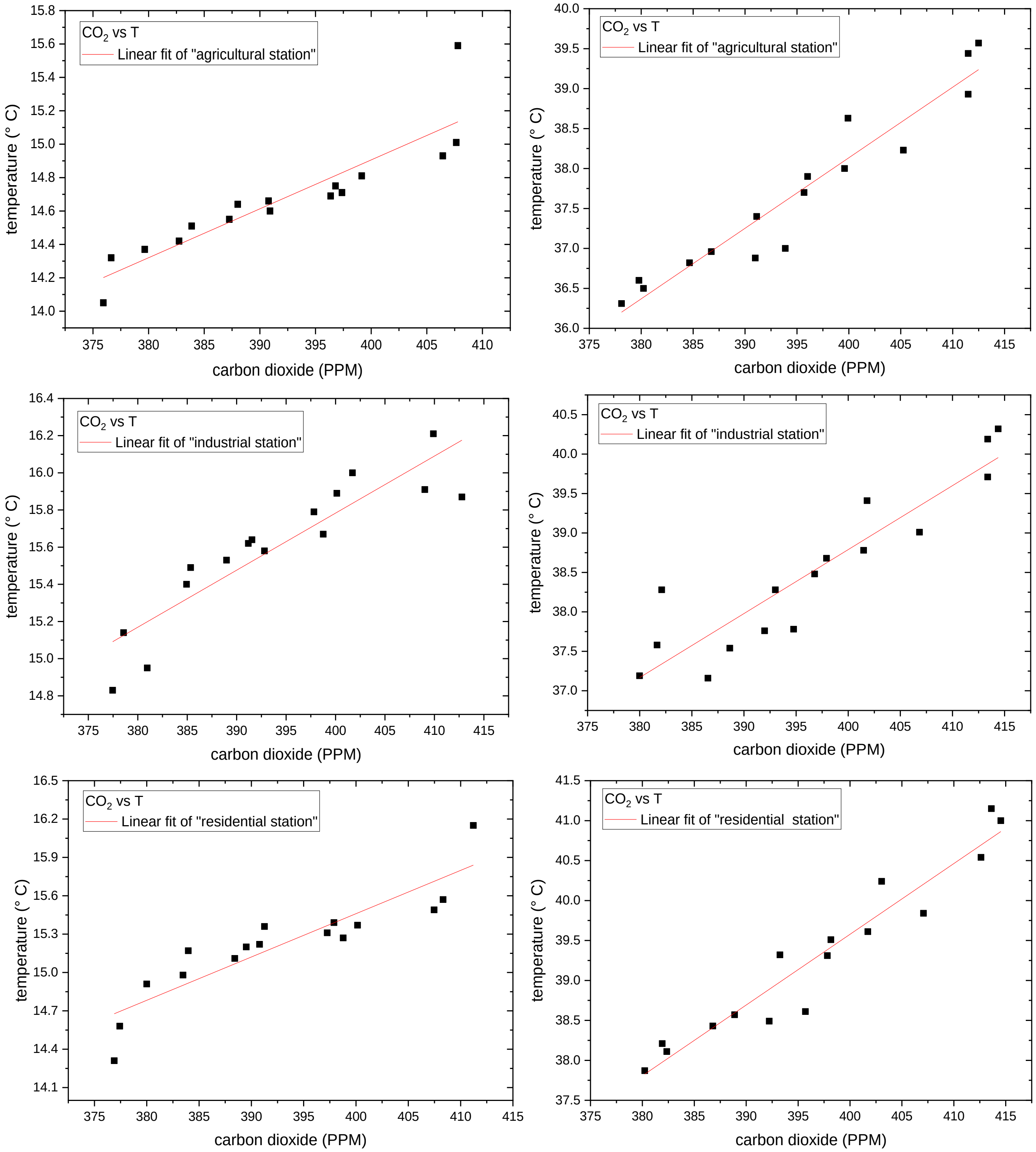

Figure 8. *Correlation of carbon dioxide concentrations vs. temperature, February (left) and July (right).*