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تطبيقات أساليب التعلم الآلي للتنبؤ بتغير المناخ

رساله مقدمة
الئ كلية العلوم في جامعة ديالى وهي جزء من متطلبات نيل شهادة الماجستير
في علوم الحاسبات

تقدم بها الباحثة
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Chapter One
Introduction

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1.1. Introduction

The meteorological dictionary [1] defines climate (from the Greek kliμa - declination of the Sun) as a statistical ensemble of weather patterns during a specific time rang (frequently several decades). Global warming of the Earth's climate is no longer basically disputed, and the global mean surface temperatures are modified by the natural variations of the climatic conditions, and it is extremelyprobable that greenhouse gas (GHG) emissions from human activity are the reason behind it [2]. Thus, in the context of climate change, it is anticipated that the forecasted increased variability and extreme occurrences will have varying effects on agriculture, industry, ecology, the environment, and even human society [3].

As stated in the Paris Agreement [4], two sets of measures are necessary to protect future generations' means of subsistence, given the socioeconomic problems brought on by global warming and an increasingly unpredictable environment. Mitigation strategies group –human efforts to lessen greenhouse gas origins and/or improve sinks, whereas variation refers to The procedure of altering the current or projected climate and its impacts as a means to reduce damage or take advantage of favorable opportunities [1].

1.2. Climate Variability and Change

Undoubtedly, the biggest and toughest problem our planet is currently experiencing is climate change [5]. The change in the climate is characterized as a shift in the climate's condition that is discernible (e.g., through statistical analysis) via modifications to either the average or the variability of its attributes and that lasts for a considerable amount of time, generally over several decades [2]. The earth's atmosphere traps heat due to greenhouse gas (GHGs) emissions, primarily carbon dioxide (CO2), and this results in climate change [6]. Natural phenomena like forest fires, earthquakes, and volcanoes, as well as human activities like those involved in industry and energy production, are the principal causes of theseemissions [7].

However, the mean conditions of the global climate are modulated by the natural inconsistency of weather conditions (climate variability), i.e., year-to-year (inter-annual) deviations (usually termed anomalies) from the mean (Figure. 1.1) [2]. After an energy distribution over the world, the climate system becomes variable due to uneven heating of the atmosphere and oceans. Precipitation, temperature, pressure, and other climate variables all exhibit altered patterns as a result of this process [8]. The diversity may be brought on by a variety of factors, including: (1) natural internal variability resulting from interactions between climate system components, such as the ocean and atmosphere; (2) natural outside factors, including fluctuations in the flow of solar radiation; (3) anthropogenic external impacts on the climate system, including emissions of GHG and aerosols; and (4) natural internal variability [9].

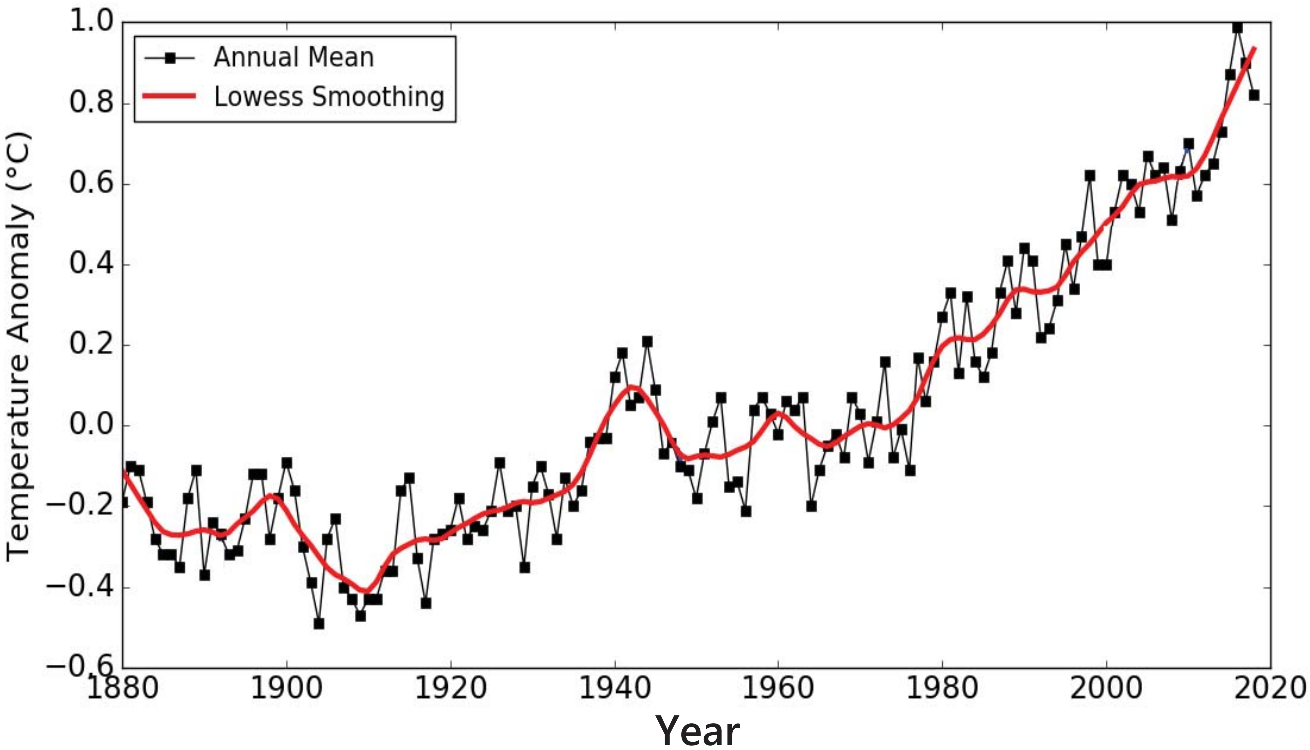

Figure 1.1. Temporal change in temperature [10].

The startling statistic that each calendar year since the turn of the millennium has been warmer than the average temperature for the period between 1981 and 2010 is presented in the State of the Climate in 2018 report [11]. The climate estimates of [12], which claim that the current warming trend of 0.2 °C per annum is projected to continue for the duration of thirty years to come, contributed even more ominous feelings. The variability of the Earth's atmosphere, hydrothermal regimes, and extreme weather and climate disturbances like heat waves, droughts, air pollution, floods, cyclones, and wildfires are all predicted to change as a result of anthropogenic GHG emissions [13]. Such climate-related extremes have a variety of negative effects on ecosystems, food production, water availability, infrastructure damage, human well-being, morbidity and mortality, and settlement harm. These effects are consistent with a serious under preparedness for current climatic variability in some sectors in countries at all levels of development [14].

1.3. Change of Climate in Iraq

In 2009, the Arab Forum for Environment and Development (AFED) detailed the Arab countries as being among the furthermost susceptible on the planet to the likely effects of climate change, primarily the augmented normal temperatures, lost and increasingly inconsistent rainfall, and rising ocean levels. The Arab countries currently suffer from aridity, frequent water shortages, and dry conditions.Five of the Middle East and Northern Africa (MENA), including Kuwait (52.6 °C), Saudi Arabia (52°C), Iraq (52°C), Sudan (49.7°C), and Qatar (50.4°C), have temperatures above freezing.The Global Environment Outlook Report (GEO6) lists Iraq as one of the nations in the area that is particularly susceptible to changes in the climate. The temperature-limited season for growth is predicted to vary the greatest in modest high-altitude locales, which is anticipated to extend by 1 to 30 days in around 6% of the country. In the vast majority of the nation(70– 90%), the moisture- and temperature-limited growing season would be reduced by 0–15 days, and up to 8% of Iraq would see an increase of 0–30 days [15].

Lacking adaptation strategies (including the implementation of micro-pressurized effective irrigation systems as well as water-from-the-soil preserving agricultural techniques like preservation agriculture), the requirement for irrigation purposes will grow significantly as the availability of water and soil saltiness, particularly in the Euphrates River basin, is anticipated to increase concurrently alongside temperature rises as a consequence of increasing evapotranspiration.

The Tigris and Euphrates are likely to be particularly impacted due to sea level rise (SLR) of 1 to 5 m, with sensitive locations influenced by salt water intrusion far into the interior, such as around Baghdad, having serious consequences on the security for water [16].

The main causes of the year-over-year precipitation decline are decreases in winter precipitation (5-20% less) and springtime precipitation (10-20% less precipitation in 70% of the area), both being undoubtedly the two largest aspects of annual precipitation. Although there are expansions of summer rainfall of over 20% in the eastern region, which can be regarded as unrelated due to the infrequenttypical sporadic rainfall, there are intermittent patterns in lost/added summer rainfall. Autumn saw an expansion of a similar pattern of increase (> 20%). A tendency toward increasingly arid conditions prevails throughout Iraq. Significant climatic changes seen in Iraq include [17]:

- Rise (2°C) in the mean yearly temperature by 2050.
- More incessantly less ice days and warmth waves.
- Reduction in mean yearly normal Precipitation by (9%) by 2050, with the best decrease (-17%) predictable in December, January, and February.
- Reduction in the greatest amount of rain that can fall in any 5-day period, but an increase in the overall amount of precipitation.
- Reduction in runoff of 22% (average countrywide).
- The farming region, water sources, human health, the energy sector, and the system in Iraq are expected to be impacted by increased temperatures, more frequent and intense dry seasons, and expanded intense precipitation events. Some of the potential effects incorporate [18].
- Stronger flood episodes are anticipated as river fluctuation increases.
- Reduced precipitation ratios may prompt longer and more extreme dryspells.
- A rise in water contamination as well as pollution is expected to exacerbate outbreaks, including cholera.
- A rise in dry spells is anticipated to result in less agricultural output with effects of important on domesticated animal creation.

- A rise in floods predictable to exasperate harm to system.
- A rise in dry spells might increment rural-urban immigration, raising pressure on the previously harassed social urban and economicallysubstructure.

Climate change was also influenced by an extensive range of additional causes, counting variations in solar radiation and pollution aerosols. Mountains and highland zones are susceptible to the change of climate. The asymmetric nature of the planet is yet another characteristic linked to climate change [19].

Figure 1.2 and 1.3 show the range of CO_2 and CH_4 concentrations in the atmosphere. As can be seen, the atmosphere's content of carbon dioxide and methane began to rise in 1760, the year the first industrial revolution began. The Revolution of Technology,additionally referred to as the following industrialization Revolution, is a time of more modern development than the last half of the nineteenth century up until World War I, and it is characterized by an increase in the amount of greenhouse gases.The pace of growth in greenhouse gas concentrations in the atmosphere accelerated in the 20th century [20]. The level of greenhouse gas absorption is on the rise with time due to arterial activity throughout the world, including Iraq, as shows in the two figures (Figure 1.2 and Figure 1.3) which represent the increase in gas concentrations (CO_2, CH_4).

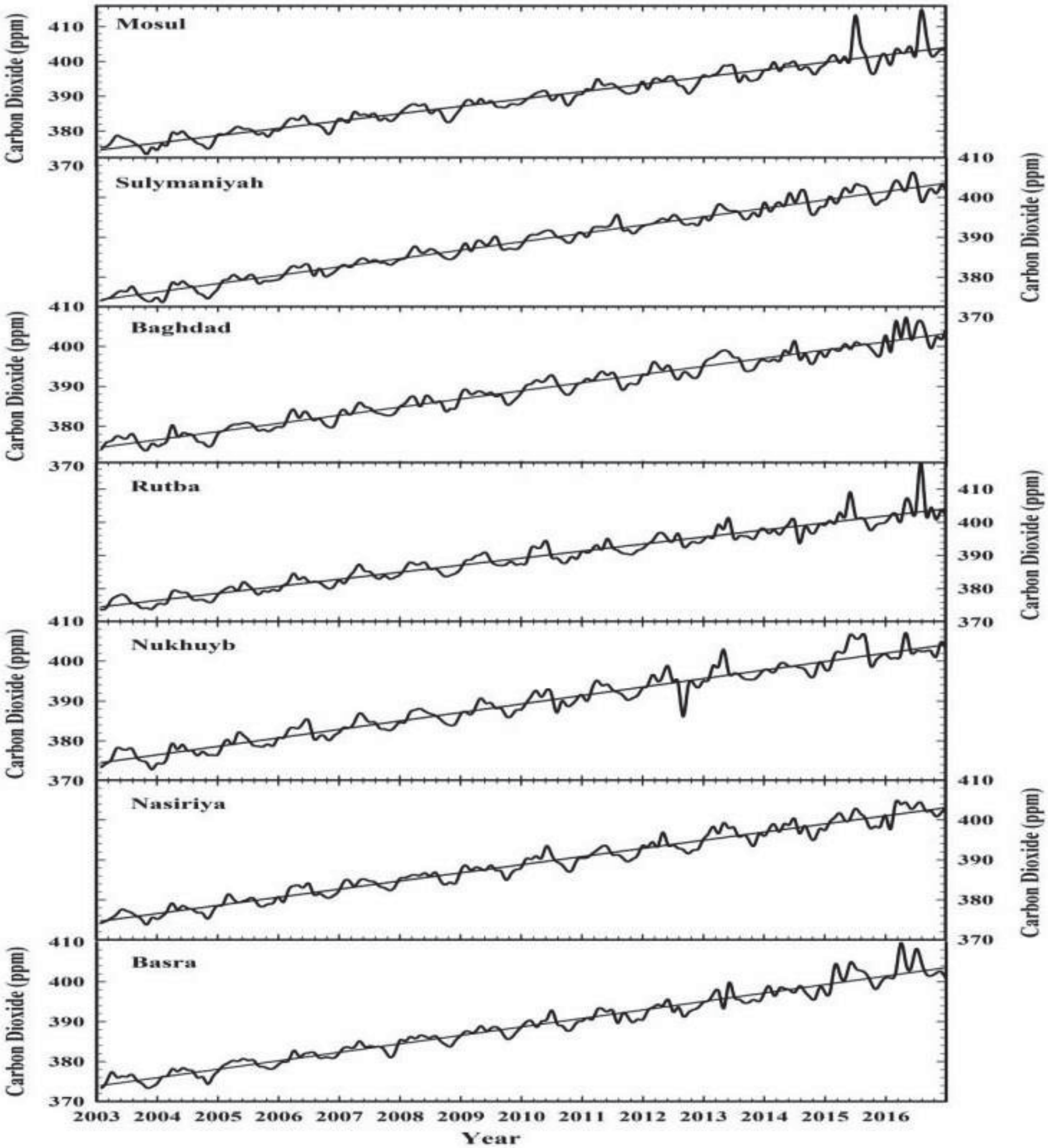

Figure 1.2. CO2 variants in number of Iraqi regions (2003–2016) [21].

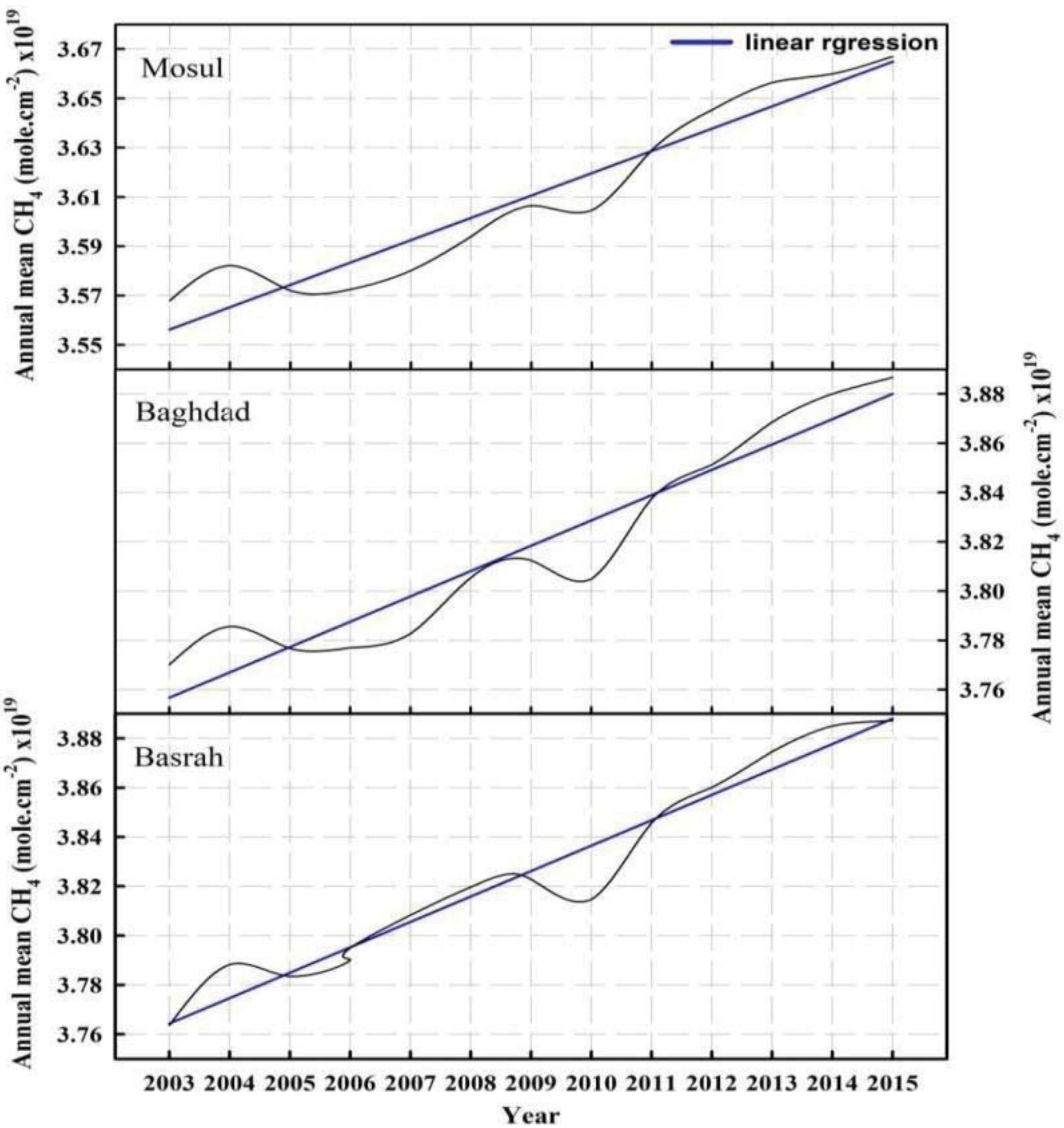

Figure 1.3. CH4 variants in number of Iraqi regions (2003 - 2015) [22].

By 2050, the quantity of greenhouse gases, in the earth's atmosphere could possibly need double due to enormous emissions [23]. Climate change has added stress to ecological and socioeconomic systems that are already under great pressure from increasing urbanization, industrialisation, and economic development in the majority of developing nations. According to the findings of various recent studies, Asia is undoubtedly warmth as well as the way it occurs is mostly compatible with the trend of global warming [24]. As a result, the South Asia continental is expected to undergo potentially severe climatic effects in several areas of the common ambient that contain water resources.

The range of the rise in the global average surface temperature (1.8 to 4) °C will be substantially exceeded by the anticipated rise in temperatures for wintertime suggested by the IPCC (2007) [25]. It is known that global warming is to blame for the growing climate variety that is present in almost every region of the planet, the Middle East included. Climate change and related issues are exacerbated in regions where economic hardship is expected to occur. Since most of the Middle East has a strong economy, it is utterly defenseless in opposition to the impact of climate change impacts.

Change in the climate includes a cascade effect, which implies that a problem in a particular region of the globe gradually but surely spreads to other areas of the world. The consequences of global warming are going to impactgreatly in the Middle East because of its warm climate [26]. Countries in the Middle East therefore have to adjust to the shifting climate. The bio-diversity of the Middle East region is likely to experience a notable impact from current climate change. Several international organizations have developed crucial plans tocombat climate change, such as the Worldwide Strategy for Plant Protection,which was approved through the Conference of the Participants to the Convention on Biological Diversity in 2002. Due to universal and anthropogenic reasons, the majority of Middle-Eastern countries have experienced significant stress [27].

1.4. Adaptation and Mitigation to Climate Change

Two strategies that address the cause and impact of climate change have been identified: adaptation and mitigation [28], [29]. In the form of two tracks, the concept of mitigating climate change is rather simple to understand. The most traditional strategy is to address the underlying issue by reducing net GHG emissions. An alternate strategy would be to counteract the greenhouse effect using geoengineering methods that (a) actively remove GHG from the atmosphere to stable reservoirs, (b) actively increase the Earth's albedo, and (c) improve the reflection of sunlight [30].

On the other hand, the Intergovernmental Panel on Climate Change (IPCC) defines adaptation to changes in the climate as "the modification in human or natural systems in accordance with current or projected climate stimuli or their repercussions, which reduces damage or exploits advantageous prospects" [31], involves making investment decisions to reduce the potential damages of climate change and taking advantage of new opportunities [32]. In order to ―moderate harm or exploit beneficial opportunities‖ from climate change effects, we mustfirst understand the links between climatic conditions and be able to predict the actual climate conditions.

The challenge presented by climate change, however, is that rates of climatic change can differ across time and between locations throughout a single time period [33]. Relative to the overall trend, certain locations are warming much more quickly than others (or at a slower rate).

1.5. Literature Review

Moving beyond "reactive" strategies and developing proactive strategies to foresee and control risks is necessary for adaptation to climate change. By definition, proactive decisions rely on projections of uncertain future events or difficulties. Making useful predictions requires scientific investment if social decision-making is to be proactive and informed by science [34]. Since preventive strategies might prevent some of the problems that a crisis in reactive mode alone would exacerbate, their potential advantages are coming to light more frequently. As in the cases of species conservation [35] and socioeconomic sectors [36], proactive measures can also allow stakeholders more time to adjust. They can even benefit from ecosystem change.

However, many types of research have used machine learning and artificial intelligence to contribute to finding solutions to this issue as reviewed:

- **AL-Naimi, Rasheed H. et al. (2014)** [37] have developed the artificial neural network (ANN) model to estimate the monthly mean daily global solar radiation in Baghdad, Iraq. The results demonstrated good agreement between the model's estimations and the measured values. The model was particularly advantageous as it can effectively handle the limited meteorological data available in the region, making it a valuable tool for solar radiation estimation in Baghdad. Based on the study's findings, the ANN model's capability to accurately estimate solar radiation and its generalization ability to produce accurate estimates in this area can be confidently affirmed.

- **O'Gorman, P. A., and Dwyer, J. G. (2018)** [38] have conducted research into the behavior of the general circulating model (GCM) with an approximate implementation of an RF-based parameterization of moisture convective. Positively, it was discovered that the RF parameterization produced valid and precise predictions of the controlling environment. Utilizing a decision-tree-based approach, it was relatively easy to ensure that each parameterization maintained physical limitations, including conserving energy. Because it guarantees that physical restrictions are accurately fulfilled to the degree that they are supported by the experimental data, a decision tree technique is interesting. Additional strategies (like applying a correction to the projected temperature tendency to exactly preserve energy) might also be utilized to guarantee that physical limitations are followed. It was found that the RF parameterization functioned well in the GCM when prediction severe precipitation incidences, despite the need for specialist instruction in particular situations.

- **Al-Mukhtar, M., and Qasim, M. (2019)** [39] have utilized the CanadianGCM model (CanESM2) and statistically down-scaling model (SDSM) to estimate the projected maximum/minimum temperature and precipitation for 12locations in Iraq for a trio of subsequent phases: the 2020s (2011-2040), the 2050s (2041-2070), and the 2080s (2071-2100). The National Center for Environmental Prediction/Atmospheric Research (NCEP/NCAR) features were used as variables in the simulation, and the station's local data was used for the projected outcome, with a partially correlated relationship and a significant rating of 0.05. After that, the model was calibrated versus a daily basis, employing 70% of the input information and verified toward the remainder, which was 30% of the collected information.

- **Seifert, A., and Rasp, S. (2020)** [40] have used completely interconnected neural networks to solve the parameterization issue of warm-rain cloud microphysics as typical ML techniques. Researchers discover that models based on machine learning accurately capture the rates of microphysical processes. In a normal two-moment model, the cloud water characteristics alone are inadequate to predict auto-conversion, as shown by the findings of the ML technique, which indicate that integrating rainfall variables is important to customize warm-rain auto-conversion. The dependence of appropriate ML models on the cloud microphysical processing ranks are stable with proven warm-rain parameterizations. The warm-rain procedures in actual models of theatmosphere can be modeled using the produced machine learning (ML) parameterizations.

- **Huang, Z.Q. et al. (2020)** [41] have suggested a two-phase weather management system that utilizes processing of data, bus movement, detectors, and deep learning technologies to supply actual time weather surveillance in buses and terminals while achieving forecasts of the weather via models of prediction for tracking and predicting data on the weather. In order to enhance measuring range and give new data for sensing depending on the sensorymeasures of buses, this study takes advantage of regional processing of data along with moving vehicles. Phase I weather data collected from sensors is used to train and validate the multilayer perceptron (MLP) as well as long short-term memory (LSTM) models utilizing the experimental environment's humidity, temperature, and atmospheric pressure measurements. In Phase II, The trained learning model was used to predict the weather data series over time. The correctness of the predictions was evaluated by the researchers by comparing the projected climate information versus genuine detection measures obtained via the Taichung observational facility of the Central Weather Bureau (CWB) and Environment Protection Administration (EPA). The outcomes demonstrate that the suggested approach performs dependably in terms of monitoring the weather and provides accurate single-day forecasts for the weather using model training.

- **Zhang, Z. and Dong Y. (2020)** [42] have suggested a method for predicting temperature fluctuations employing an artificial neural network and historical temperature data. The researchers particularly developed a convolutional recurrent neural network (CRNN) model, which comprises a convolutionalneural network (CNN) part and a recurrent neural network (RNN) part. Through neural networks, the model may learn from historical data the time and spatial connection of temperature changes. The suggested CRNN model was evaluated by the researchers using daily basis temperature readings for China's mainland from 1952 to 2018. The findings demonstrate that the created modelis capable of predicting temperature changes with an inaccuracy of about 0.907°C.

- **Mohsenzadeh, S. K. et. al. (2020)** [43] have used support vector machine (SVM), randomforest (RF), and geostatistical (GS) approaches for modeling on a monthly basis air temperatures. The applications utilized an information scanning method and data from 30 different places across Iran. Geographical directions, including longitude, latitude, and height, in addition to the recurring parameter(month of the year),have been provided to the proposed models. Furthermore, neural networks (ANNs) and neuro-fuzzy (NF) methods were contrasted with SVM and RF models using k-fold analysis. SVM and RF models performed better than ANN and NF models, according to assessments. In each of the stations, theRF model produced more accurate predictions than the SVM model, which had a typical standard deviation of 1.855 on average. However, the outcomes showed that the use of the geo-statistics-based criticizing technique can accurately replicate air temperature.

- **Astsatryan, H. et al. (2021)** [44] have created a machine learning-based climate prediction strategy to enhance the hourly air temperature prediction for a maximum of 24 hours in the Ararat valley (Armenia). The method makes use of big satellite databases that are available for processing as well as terrestrial observational information collected from numerous meteorological observatories at various frequencies and resolutions. Numerous neural networkswere used in the trials to predict the temperature of the air for 24 hours over the Ararat valley. The proposed model can be utilized in conjunction with the most cutting-edge methods because it has accuracy levels of 87.31% and 75.57% for predicting the temperature for the following three and twenty-four hours, respectively.

- **Villegas-Mier, C. G. et al. (2022)** [45] have utilized the Random Forest (RF) method for optimization efforts. The outcomes were then contrasted against those from various machine learning models. The investigation is carried out in Queretaro, Mexico, where more than 75 percent of the year is favorable for climate conditions and exposure to ultraviolet radiation. The findings show a successful enhancement when enhancing the hyper parameter values of the RF and the Adaboost system models, with an improvement of 95.98% reliability contrasted with more conventional techniques like linear regression (54.19%) or the recurrent neural networks (53.96%). This boost in accuracy is achieved with no enhancing the amount of time required to compute or requirement for performance for achieving the prediction. The investigation has been effectively finished in Juriquilla over two separate scenarios for 2020 and 2021. The developed approach provides predictable outcomes with identical outcomes, illuminating the sustainability and effectiveness of the strategy we have developed.

- **Dong, J. et al. (2023)** [46] have assessed a technique for adjusting the bias of the Global Ensembles Forecasting Systems V2 predictions employing the severe gradient booster (XGBoost) model (M3) using 689 meteorological observatories in seven distinct meteorological areas of China. The method used a standard variation adjustment for different climatic parameters to predict P for 1–8 days in advance. It was also compared to the XGBoost model (M2) and the EDCDFm

(M1), which are indistinguishable continuous distributing curves that fit just one weather variable. The M3 method generated extremely precise projections. For the M1, M2, and M3 methods, the average of the root- average square error (RMSE) was 2.292-17.049 mm, 1.844-18.835 mm, and 1.819-13.608 mm, respectively.

Table 1.1. Summary of literature review related to thesis topic

Reference	Period	Region	Models used	Outputs
AL-Naimi, Rasheed H. et al. **[37]**	1971-2000	Iraq	Artificial Neural Network (ANN)	Solar Radiation
O'Gorman,P.A. and Dwyer, J.G. **[38]**	2005-2015	Global	Random Forest (RF)	Surface Precipitation
Al-Mukhtar, M. and Qasim, M. **[39]**	2011-2100	Iraq	GCM model (CanESM2) and Statistically Down-Scaling Model (SDSM)	Maximum and Minimum Temperature and Precipitation
Seifert, A. and Rasp, S. (2020) **[40]**	Not Real Data (Results of Simulations)	Germany	Neural Networks and Monte Carlo Super Drople	Warm-Rain Cloud
Huang, Z.-Q. et al. (2020) **[41]**	2013-2019	Taiwan	Multilayer Perceptron (MLP) and Long	Humidity, Temperature, and

المستخلص

يعتبر المناخ نظاما معقدا وفوضويا، ويشكل التنبؤ بعوامله الجوية على المدى المتوسط والطويل تحديا اجتماعيا واقتصاديا وبيئيا. إضافة إلى ذلك، لا تقدم هيئة الأرصاد الجوية العراقية سوى تنبؤات جوية قصيرة المدى لم تعد ذات فائدة. ولذلك، تصف الدراسة الحالية تطبيق استخدام العديد من أساليب التعلم الآلي للتنبؤ بستة عوامل مناخية رئيسية في ١ و٣ و٦ و١٢ شهرًا مقدمًا، وذلك باستخدام البيانات الشهرية المتأخرة فقط لهذه العوامل كمتنبئات.

تم استخراج المعلمات المناخية (ممثلة بستة عوامل للأرصاد الجوية) خلال الفترة من ١٩٨١ إلى ٢٠٢١ من مجموعة بيانات التحليل الاسترجاعي MERRA-2 هذه العوامل الستة هي: الرطوبة النسبية (RH) ، الهطول الكلي (Prec) ، درجة الحرارة القصوى (Tmax) ، درجة الحرارة الدنيا (Tmin)، الإشعاع الشمسي(SR) ، وسرعة الرياح (WS) لأربع محافظات في العراق (نينوى والأنبار وبغداد والبصرة). كانت نماذج التعلم الآلي التي تم تنفيذها هي الغابة العشوائية(RF) ، وآلة ناقل الدعم(SVM) ، والشبكة العصبية الاصطناعية(ANN) ، وجيران K الأقرب (KNN) استخدمت الدراسة الحالية ما يصل إلى ١٢ من بيانات السلاسل الزمنية المتأخرة كمتغيرات تنبؤية للمدخلات. تم استخدام البيانات في الفترة (١٩٨١-٢٠١٥) لتدريب الخوارزميات، في حين تم استخدام البيانات المتبقية (من ٢٠١٦ إلى ٢٠٢١) للتحقق من النماذج.

تم تقييم النتائج باستخدام ثلاثة مقاييس أداء :معامل التحديد (R^2) وجذر متوسط مربع الخطأ، (RMSE) و يعني الخطأ المطلق(MAE). ووفقا للنتائج، فإن المهلة الزمنية لكل محافظة لكل معلمة

مناخية لها مقدار شهري متميز من التأخير ونهج التعلم الآلي التنبؤي. وكشف البحث أن خوارزمية RFكانت الأفضل من حيث دقة التنبؤ، في حين كانت خوارزمية SVR هي الأقل. كما أظهرت النتائج أن التنبؤ Prec حقق أدنى أداء بمتوسط RMSE قدره ١٩,٠٠٢. في المقابل، كان أداء التنبؤ لـ RHو WSأفضل بكثير بمتوسط RMSE قدره ٧,٢٥٩ و٠,١٩٢ على التوالي.

وقد لوحظ أعلى أداء لتنبؤات (Tmin و Tmax و SR) كان متوسط قيم RMSE 2.346 و٢,٢٤٤ و٥,٣١٤ على التوالي.

يقدم البحث الحالي بيانات حديثة مشجعة حول استخدام التعلم الآلي للتنبؤ بالطقس والمناخ قبل أشهر قليلة، وهو أمر بالغ الأهمية لتحقيق العديد من أهداف التنمية في العراق، بما في ذلك حماية حياة الناس وممتلكاتهم وتعزيز الأمن والسلامة والصحة.