



Climate Change and its Environmental Implications for Sustainable Energy in Iraq Using GIS and RS

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Abstract

This research investigates climatic changes, their core indicators, and their environmental repercussions on renewable energy sources in Iraq. The study analyzes meteorological data from fourteen (14) stations comprehensively covering Iraq's geographical diversity from north to south and east to west. Advanced spatial and statistical software, including ArcGIS (V.10), ERDAS Imagine, ILWIS (V.3.7), and SPSS (V.16), were utilized alongside mathematical formulations, linear regression, and correlation analyses to process spatial visuals and carbon dioxide (CO₂) emission trends. The findings indicate a significant shift in climatic elements: a continuous rise in average temperatures, elevated evaporation rates, and increased solar radiation intensity, contrasted by a decrease in average wind speeds and annual rainfall. Additionally, an increase in the frequency and severity of dust storms and greenhouse gas emissions was observed. A Geographic Information Systems (GIS) database was constructed to map regions demonstrating high efficiency for renewable energy production. Spatial analysis revealed that the Nasiriyah, Al-Amarah, Najaf, and Samawah stations are highly efficient for solar energy harvesting. Conversely, wind energy potential peaked at the Basra, Najaf, Samawah, and Wasit stations, while hydroelectric power generation experienced noticeable recessions at major dam reservoirs, including Mosul, Dukan, and Darbandikhan dams, due to water scarcity.

Keywords:

Climate change - global warming - indicators of the electricity sector hydropower - solar radiation climate requirements - sustainable energy

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1. Introduction

Climate change is one of the most serious risks to long-term growth, despite the fact that it accounts for a small percentage of overall greenhouse gas emissions owing to the economies of these countries, including Iraq (Al-Mashat et al., 2017).

Hydropower plants are distinguished from other types of plants that rely on water for electricity generation by relying on the power of a waterfall to generate energy by converting the kinetic energy inherent in water into electric power, as well as the availability of the right amount of water, which is strong enough to trigger the turbines and then generators to provide nutrition for the basic load economically fuel, and several natural factors (Mohammed, 2020).

The study area is determined in the State of Iraq,

the international borders are: north by the State of Turkey, the south of Kuwait and Saudi Arabia, the east by Iran, west by the State of Syria location coordinates of Iraq longitude (43° 41' 5.13" E) latitude (33° 13' 15.34" N) Fig. 1, while the time limits for the study were from 2015 to 2020..

2. Aim of study

The study aimed to address an answer for a range of questions: what is the impact of climate change on the environment in Iraq, and what is the impact of power generation on Iraq's climate? How is the environment affected by climate change in the quarterly term? How does pollution affect climate change and increase temperature? The study is based on several hypotheses, which leads to familiarity with all of the study's contents. Iraq is expected to be one of the countries most affected by the effects of climate change, which include

rising temperatures, changing rainfall patterns, rising sea levels, and an increase in the frequency of climate-related disasters. The major evidence of climate change in the Iraqi environment are: Salinity of water resources, due to high temperatures, low water nutrients, and low groundwater levels, high frequency and severity of land degradation and desertification, and resulted Decrease in green spaces due to the expansion of desertification and dry areas, where the percentage of desertification increased about (70%) for irrigated agricultural lands and approximately (74%) for rain-fed agricultural lands and (90%) for natural pastures due to water scarcity, this led to decrease in the scale of vegetation cover in agricultural lands by (8%) in 2020, a decrease in rainfall rates by (2.4%) during the year 2020 (National Action Program to Combat Desertification, Ministry of Environment and Health, 2015). Another important climate element effecting is wind speed it Decreased, as the control of the pressure system effecting on large areas of Iraq, which helped push and move the impact of the Mediterranean depressions to the north (spring season), this caused Increasing the intensity and frequency of dust storms due to the lack of rainfall, instability of the atmosphere, which leads to the activity of rising and descending air currents) and the arrival of depressions coming from the northern Arabian Gulf and Middle Asia, causing northwesterly winds that change in intensity according to the intensity of the depression, in addition to the thermal heights. All of this contributed to the intensity and increase in the number of storm days, 200-220 days per year (2008-2009). (General Authority for Meteorology and Seismic Monitoring, Unpublished Data, 2011).

Geographic Information Systems (GIS) can be utilized to examine energy consumption patterns across different scales, such as regional, urban, and building levels, helping to identify areas with high energy demand or operational inefficiencies. These insights support the development of targeted energy-efficiency initiatives and effective demand-side management strategies. In addition, GIS plays a vital role in mapping and managing energy infrastructure, including transmission lines, pipelines, and distribution networks. By enabling efficient spatial data management, GIS supports better infrastructure planning, route optimization to minimize costs and environmental impacts, and

improved maintenance and monitoring of existing energy assets.

3. Materials and Methods

Some programs were used to analyze the data and prepare the research outputs, including ArcGIS v. 10, Erdas, Eloise v. 9, SPSS v. 16, mathematical equations, linear regression, and correlation programs.



Fig. 1: Geographical setting of the study area.

The research also looked at the expected effects of climate change on the environment, energy, and water resources, as well as the impact of climate change on the environment and energy, to identify the risks to Iraq's environment and food security in 2050, and then present solutions to overcome or mitigate these effects.

Climate change is a global phenomenon, but its effects are local due to variations in the nature and sensitivity of terrestrial ecosystems from place to place on the earth's surface in each region, and there is no doubt that climate change has become one of the issues that is always raised at the global level in light of the potentially dangerous changes that threaten man's future on Earth (Al-Hadithi and Al-Araji, 2016)

The research is primarily descriptive in nature, to determine the current state and future perceptions of climate change and its effects on the Iraqi environment, as well as identifying some scenarios for estimating climate change and its effects on Iraq's sustainable energy development. The standard, the correlation rate and the coefficient of variation, have been used a set of programs in this study completing others and not canceling them to produce this study as required, which is aimed at the program Erdas Version IX: (Erdas V.9.1) which contains all Tools for the processing and analysis of space visuals and some GIS applications and the Eloise Program (IL WIS

3.7) is a dual-purpose integrative program with remote sensing video processing commands and ArcGIS-V.10, one of the most important Geographic information systems Produced by ESRI (Environmental Systems Research Institute), the program provides a wide range of effective tools that help understand data, perform calculations and logical calculations, and build a geographic database.

II Carbon monoxide, methane, nitrogen oxides, chlorofluorocarbons, and the most important climate changes: overheating, the difference in rainfall amount and rainfall times, and subsequent change in the water cycle and its various processes. The Intergovernmental Climate Change Task Force (GIEC) defined climate change as "all forms of changes that can be expressed as statistical descriptions" (Shanshol, 2014), which can last for decades, are caused by human activity, or are caused by the internal interactions of the climate system's components. This definition adds a characteristic of the phenomenon's continuity, even though its causes are selfish.

1-Quantitative assessment of Iraq's greenhouse gases and climate change scenarios:

In 2020, the electricity sector will be the main source of CO₂ emissions from the consumption of petroleum products in Iraq, accounting for about 40.8 percent of total emissions, followed by transportation (17.6%) and industry (16.6%). 7 percent, while the bandits and contracting sectors contributed the lowest accounting of CO₂ emissions, accounting for about 2.3 percent of total emissions (Iraqi Ministry of Energy). According to unpublished data (2021), the quantitative estimates of greenhouse gas emissions in Iraq, as shown in Fig. 2, reached approximately 197 million tons of CO₂ equivalent in 2020. Based on United Nations data regarding CO₂ emissions resulting from the consumption of petroleum products and natural gas, emissions increased by about 0.1%, rising from nearly 107 million tons in 2014 to approximately 197.1 million tons in 2020 (Al Laftah, 2016).

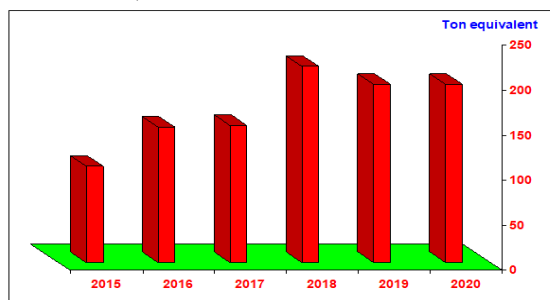


Fig. 2: Chart representing carbon dioxide emissions in Iraq 2014-2020.

2- Indicators of the electricity sector in Iraq:

Geographic Information Systems (GIS) and remote sensing technologies play an important role in analyzing electricity sector indicators in Iraq through the assessment of climatic data and the production of maps that identify the country's energy resources. The study demonstrated that Iraq possesses diverse electricity sources, including solar energy, wind energy, and hydroelectric power generated from its major rivers, particularly the Tigris and Euphrates. In 2020, imported electricity reached approximately 1,540 MW. However, electricity production in Iraq remains insufficient to satisfy the continuously increasing demand for electrical loads. As a result, the country relies heavily on local diesel generators to compensate for a significant portion of domestic consumption. This dependence has several negative consequences, including high fuel operating costs, expensive maintenance requirements, and environmental pollution caused by the emission of carbon oxides, sulfur compounds, and other harmful gases into the atmosphere. Fig. 3 indicates that electricity demand exceeds production capacity, reflecting a clear deficit in the electricity sector (Al-Mashat et al., 2017).

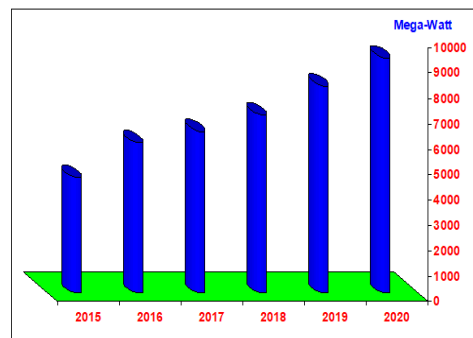


Fig. 3: Rate of electricity in Iraq for the period between 2015 and 2020 (Based on International Estimates, the World Resources Institute Database, Washington, United States, 2020).

3- Hydropower:

Many hydroelectric power plants exist in Iraq, consisting of dams and waterfalls scattered across the country depending on the amount of water in the Tigris and Euphrates rivers and their tributaries from north to south, which provide sufficient capacity to ensure the economic viability of constructing a hydroelectric power plant, with these plants contributing 3.3 million megawatt/h and an 88.2 percent relative importance.

4- Hydropower in the Tigris and Euphrates rivers:

The data in Fig. 4 show the Iraqi dams used in the generation of hydropower. there is about 68% of the revenues of the Tigris River basin and 97% of the revenues of the Euphrates River are received from outside Iraq (Turkey, Syria, and Iran).

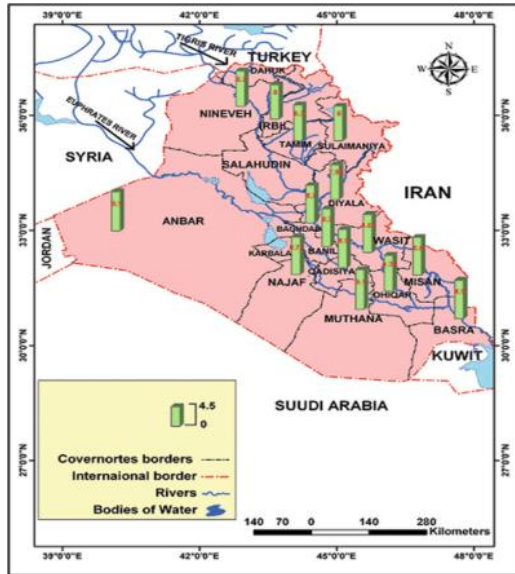


Fig. 4: Illustrates the distribution of hydroelectric power plants in Iraq in 2020.

The Euphrates and Tigris Rivers are located in Southwest Asia, and their waters and tributaries are primarily utilized by Turkey, Syria, Iran, and Iraq. Both rivers originate in Turkey, giving it a dominant upstream position within the basin. In addition, several tributaries of the Tigris and the Shatt al-Arab Rivers originate in Iran, placing Iran in a similarly influential upstream role over these waterways. Iraq and Syria, situated downstream within the basin, continuously seek to secure sufficient water supplies to meet their domestic, agricultural, and industrial needs.

All of these countries are part of the Middle East, a region characterized by limited water resources and increasing water scarcity. Since the 1970s, disputes among the riparian states have intensified due to declining water availability, rapid population growth, rising food and energy demands, economic and technological expansion, and political fragmentation. Moreover, the absence of effective public awareness programs and the continued reliance on outdated water management practices have resulted in significant water losses and inefficient resource use. These factors have contributed to growing regional tensions, at times approaching the risk of armed conflict.

Accordingly, the involvement of a capable mediator is essential to facilitate negotiations among the concerned states. Iraq and Syria may also need to provide incentives to encourage cooperation from Turkey and Iran. Furthermore, the riparian countries should adopt a comprehensive strategic plan focused on integrated water resources development, efficient water management, and the reduction of water losses and waste. Such measures are increasingly necessary, as future modeling studies indicate that water scarcity in the region is likely to worsen.

5- The possibility of exploiting solar radiation and wind speed to produce energy:

The natural potential of new and renewable energy sources, along with energy efficiency improvement policies, plays a key role in energy sustainability, so any geographical location has characteristics that enable it to invest one of these characteristics and clean sources of energy or a combination of them with a good amount of energy, it is necessary to invest in them and avoid losses from energy production as in traditional or fossil fuel sources (Mahmoud and Ali, 2018).

6- Climatic requirements for the calculation of photovoltaic and electrolytic energy:

The suitability of solar radiation in a place is determined by the number of hours of solar brightness, the intensity of its radiation, and the speed of the wind in a place, as the study includes determining the hours of solar brightness and wind speed in Iraq (Reza Abdul Jabbar, 2007, P. 88).

A. Brightness of solar radiation:

Iraq has good solar brightness hours that qualify it to be one of the best Arab countries that are characterized by the production of clean electricity (Herat, 2010), the peak of the average number of brightness hours in its seasons is very good compared to the countries of the world, the average brightness hours in Iraq 11.8 hours/day, in June reached the highest rate in the number of hours of sunrise reached 11.9 hours/ day. In winter, the lowest rate is 6.5 hours/day.

7- Estimating the amount of solar radiation in Iraq:

Geographic Information Systems (GIS) play a significant role in estimating solar radiation in Iraq through the integration of spatial data analysis, remote sensing techniques, and meteorological data to produce detailed solar radiation maps.

These maps assist in identifying regions with high solar energy potential, thereby supporting the planning and development of solar energy projects.

The amount of solar energy incident on a unit area outside the Earth's atmosphere at the mean distance between the Earth and the Sun is referred to as the solar constant. The value of the solar constant is approximately 1353 W/m². Since the distance between the Earth and the Sun varies slightly throughout the year, the value of extraterrestrial solar radiation also changes annually by about 3.5%. The following equation illustrates the variation in extraterrestrial radiation during the days of the year.

$$[(H_{on} = H_{sc} [1 + 0.0033\cos(360n/365)]$$

H_{on} = the rate of solar radiation outside the Earth's atmosphere on a surface perpendicular to the sun's rays on one day during the year, H_{sc} = solar constant, N = number of the day in the year beginning January 1.

Through the previous equation estimated the amount of solar radiation falling on a unit of space during a specified period of time is estimated and called intensity. Fig. 5 showed that Iraq receives an excellent amount of it, especially during the summer, with an average of 700.1 MW / cm³, which is a high value so the intensity in June, July and August are 775.5, 707.1, 700 MW/cm³ respectively followed by spring at a rate of 650 MW/cm³, as the intensity is gradual in March, April May upwards whenever it was close towards summer and was valued at 470, 620, 690 MW/cm³ respectively, followed by autumn in the intensity of its solar radiation, with an average of 423 MW/cm³ in September, October, and November, ranging downwards whenever Near winter it was 519, 400, 380 MW/cm³ respectively, to decrease to the lowest value of winter due to the tendency of the angle of the fall of sunlight to reach 3.7 MW /s³ which is also good value, as the intensity begins to rise Progressive in December, January, February namely 290, 301, 304 MW/cm³.

B. Wind speed:

Wind energy can be used to convert wind kinetic energy into mechanical or electrical energy, which can be used to save energy. Iraq is expected to have a clear peak of wind speed in summer, with an average of 5.9 mph in the months June, July, and August 5.5, 6.6, 7.2 mph, while the rest of the seasons converge in their rates; in fall and spring, it is 4.0 mph (March, April, and May).

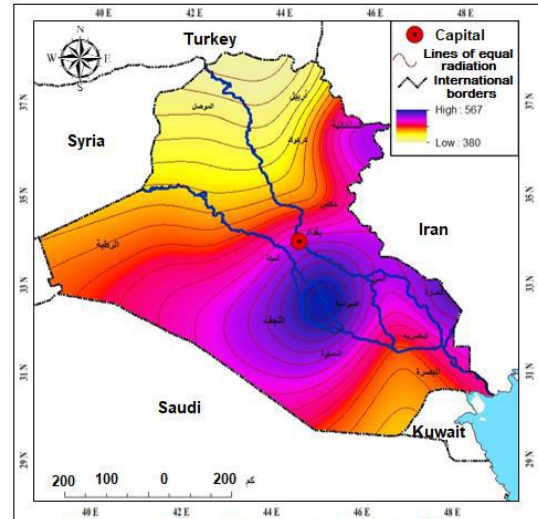


Fig. 5: Solar brightness levels at selected stations during the period 1970–2020.

8- The future of sustainable energy in the light of climate change:

Renewable energy can be defined as alternative energy to fossil energy, sourced from clean and natural resources that are available in nature and are renewable and non-depleting, such as solar, wind, biomass, etc., and there is continuous growth in all types of renewable energy as a result of technological development and continuous innovations. The changes in energy at the global level have important implications for the future of sustainable development, economic and social development, and the future of the oil and gas sector in Iraq are closely interconnected, as Iraq possesses abundant natural resources, particularly oil and gas, and is heavily dependent on the revenues of these resources (Al-Musari, 2019). Iraq has begun to pay attention to energy diversification by increasing gas production and its use in domestic consumption because of its importance in sustainable development, and has developed plans for clean and renewable energy projects such as solar energy projects (Livor Al-Rfo and Bahgat Shaheen, 2010).

9- International and local efforts to cope with the effects of climate change for international efforts:

World made many Efforts to reduce these impacts through a series of summits and conferences to raise awareness of the serious situation; the most important of these efforts:

-The United Nations Summit on the Environment (Earth Summit) held in Rio de Janeiro, Brazil, in 1992, and three major international agreements on the environment were

negotiated: the Climate Change Convention (UNFCCC), the Convention against Desertification (UNCCD) and the Convention on Biological Diversity (CBD) under which member states meet periodically to review progress and formulate political lines for the future.

In September 2000, the United Nations General Assembly adopted the Eight Millennium Development Goals, which included incorporating the principles of sustainable development into governmental policies and programs across different countries worldwide, alongside promoting a shift in the prevailing pattern of natural resource consumption (Al Laftah, 2016).

-Johannesburg Sustainable Development Summit in 2002, where a new philosophy was identified that should inspire economic growth; the process of growth cannot neglect the needs of social balance and environmental protection.

-The Kyoto Protocol is based on the Earth Summit Convention, and in that agreement the international community had unanimously agreed to reduce the emission of harmful gases to the environment to allow the ecosystem to adapt naturally to climate change and to ensure that food production was not endangered.

Between 2008 and 2012, the agreement entered into action, on February 16, 2005, and in February 2009, 187 countries signed and ratified the Protocol, including the State of Iraq (Mahmoud and Ali, 2018).

-The Doha Forum on Climate Change of the United Nations in December 2012 decided after the Doha Forum in Qatar on climate change of the United Nations to amend the Kyoto Protocol, as the only existing and binding under which countries are committed to reducing greenhouse gases, so that it will be effective from January 1, 2013 and the second commitment period will be eight years, as agreed on the timetable for the global agreement On climate change 2015 (Mohammed, 2020).

10- Iraq's efforts to address climate change:

In the present study, the Geographic Information System (GIS) was utilized to develop temperature maps illustrating the spatial distribution of air temperature and the variations between two different time periods (historical and recent) across meteorological stations covering the Iraqi governorates. In 2007, the National Committee for Climate Change was re-established to coordinate climate change issues at the national level and to formulate the policies and strategies

required to address these challenges. The committee also proposed implementation mechanisms and sought to maximize Iraq's benefit from the Kyoto Protocol mechanisms through the execution of Clean Development Mechanism (CDM) projects. A total of 36 projects were approved under this mechanism, covering sectors such as renewable and new energy, industry, waste management, afforestation, energy efficiency improvement, and fuel conversion to natural gas. These projects, with an estimated total cost of approximately \$1.2 million, contributed to attracting foreign investment, generating employment opportunities, and supporting the implementation of the country's sustainable development plans.

One of the themes of the climate change plan is cooperation with the international community in preserving the environment, and it contains national objectives for the need to share information in order to achieve the true dimensions of the climate change phenomenon and its environmental implications. The plan includes areas such as raising public awareness about climate change and its economic dimensions and ways to address it, capacity-building, activation of international financial and technical assistance programs, technology transfer, and the development of policies and programs to adapt to climate change in all sectors, as well as activating the participation programs of associations and businesses (Al-Jurani, 2015).

11- Role of GIS & RS in monitoring future climate changes in Iraq:

In Iraq, Geographic Information Systems (GIS) and Remote Sensing (RS) play an essential role in monitoring and managing the impacts of climate change. These technologies provide valuable data that support the analysis of environmental changes and assist in developing effective adaptation and mitigation strategies. Climate change results from the increasing concentration of greenhouse gases in the atmosphere due to human activities, which leads to greater heat retention on a global scale. The Earth's temperature is influenced by the balance between the energy absorbed from the sun and the energy lost to space, while atmospheric circulation, ocean currents, and other environmental systems distribute this energy across the planet, causing climatic variations between regions.

Climate models in Iraq are mathematical simulations based on actual climatic data collected within the country. Some of these models simplify complex climate processes into relatively basic equations to better understand the mechanisms responsible for climate change. Long-term climate forecasts generally rely on widely accepted climate models in which certain variables and equations are adjusted within reasonable limits to reproduce past climate conditions and improve the accuracy of present and future predictions. According to the model projections for CO₂ emissions in Iraq, emissions reached 217 million tons in 2020 and are expected to rise to 245 million tons in 2030, 289 million tons in 2040, and 310 million tons by 2050 (Fig. 6 and Table 1). This increase is mainly attributed to Iraq's growing industrialization and its efforts to meet domestic demands for manufactured products without relying heavily on imports (Seventy-Nine, 2015).

Table 1: Future projections of carbon dioxide emissions in Iraq until 2050

Years	The number of emissions in Iraq, million tons of carbon dioxide equivalent (million tons)
2020	217
2030	245
2040	289
2050	310

Based on the output of the remote sensing and geographic information systems program, some plans can be drawn up to address climate change and energy shortages in Iraq and can be presented as follows:

-Planting more trees: Tree planting has enormous potential for addressing the climate challenge; according to a recent study, an additional 10 million hectares of tree cover over Iraq would be sufficient to store 25% of current carbon emissions in the atmosphere.

-Conversion of Carbon Dioxide into Rocks: Carbon mineralization is the process of converting CARBON DIOXIDE into carbon minerals by simulating the natural manufacturing of shells and limestone. Iraqi experts have discussed several techniques, including capturing CARBON DIOXIDE from industrial facilities using bacteria and then using it to produce useful building materials as a by-product.

Enhancing the reflectivity of the Earth's surface: Experts have emphasized the use of techniques that reflect solar energy (sunlight) into space, thereby counteracting global warming. Modifying the reflectivity of surfaces, such as applying white coatings to dark roofs, can significantly reduce absorbed heat and contribute

to cooling urban areas. Within this approach, asphalt roads may also be covered with limestone, and studies indicate that these methods indirectly reduce greenhouse gas emissions by lowering heat absorption. Similar to solar energy applications, these technologies are also employed to evaluate wind speed and direction, helping to identify locations with strong and stable wind patterns suitable for wind turbine installation. Studies conducted in the Kurdistan Region of Iraq have applied GIS and remote sensing techniques to map wind resources and determine potential sites for wind farms. In a country such as Iraq, where water resources are essential for both energy generation and agriculture, GIS and remote sensing are utilized to monitor water bodies such as lakes and rivers. This contributes to understanding water availability, managing water resources for energy production, and reducing the impacts of drought. In addition, GIS and remote sensing are applied to map and monitor land-use patterns, including areas allocated for energy infrastructure, agriculture, and other activities. Such information is essential for evaluating the environmental impacts of energy development and for planning sustainable energy strategies. These technologies are also used to assess air quality, including the effects of energy production activities on particulate matter and other pollutants. Through the analysis of satellite imagery and ground-based observations, researchers can identify regions with poor air quality and develop appropriate mitigation strategies. Furthermore, remote sensing is employed to monitor drought conditions that may affect water availability for both energy production and agriculture, thereby supporting the development of drought mitigation measures and ensuring a sustainable energy supply.

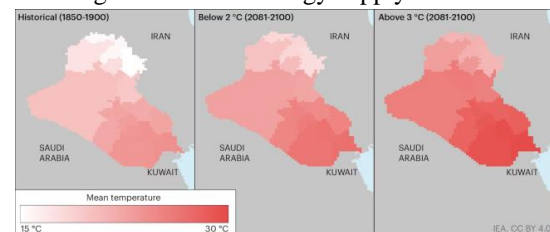


Fig. 6: Future projections of carbon dioxide emissions in Iraq up to 2050, based on outputs generated by the ArcGIS 10.8 program through predictive modeling until 2050.

4. Results

Encouraging the trend of renewable energies in transportation: Experts called for generous financial incentives to encourage zero-emission

vehicles (hydrogen or electricity), including sales tax exemption and free parking in some areas, and experts said Norway has pioneering experience in this area, with approximately 60% of new cars sold in March 2019 being electric-powered, and Iraq could benefit from the Norwegian experience and apply it.

Sustainable development of renewable energy in Iraq:

Geographic Information Systems (GIS) play a vital role in selecting energy-efficient sites in Iraq by enabling spatial analysis of various factors influencing renewable energy potential and infrastructure development. GIS tools help identify optimal locations for solar, wind, and biomass energy projects by integrating data on solar irradiance, wind speed, terrain, land use, proximity to infrastructure, and environmental constraints. This systematic approach aids in targeted and efficient planning for renewable energy projects, promoting sustainable energy strategies in the country. Iraq is one of the non-pioneering countries in this field despite the availability of suitable conditions for this field (solar, wind, and water energy). At the end of 2010, the "Renewable Energy Center" was established as a result of the unstable conditions and the continuous power outages, and a program was developed for the years 2012-2015.

Choosing energy-efficient locations in Iraq:

Iraq has seen small-scale solar energy projects that alternate between production and distribution, depending on the development of stations and the manufacture of solar heaters. As part of the university's policy to develop renewable energy that is dependent on wind and solar energy, and in collaboration with the departments of energy and environment engineering, solar energy has a total of 20 cells with a power output ranging from 30 to 130 watts on average. In addition to the presence of a barometer (2) to measure the amount of rain, it is used in water desalination, electric power generation, and water heating. The speed of the wind determines the amount of electricity generated, and the amount of sunlight determines the amount of electricity generated.

Iraq possesses significant potential for renewable energy development, particularly in the field of wind energy. The application of Geographic Information Systems (GIS) has demonstrated the importance of utilizing

renewable energy resources derived from wind and other sustainable sources. Wind energy converts the kinetic power of wind into electricity through the use of turbines, providing a sustainable alternative to fossil fuels. Since the availability of wind resources varies geographically, this study aimed to identify the most suitable locations for wind energy development in Iraq and to support future energy demands through renewable resources.

To achieve this objective, a multi-criteria analysis based on Geographic Information Systems (GIS) was conducted to determine the optimal areas for wind energy exploitation. The analysis incorporated essential climatic and environmental datasets, including raster files representing annual wind speed, temperature, precipitation, soil moisture, and the Normalized Difference Vegetation Index (NDVI) for the study area. Additional factors such as road networks, urban centers, terrain slope, and land use patterns were also integrated into the GIS-based model. The weighted overlay tool within the Spatial Analysis Tools of ArcGIS 10.7.1 was applied to classify and combine the different raster datasets.

The results indicated that the southeastern regions of Iraq represent the most suitable areas for wind energy development. These areas are characterized by strong wind speeds exceeding 6.2 meters per second, in addition to their proximity to electrical power grids, accessible transportation routes, and relatively gentle terrain slopes, making them highly appropriate for wind farm construction. The study further revealed that areas with high suitability for wind energy projects account for 5.3% of the total study area, reflecting Iraq's considerable capacity for wind energy utilization. In contrast, 79.7% of the area was classified as moderately suitable, 9.5% as poorly suitable, and 5.4% as unsuitable for wind energy development. These findings highlight the substantial potential for wind energy investment in Iraq and provide valuable guidance for future strategic planning and implementation.

5. Discussion

Steps taken by Iraq to address climate change and energy shortages:

1. Create a contingency plan for towns and provinces that are influenced by climatic variability, such as extreme heat or cold, increased beach erosion, and sandstorms.

2. Rationalizing the use of natural resources, such as water and electricity, as well as educating citizens and including them in climate change plans.
3. Reliance on renewable energy in energy production, and gradual abandonment of fossil fuels (petroleum, coal, natural gas).
4. The completion of Iraq's peaceful nuclear program for energy production, given that atomic reactors are considered the least greenhouse gas-emitting.
5. Planting trees in all communities and around cities to reduce carbon dioxide levels in the atmosphere and raise oxygen levels.
6. Filtration of factory chimneys, taking in mind that Baghdad industrial factories (12,600 factories) are responsible for 50% of carbon generation in the atmosphere.
7. Recycling waste properly and converting it into useful products and electric power, because burning garbage in Iraq causes 15% of air pollution; leaving it to burn in the streets increases methane gas emission levels into the air.
8. Reducing water evaporation from agricultural canals by covering them with solar panels, as implemented in many countries such as India, can help minimize surface water evaporation while simultaneously generating clean and sustainable electricity to address energy shortages.
9. GIS facilitates the assessment of renewable energy resources, such as solar and wind energy, by analyzing data related to solar irradiance, wind speed, and other relevant environmental factors (Fig. 7).
10. GIS can be utilized to determine optimal routes for new transmission lines by considering factors such as cost, regulatory constraints, and potential environmental impacts.
11. GIS can map local energy consumption patterns, helping to identify areas with high energy demand and opportunities for improving energy efficiency.
12. GIS can be applied to map and analyze areas vulnerable to natural disasters, such as floods, which may affect energy infrastructure, while also supporting emergency response and disaster management efforts.
13. GIS can be integrated with remote sensing data to obtain detailed information on land cover, vegetation, and other environmental factors

that influence the selection and suitability of energy project sites.

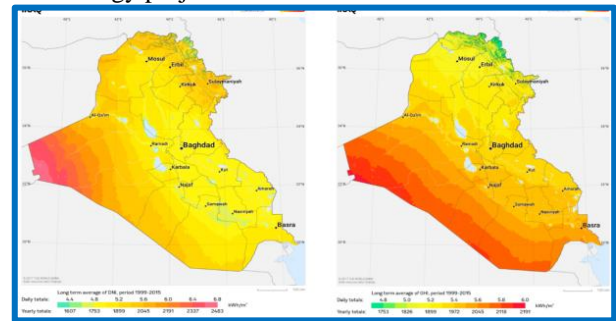


Fig. 7: Proposed locations for the establishment of solar and wind energy plants in Iraq (ArcGIS 10.8 output).

6. Conclusion

1. The study showed that quantitative estimation of greenhouse gases in Iraq reached about 197.1 million tons equivalent of CO₂ in 2020, rising by about 0.1% every 10 years, compared to about 197 million tons in 2010.
2. Using remote sensing programs to design models to predict carbon dioxide emissions for the future showed an increase in the amount of emissions; it rose from 217 million tons equivalent in 2020 and reached 310 million tons equivalent by 2050
3. According to the report, the energy sector is the major source of CO₂ emissions in Iraq in 2020, accounting for roughly 40.8 percent of total emissions, followed by the transportation sector at around 17.6 percent and the industrial sector at around 16.7 percent.
4. The study suggested the location for the energy plants in different sites according to the data of the energy resources available in the area and the consumption rates for each area.
5. Iraq as one of the richest countries in water energy, the study showed that Tigris, Euphrates and tributaries estimated the power generated is about 68.5 billion kilowatt hours per year, with water estimates in the two rivers and their tributaries varying at 71 billion m³ per year, and the flow of water from the two rivers in the dry years decreases to 59.6 billion m³ and the overall guaranteed rate of water energy, including tributaries is about 45.3 billion m³ per year.
6. The study showed that the Kyoto Protocol is based on the Earth Summit Agreement, adopted this agreement, and the industrialized countries in the City of Kyoto, Japan, committed to reduce the emission of harmful

gases to the environment between 2008 and 2012 by more than 5.0% compared to 1990.

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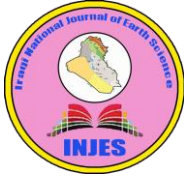
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تغير المناخ وانعكاساته البيئية على الطاقة المتجددة العراق نموذجاً باستخدام تقنية

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الملخص

يحدث تغير المناخ عندما تؤدي التغييرات في نظام مناخ الأرض إلى ظهور أنماط مناخية جديدة تظل قائمة لفترة طويلة من الزمن وهذه الفترة الزمنية قد تكون قصيرة فتصل إلى عدة عقود فقط أو قد تصل إلى ملايين السنين، ويستهدف البحث بصفة رئيسية الوقوف على الآثار المتوقعة للتغيرات المناخية على كل من البيئة والطاقة وموارد المياه، وكذلك تستهدف البحث الوصول إلى أفضل سيناريو للتوقعات المحتملة، حيث تشير التقديرات الكمية لغازات الاحتباس الحراري في العراق أنها بلغت نحو 197 مليون طن مكافئ من ثاني أكسيد الكربون في عام 2020م، ويعد العراق من الدول الغنية بالطاقة المائية إذ يتمتع بوجود نهري دجلة والفرات ورافدهما واللذين ينبعان من الشمال حتى الجنوب ويتميزان بانحدار شديد خاصة في المناطق الجبلية والتموجة من العراق يمكن الاعتماد على أنهار العراق مصادراً لإنتاج الطاقة الكهربائية، فقد أظهرت الدراسة أن نهري دجلة والفرات ورافدهما تقدر بـ 68.5 مليار كيلو وات / ساعة في السنة، كما يتمتع العراق بساعات سطوع شمسي جيدة تؤهله لأن تكون في مقدمة البلدان العربية التي تمتاز بإنتاج الطاقة الكهربائية النظيفة، فذروة معدل عدد ساعات السطوع في فصوله جيدة جداً قياساً بدول العالم، إذ يبلغ معدل ساعات السطوع في العراق 11.8 ساعة / اليوم.

الكلمات المفتاحية:

التغيرات المناخية، الاحتباس الحراري، مؤشرات قطاع الكهرباء، الطاقة المائية، الإشعاع الشمسي المتطلبات المناخية، الإشعاع الشمسي، الطاقة المستدامة.

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