International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

Climate Change Impacts on Temperature and Water of the Soil in Iraq for the Period 1980-2022

Fadwa S. Abdalfatah[1], Iqbal H. Abdulkareem[2], Farah H. Jasim[1], Osama T. Al-Taai[1], and Zainab M. Abbood[1]

[1] *Department of Atmospheric Sciences, College of Science, Mustansiriyah University, Baghdad, Iraq.*

[2] *The Scientific Affairs department, Al-Iraqia University, Baghdad, Iraq.*

[a)] Correspondence Author Email: osamaaltaai77@uomustansiriyah.edu.iq

Abstract. Soil temperature is a fundamental issue in applied climate studies. It has great importance in overall plant activity in terms of the speed of seed germination and the process of water absorption by the roots. When the soil temperature rises, the effectiveness of biological organisms increases, which in turn increases the speed of decomposition of organic matter, provides organic nutrients to the plant, and determines Suitable conditions for seed germination and seedling growth in the early stages of the plant's life. Data are taken by high vegetation Cover (HVC), soil temperature (ST), soil water (SW), total precipitation (TP), and temperature (T) from satellites recorded by the European Centre for Medium-Range Weather Forecasts (ECMWF). The choice period from 1980-2022 over Iraq extends between two latitudes (29.55° - 37.225°) North of the equator and between two longitudes (38.455° - 48.548°) East of the Corniche line. Otherwise, we have studied the behavior of monthly, seasonal, and yearly means of HVC, ST, SW, TP, and T as well as the relationship between them. The results showed that the strongest correlation was between the soil temperature and the temperature, as the relationship was very strong and positive. While the other relationship between soil temperature and water content was a very strong inverse relationship, the other relationship between soil temperature, high vegetation cover, and total precipitation was inverse and weak.
Keywords. Soil temperature, Soil water, High vegetation cover, Climate change, Iraq.

INTRODUCTION

Soil temperature plays an important role in determining when flowers and plants grow in the spring and determining the safe time for farmers to plant their crops [1][2]. Every spring, the surface of the soil is heated by warm air and sunlight. Once the soil temperature reaches a certain limit, it is time to plant and grow [3][4]. Changes in soil temperature are slower than air temperature, so there is always a time lag between the two extremes of air temperature and soil temperature [5][6]. Due to daily temperature fluctuations, the soil can be cooler than the air during the day and warmer than the air at night [7][8]. Soil temperatures change with depth [9][10]. The deeper the soil, the more stable the temperature [11][12]. As a result, when referring to soil temperatures, the depth at which the measurements were taken must be indicated because it is also important [13][14]. As shown in the following series of chemical reactions [15][16][17]:

Soil temperature

Heat from sunlight may also be derived some heat from falling rain [18][19]. It is decomposed organic matter [20][21]. Soil components store a large portion of the energy they receive heat during the day and the hot season, then it is released back into the atmosphere during the night and in the cold part of the year [22][23]. Heat is transferred into and out of the soil through the process of thermal conduction (contact) [24][25].

Given the difference in the specific temperature of the soil, as well as its ability to conduct heat, as a result of the variation in the properties of the soil in terms of its composition, porosity, moisture...etc., the temperature varies from one soil to another, as well as depending on the depth below the surface [26][27]. All energy flowing to the surface is positive, while all energy leaving the surface is negative [28][29]. The thermal conductivity of soil depends on its porosity, degree of moisture, and the amount of material membership therein [30][31]. If the soil moisture is equal, its thermal conductivity then decreases. increased porosity; It decreases from fine sandy soil to alluvial loam soil and clay [32][33]. The thermal conductivity of soil determines the rate of heat transfer [34][35]. What is the change in temperature in the soil? Other materials, except for the product of heat transfer, depend on the difference in their thermal capacity [36][37]. Thermal diffusion is related to the soil's conductivity of heat and its heat capacity [38][39]. Increasing soil moisture leads to a noticeable increase in thermal diffusion and heat capacity as well as thermal conductivity [40][41]. The presence of water in the soil results in a decrease in the insulating effect [42][43]. It is practiced in spaces filled with air. However, the increase in organic matter in the soil works to reduce thermal diffusion due to the role of this material in increasing porosity [44][45]. As it result of Increased soil compaction [46][47]. Increased thermal diffusion as a result of a decrease in the size of the voids (pores) [48][49]. Buffer. there is no doubt that thermal diffusion in the soil is much less than it is in still air [50][51].

Variation of soil temperature with depth

The degree of permeability of radiant energy into the soil, and thus the transfer of heat, varies according to the quality of the soil, its porosity, color, the amount of organic matter in it, and its moisture [52]. In light of this, its temperature varies with depth. Soil texture (texture) has a clear effect on soil temperature. Sandy soil (coarse texture) differs in heating from silty soil (fine texture). Assuming that both types of soil were saturated with water at the end of the winter, the thermal conductivity in them would then be equal. However, because sandy soil is unable to retain water because it has good drainage, it will dry out more quickly with time than alluvial soil [53]. Within several days, the thermal conductivity in the sandy soil will decrease sharply because the pore spaces remain filled with air, which is a poor conductor of heat. However, the heat capacity will decrease as water has a greater heat capacity than any substance in the soil [54]. Moreover, evaporative cooling at the surface will stop when water becomes unavailable. For these reasons, sandy soils heat up faster in the spring and cool faster in the fall than silty or clay soils under the same weather conditions, due to the lower amount of moisture and lower heat capacity [55][56]. The degree to which the soil retains the thermal energy it has stored also varies during the day and in the season. The effectiveness of daily heating and cooling of the soil is almost determined by a depth range of about 20 cm from the surface. During daylight hours, the soil temperature decreases sharply up to a depth of 20 cm, and the rate of decrease decreases after that. At night, the temperature increases with depth up to a depth of 20 cm, approximately 2-4 cm to then reverses towards a decrease. In summer, the upper layers of soil are warmer than the lower ones, and in winter, the lower layers are warmer [57][58].

The importance of soil temperature

Soil temperature and the pattern of its change in time and space have a significant impact on the physical, chemical, and biological processes in the soil system. The effect of soil temperature can be summarized in the following points [59][60][61][62]:

- Soil temperature controls the speed of chemical reactions that occur in the soil, such as the decomposition of minerals in the aqueous solution. The higher the temperature, the faster the decomposition reactions of both minerals and organic matter in the soil increase.

- The temperature of the soil affects the solubility of carbon dioxide gas (CO_2) in the soil solution, as the higher the temperature, the lower its solubility. Carbon dioxide dissolved in the aqueous solution has a major role in the rest of the chemical reactions in the soil solution, as it affects the acidity of the solution or the concentration of the hydrogen cation H^+ in it.
- Fluctuations in soil temperature cause its minerals to contract and expand to varying degrees, resulting in mechanical weathering and changing the soil's texture and properties.
- Soil temperature affects biological activity, whether plant or animal. If the soil temperature drops below zero degrees Celsius, or approximately five degrees Celsius above zero, biological activity in the soil stops.

The process of seed germination depends mainly on the temperature of the soil, as it makes the germination process fast and reduces the size of the loss of planted seeds [63]. The opposite happens when the soil temperature decreases, the germination process is slow and low and the amount of seed loss increases as a result of the inappropriate temperature for the seed germination process, as the effect of soil temperature is not limited to seed germination, but rather affects other stages of plant growth, as when it drops below the minimum, it leads to the freezing of water inside the plant roots and in the spaces between them, which leads to the plant wilting, because it is unable to It obtains the water it needs to complete vital processes, which leads to the disruption of root activity and their death [64]. Soil moisture is a key land surface variable that is involved in the exchange of water and heat between the land surface and the atmosphere. It affects vegetation growth along with the formation of precipitation and runoff, with direct consequences for the agricultural yield [65]. Soil moisture also plays an important role in the climate system and affects the predictability of the atmosphere on sub-seasonal to seasonal time scales, which is important for weather and climate forecasting, see Figure 1 [66].

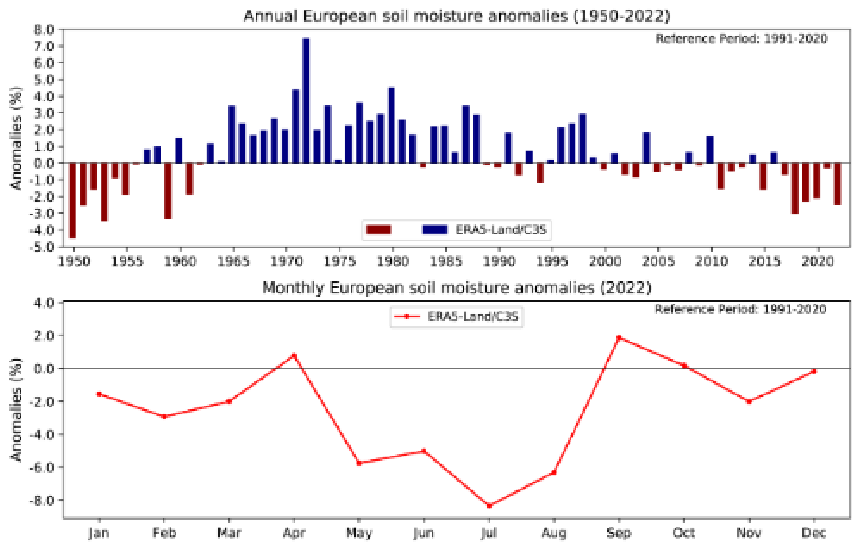


Figure 1. (Top) Time series of annual European soil moisture anomalies (%) in the top soil layer from 1950 to 2022. The anomalies are expressed as a percentage of the annual average for the 1991–2020 reference period. (Bottom) Time series of monthly European soil moisture anomalies (%) in the topsoil layer in 2022. The anomalies are expressed as a percentage of the monthly average for the 1991–2020 reference period. Data source: ERA5-Land. Credit: C3S/ECMWF [67].

MATERIALS AND METHODS

Data source and study station

The work was performed using data on soil temperature (ST), high vegetation cover (HVC), soil water (SW), and Temperature (T) taken from ECMWF [68]. This data was converted into monthly rates to show seasonal effects. The data was processed by MATLAB and drawn by SigmaPlot. Also, the Surfer 13 program was used to map Iraq for the following data, such as temperature, plant temperature, high vegetation cover, rainfall, and soil water. The choice of 1980-2022 over Iraq Stations, as well as Table 1. It extends between two latitudes (29.55 - 37.225) north of the equator and between two longitudes (38.455 - 48.548) east of the Corniche line [69].

Table 1. The Meteorological station was used in the study [25].

	Station	Longitude (degree)	Latitude (degree)	Elevation (meter)
1.	Mosul	43.15	36.31	223
2.	Rutba	40.28	33.03	222
3.	Baghdad	44.4	33.3	32
4.	Basrah	47.78	30.52	2

Results and discussion

Analysis of the behavior of the annual rate of high vegetation cover over Iraq

Figure 2, shows the annual rate of high vegetation cover data for the period 1980-2022 over Iraq, as it shows that during this period Mosul had the highest value of vegetation cover, as it is characterized by forests, its geographical location is within the northern regions, and its environment is characterized by abundant rainfall, where the weather is moderate, there is no desertification and low temperatures. These factors significantly affect plant growth, while the lowest values for vegetation cover were in Sinjar, Makoor, Qaim, Anah, Haditha, Ramadi, Kerbela, Nukhen, Najaf, Dawaniya, Amara, Samawa, and Kahalis. This is due to the hot and dry climate during the summer and the lack of rain during the winter, which led to a lack or absence of high vegetation cover during these stations.

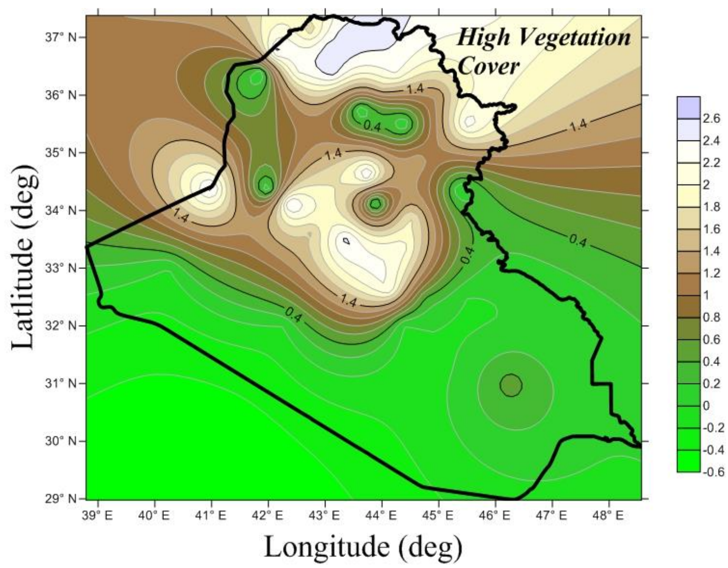


Figure 2. Annual average of high vegetation cover for the period 1980-2022 over Iraq.

Analysis of the behavior of the annual rate of soil temperature over Iraq

Figure 3 shows the annual average soil temperature data for the period 1980-2022 over Iraq. It also shows that during this period, Nasiriyah obtained the highest value for soil temperature, as it is characterized by high air temperature and its geographical location within the borders of the southern regions, and is characterized by a lack of rain, as it is the weather is very hot, in addition to desertification. These factors helped to greatly influence the rise in soil temperature, which reduces the growth of plants, while the lowest value of soil temperature was in Emadiyah, where it was characterized by low air temperature and frequent rainfall, which contributes to the growth of plants and trees.

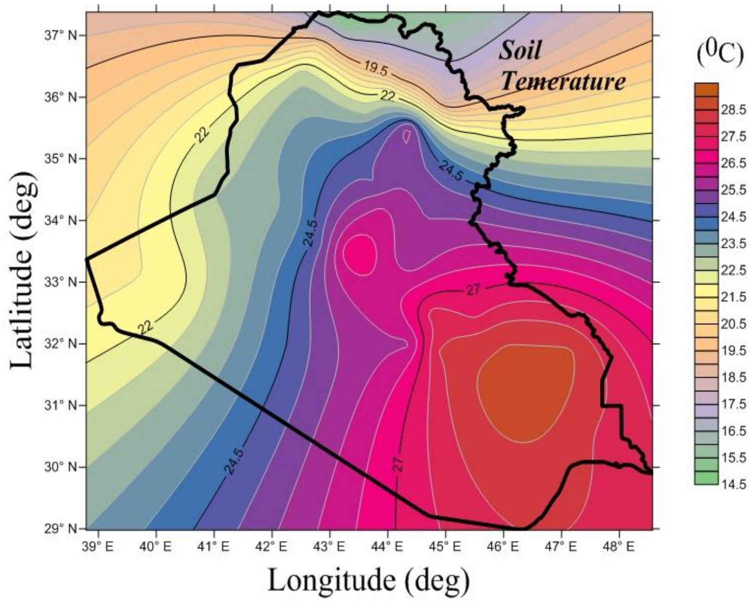


Figure 3. Annual average of soil temperature for the period 1980-2022 over Iraq.

Analysis of the behavior of the annual rate of soil water over Iraq

Figure 4 shows the annual average soil water data for the period 1980-2022 in Iraq. It also shows that during this period, the Basra station obtained the lowest value for soil water, as it is characterized by high air temperature and its geographical location within the borders of the southern regions, and is characterized by a lack of rain, where the weather is Very hot, in addition to desertification. These factors helped significantly influence the lack or absence of water retention in the soil due to the intensity of solar radiation that works to the dryness of the soil and the difficulty of plant growth, while the highest value of soil water was in Zakho, where it was characterized by low air temperature and frequent rainfall, which works to retain water in the soil and encourage the growth of plants and trees.

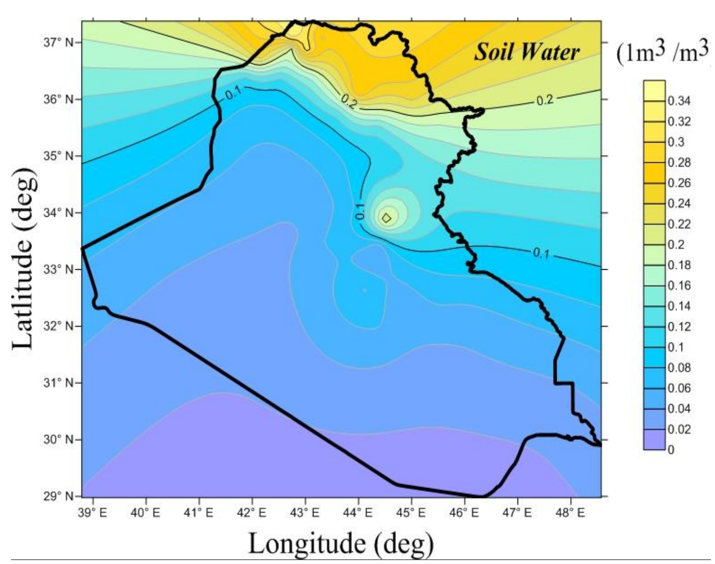


Figure 4. Annual average of soil water for the period 1980-2022 over Iraq.

Analysis of the behavior of the annual temperature rate over Iraq

Figure 5 shows the annual average of temperature data for the period 1980-2022 in Iraq. It also shows that during this period the Nasiriyah station obtained the highest temperature, as it is characterized by a high soil temperature and its geographical location within the borders of the southern regions, where the weather is very hot, and desertification, in addition to the intensity of solar radiation, helped these factors the dryness of the soil and the difficulty of plant growth, while the lowest temperature value was in Emadiyah, which was characterized by low soil temperature and frequent rain, which encourages the growth of plants and trees.

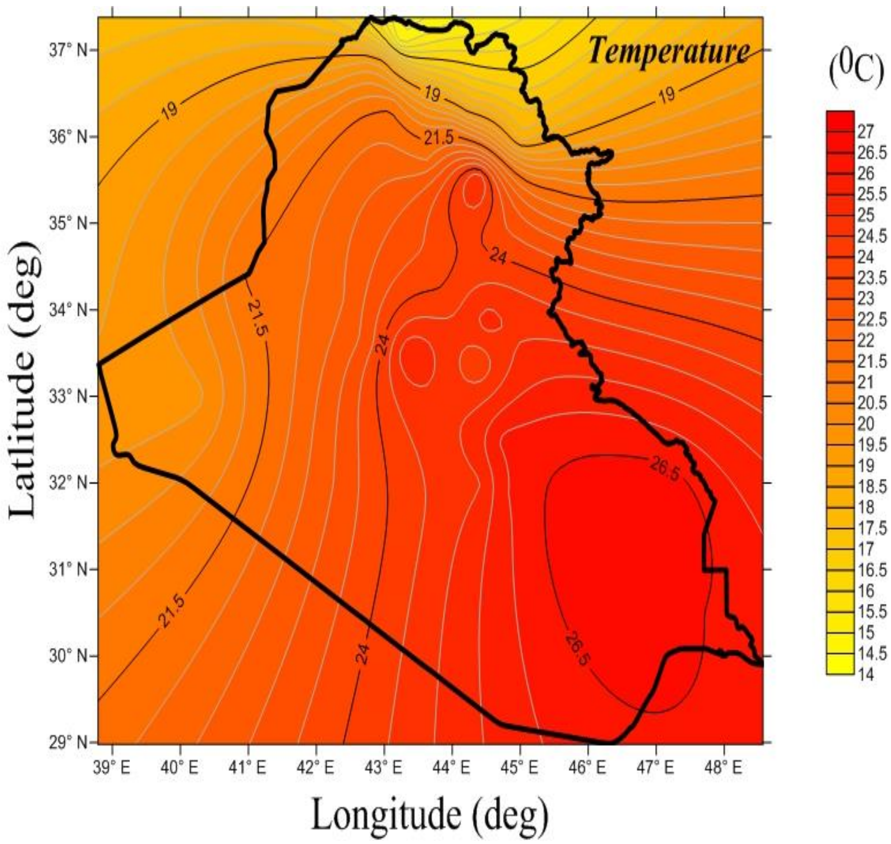


Figure 5. Annual average of air temperature for the period 1980-2022 over Iraq.

Analysis of the behavior of the sum rate of temperature over Iraq

Figure 6 shows the annual sum of soil water data for the period 1980-2022 in Iraq. It also shows that during this period, Najaf station obtained the lowest precipitation, as it is characterized by a high air temperature and its geographical location within the borders of the southern regions, where the weather is very hot, in addition to desertification, in addition to the intensity of solar radiation, helped these factors lack of precipitation, while the highest value of precipitation was in Emadiyah, where it was characterized by low air temperature, lack of solar radiation, and its geographical location and the nature of the surface, which led to abundant rain.

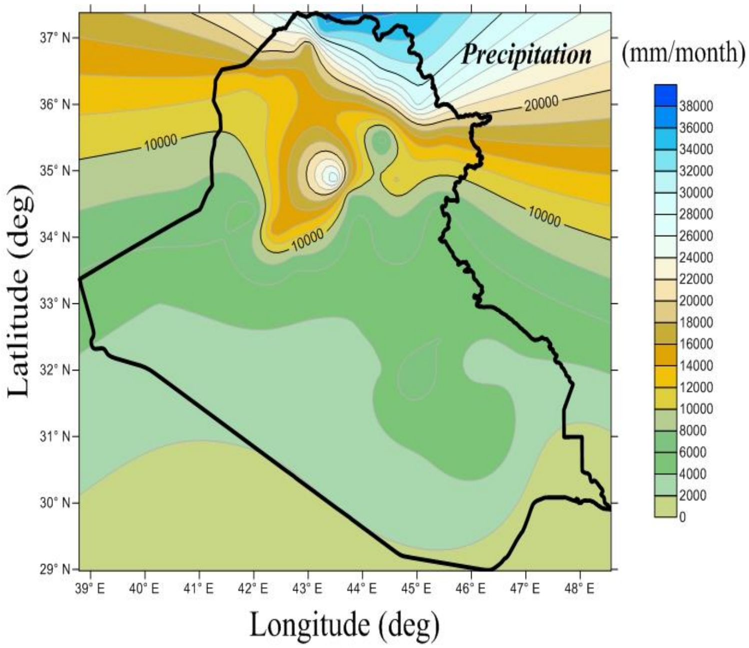
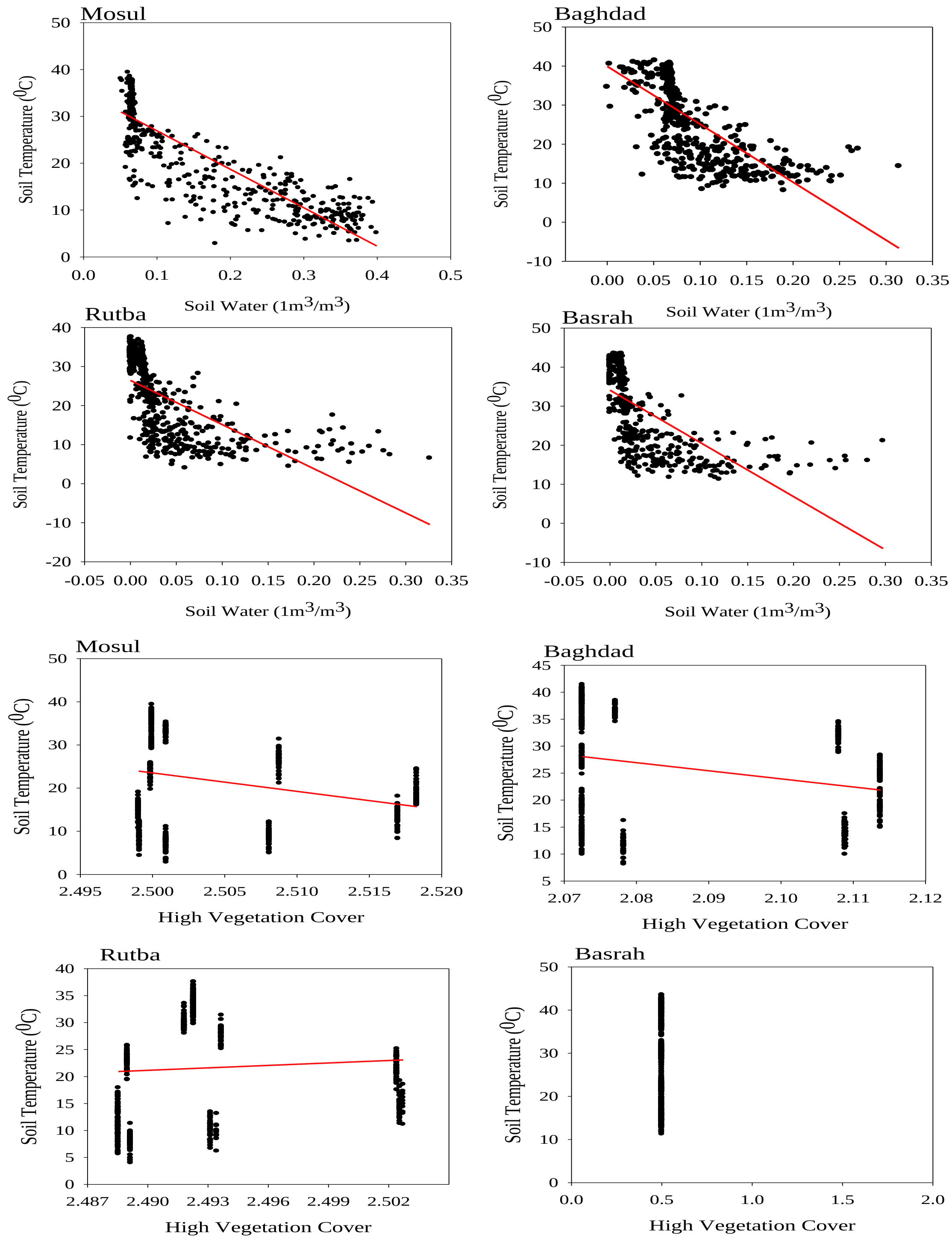


Figure 6. Annual sum of Precipitation for the period 1980-2022 over Iraq.

Relationship of soil temperature with soil water content, temperature, total precipitation, and high vegetation cover over Iraq

Figure 7 shows the type of relationship and the strength of the association between soil temperature and factors affecting it, such as soil water content, high vegetation cover, temperature, and total precipitation for the period 1980-2022 over stations in Iraq, such as Baghdad, Basra, Mosul, and Rutba. The strongest correlation was between the soil temperature and the temperature, as the relationship was very strong and direct, and the nature of the soil temperature data was similar to the same behavior. The temperature data was taken at an altitude of 2 m, whereas the soil temperature increased, the air temperature increased. While the other relationship between soil temperature and water content was a very strong inverse relationship, because as the soil temperature increases, the water content decreases, and this is observed in the southern stations. While the other relationship was between soil temperature, high vegetation cover, and precipitation, it was an inverse and weak relationship, as it decreased. Soil temperature, precipitation, and high vegetation cover increase, leading to the growth of plants and trees. As shown in the table 2.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php



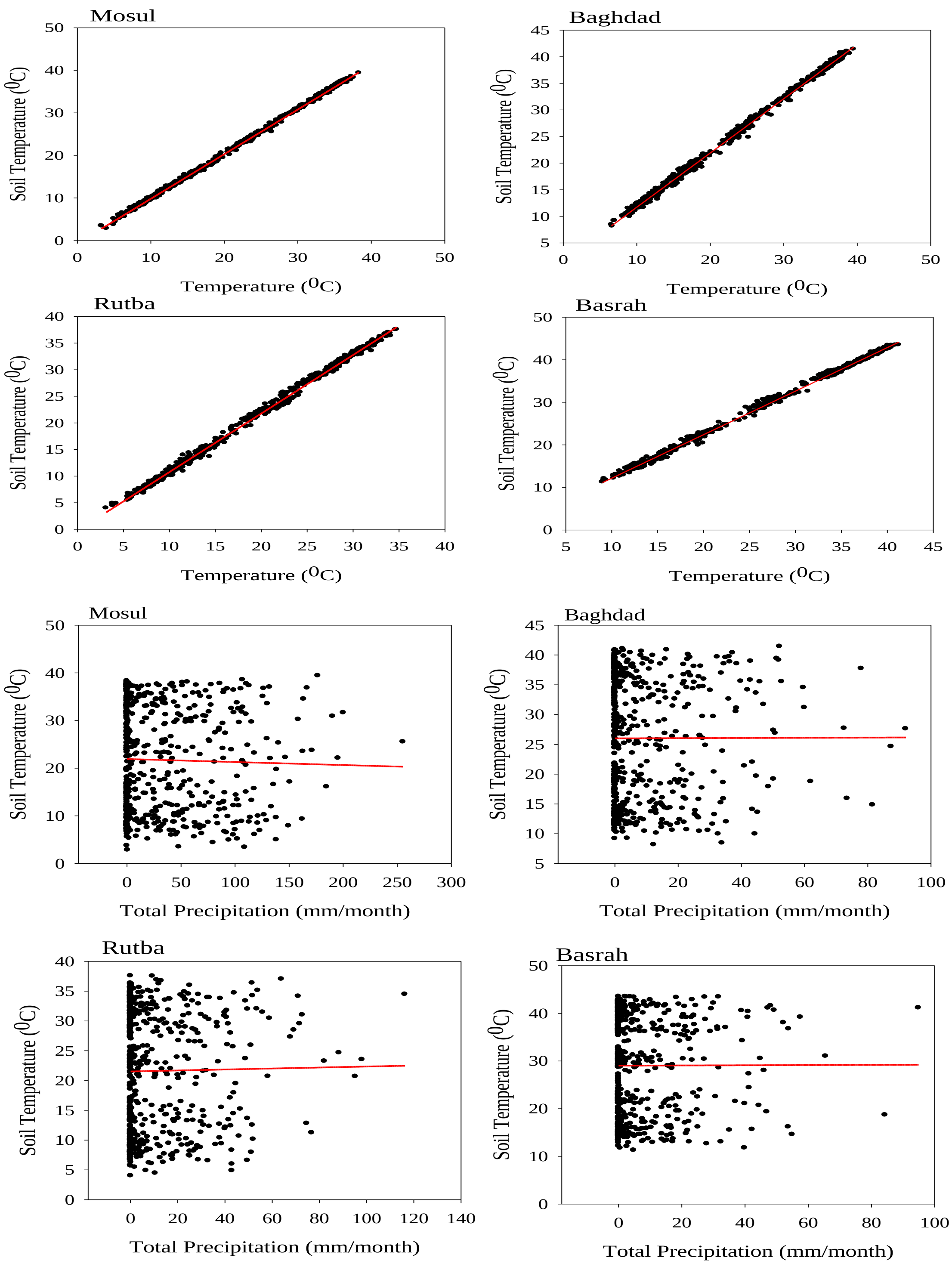


Figure 7. Relationship of soil temperature with effect factors over Iraq.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

Table 2. The relationship between Soil Temperature with High Vegetation Cover (HVC), Temperature (T), TP, and Soil Water (SW) for the period 1980-2022 over Iraqi Stations.

Hour	**Spearman rho**		**Linear regression Simple**	
Soil temp and Soil water	**R**	**Correlation degree**	**P-value**	**Interpretation of the relationship**
Mosul	-0.86	The very high inverse correlation	0.001 <	Linear relation
Rutba	-0.71	High-Low inverse correlation	0.001 <	Linear relation
Baghdad	-0.63	medium inverse correlation	0.001 <	Linear relation
Basrah	-0.65	medium inverse correlation	0.001 <	Linear relation
Soil temp and HVC	**R**	**Correlation degree**	**P-value**	**Interpretation of the relationship**
Mosul	- 0.4	Medium inverse correlation	0.001 <	Linear relation
Rutba	-0.3	Low inverse correlation	0.001 <	Linear relation
Baghdad	0.2	Low inverse correlation	0.001 <	Linear relation
Basrah	0	No correlation	0	No relation
Soil temp and Temp	**R**	**Correlation degree**	**P-value**	**Interpretation of the relationship**
Mosul	0.9994	The very high positive correlation	0.001 <	Linear relation
Rutba	0.988	The very high positive correlation	0.001 <	Linear relation
Baghdad	0.985	The very high positive correlation	0.001 <	Linear relation
Basrah	0.987	The very strong positive correlation	<0.001	Linear relation
Soil temp and Precipitation	**R**	**Correlation degree**	**P-value**	**Interpretation of the relationship**
Mosul	0.027	The very Low positive correlation	0.001 <	Linear relation
Rutba	0.003	The very Low positive correlation	0.001 <	Linear relation
Baghdad	0.02	low positive correlation	0.001 <	Linear relation
Basrah	0.003	The very Low positive correlation	0.001 <	Linear relation

Analysis of the monthly and seasonal behavior of air temperatures over Iraq

Figure 8 (a, b) shows the monthly and seasonal averages of temperature data for selected stations over Iraq, such as Mosul, Baghdad, Rutba, and Basra. It was found that there was a noticeable increase in June, July, and August and a decrease in the months of January, February, and December. This is due to the fall of the sun's rays, as they fall vertically in the summer and are inclined in the winter. In addition, the Rutba station witnessed low temperatures, while the Basra station witnessed a significant rise in temperatures, and this is due to the nature of the region and the large number of human activities, in addition to weather factors.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

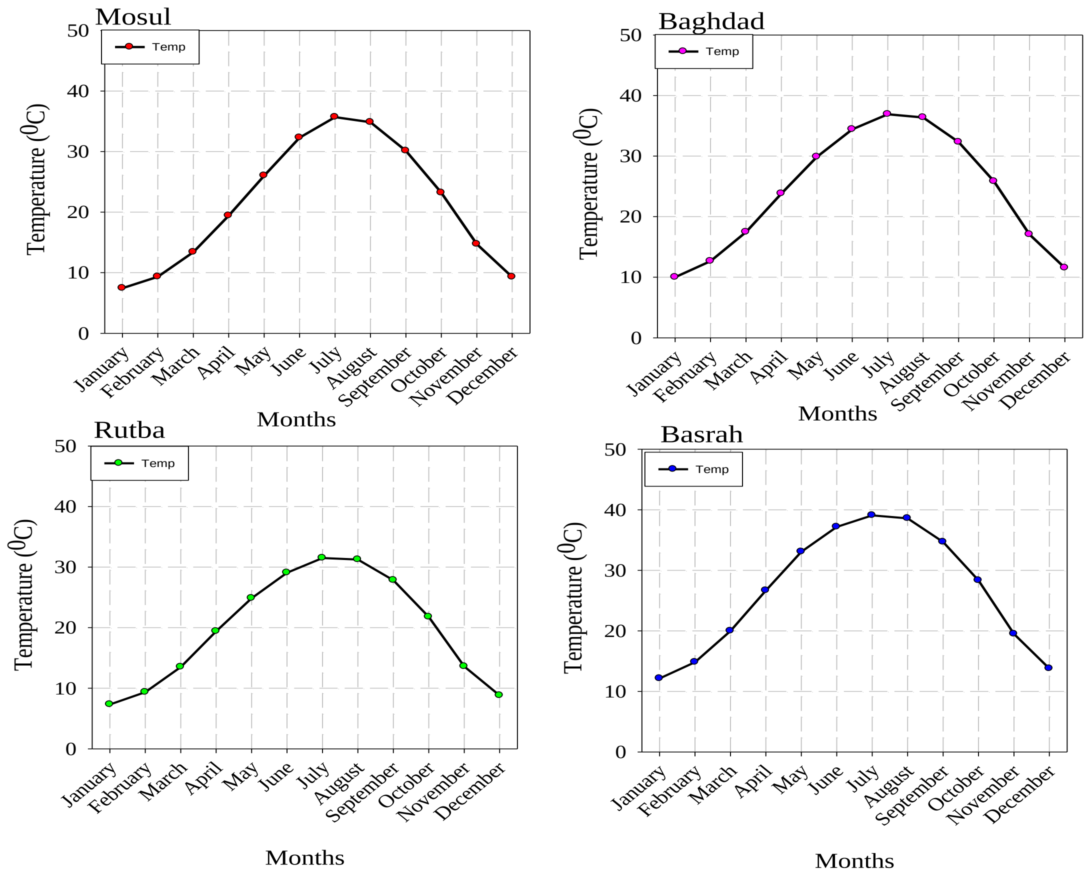


Figure 8 (a). Analysis of the monthly behavior of air temperatures for the period 1980-2022 over Iraq.

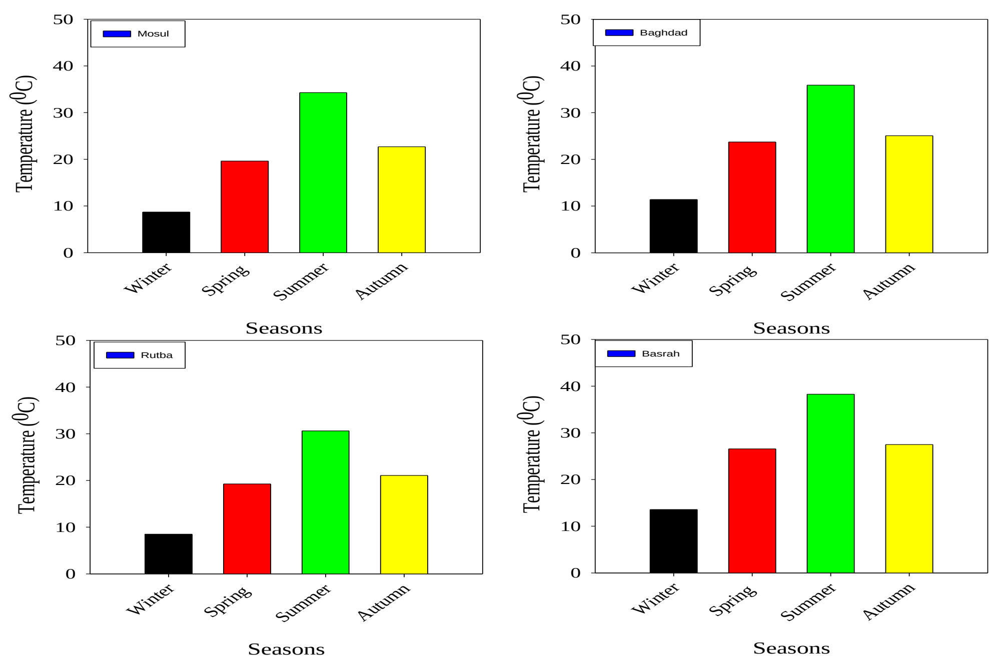


Figure 8 (b). Analysis of the seasonal behavior of air temperatures for the period 1980-2022 over Iraq.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

Analysis of the monthly and seasonal behavior of high vegetation cover in Iraq

Figure 9 (a, b) shows monthly and seasonal averages of high vegetation cover data for selected stations across Iraq, such as Mosul, Baghdad, Rutba, and Basra. It was found that there was a noticeable increase in February, March, and April, and a decrease in June, July, and August. This is due to the fall of the sun's rays, which fall vertically in the summer and obliquely in the winter. This leads to a decrease in the air temperature, a decrease in the soil temperature, an abundance of rain, and an increase in the water content of the soil. Growth and increase of plants. In addition, the Mosul station witnessed a high vegetation cover, while the Basra station witnessed a very low vegetation cover. This is due to the high temperature, the nature of the region, and the large number of human activities, in addition to weather factors.

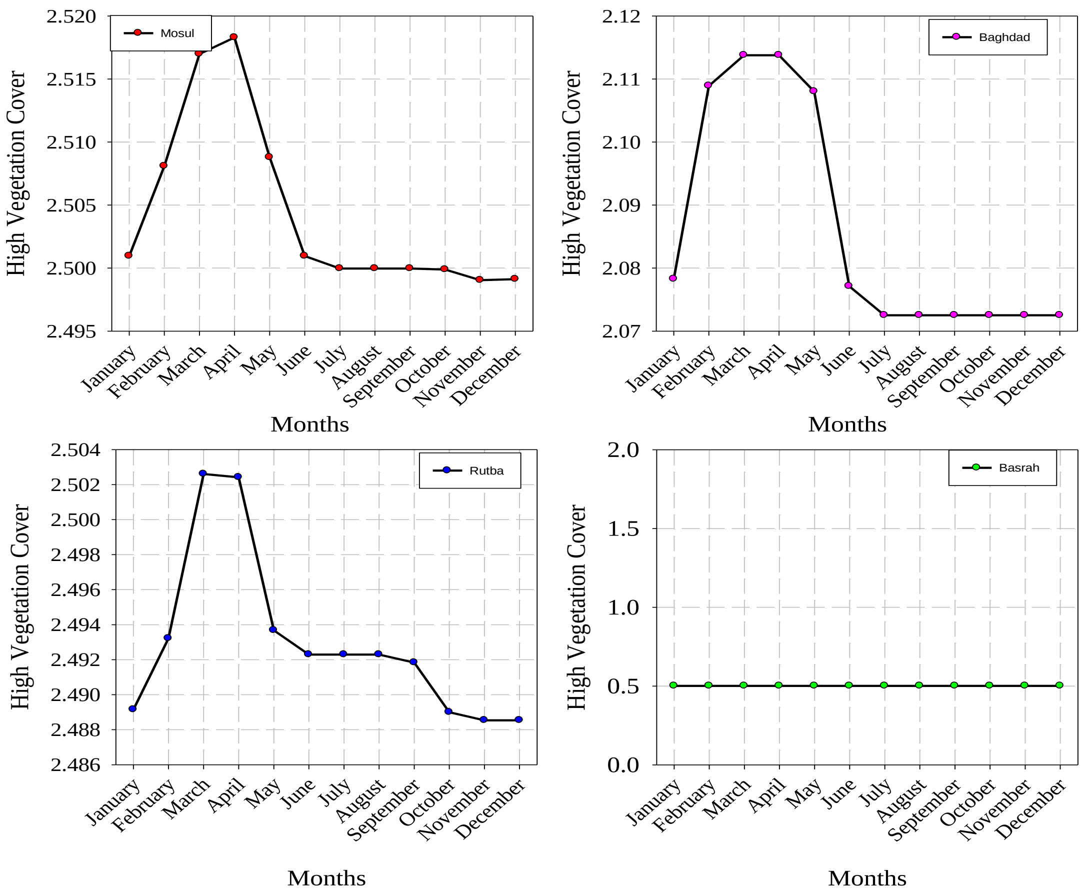


Figure 9 (a). Analysis of the monthly behavior of high vegetation cover for the period 1980-2022 over Iraq.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

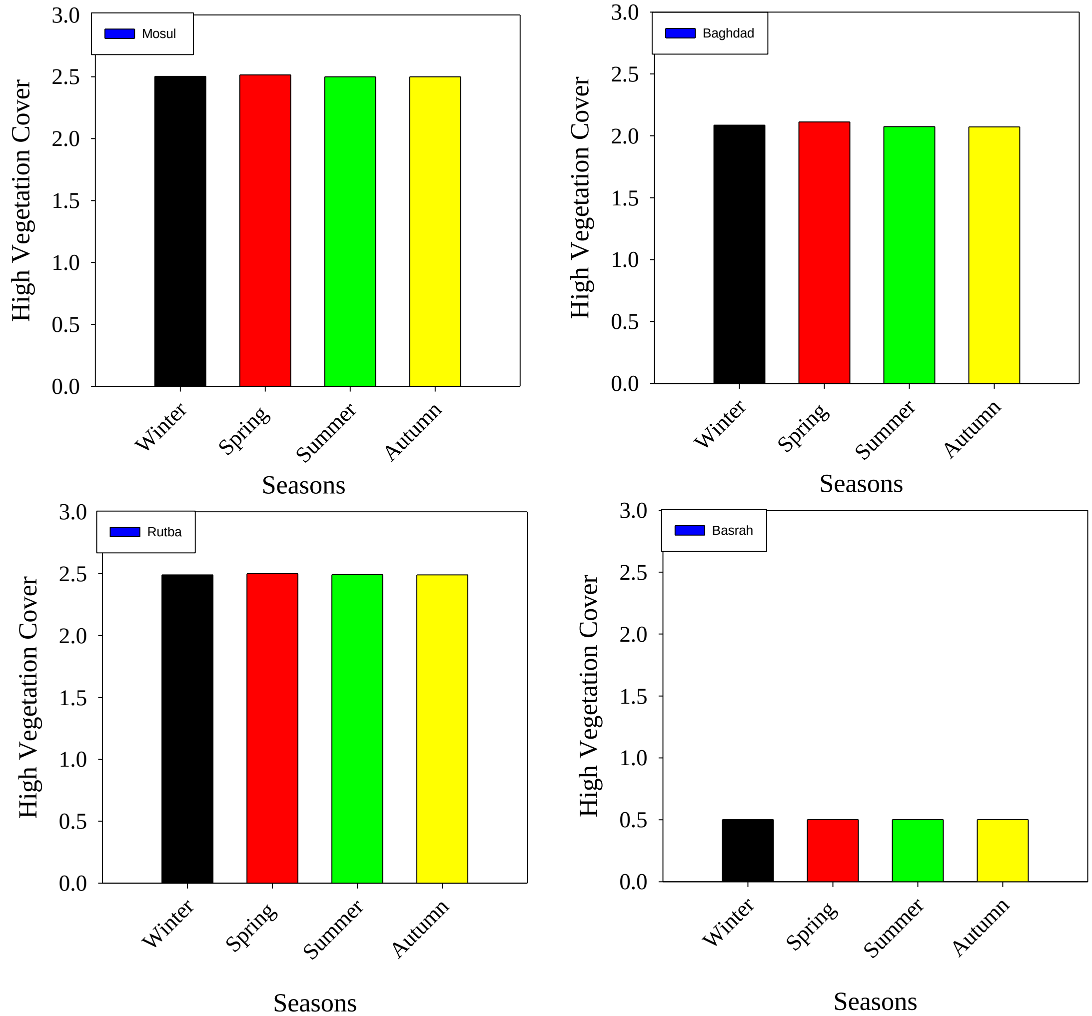


Figure 9 (b). Analysis of the seasonal behavior of high vegetation cover for the period 1980-2022 over Iraq.

Analysis of the monthly and seasonal behavior of soil temperature in Iraq

Figure 10 (a, b) shows the monthly and seasonal averages of soil temperature data for selected stations over Iraq, such as Mosul, Baghdad, Rutba, and Basra. It was found that there was a noticeable increase in June, July, and August (Summer season) and a decrease in January, February, and December (Winter season). This is due to the fall of the sun's rays, as they fall vertically in the summer and are inclined in the winter. In addition, the Rutba station witnessed low soil temperatures, while the Basra station witnessed A significant rise in temperatures, and this is due to the nature of the region and the large number of human activities, in addition to weather factors. We notice that the behavior of the air temperature is similar to the behavior of the soil temperature because it was taken at an altitude of 2 m is the air temperature.

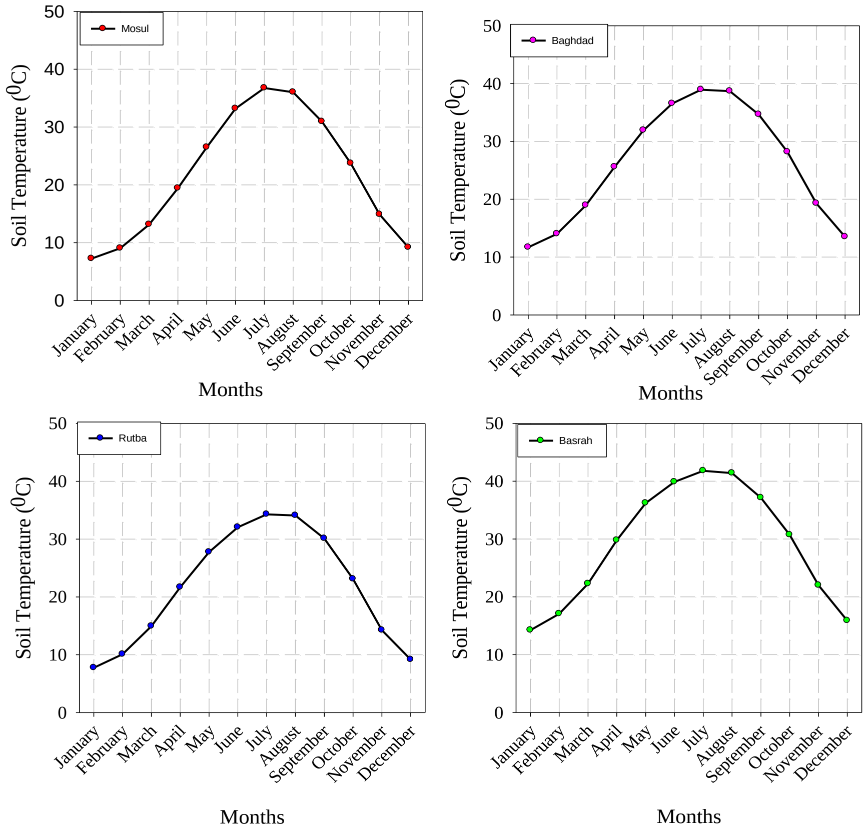


Figure 10 (a). Analysis of the monthly behavior of soil temperature for the period 1980-2022 over Iraq.

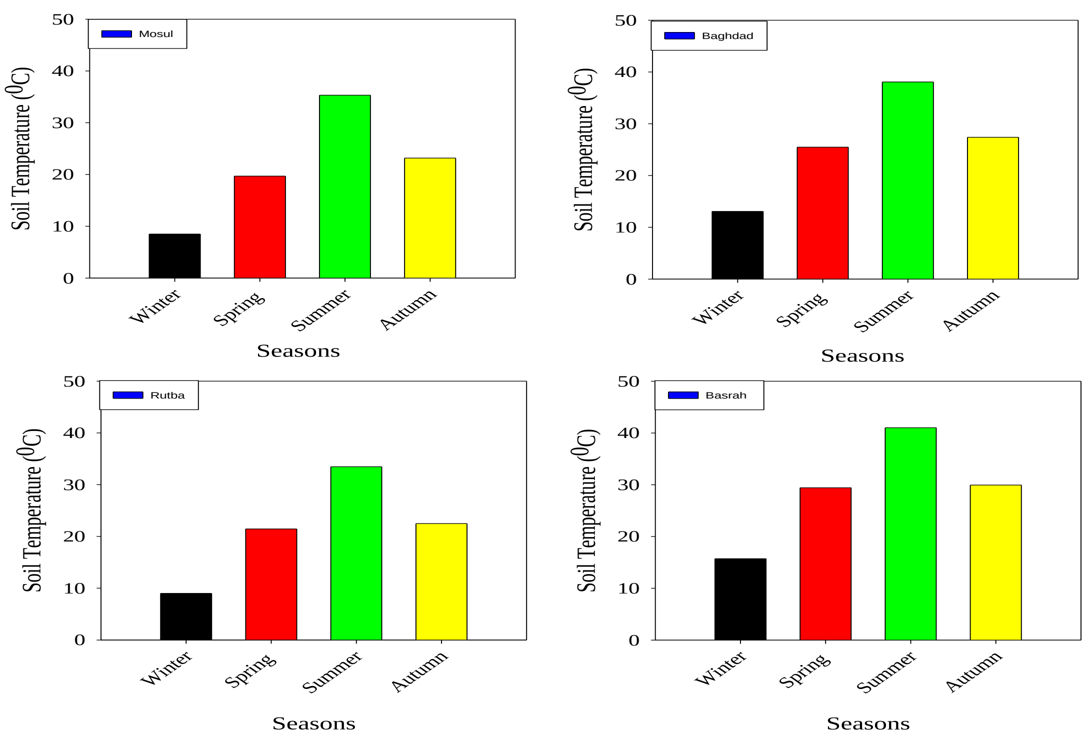


Figure 10 (b). Analysis of the seasonal behavior of soil temperature for the period 1980-2022 over Iraq.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 1s, 2025
https://www.theaspd.com/ijes.php

Analysis of the monthly and seasonal behavior of soil water in Iraq

Figure 11 (a, b) shows the monthly and seasonal averages of soil water data for selected stations over Iraq, such as Mosul, Baghdad, Rutba, and Basra. It was found that there was a noticeable increase in January, February, and December (Winter season) and a decrease in June, July, and August (Summer season). This is due to the frequent rainfall and low temperature during the winter, which makes the soil moisture high and increases in soil water. It was noted that the Mosul station had the highest soil water, while the Basra station had the lowest soil water. This is because the Mosul station is considered a mountainous northern region with a lot of rainfall, while the Basra station is very hot in the south.

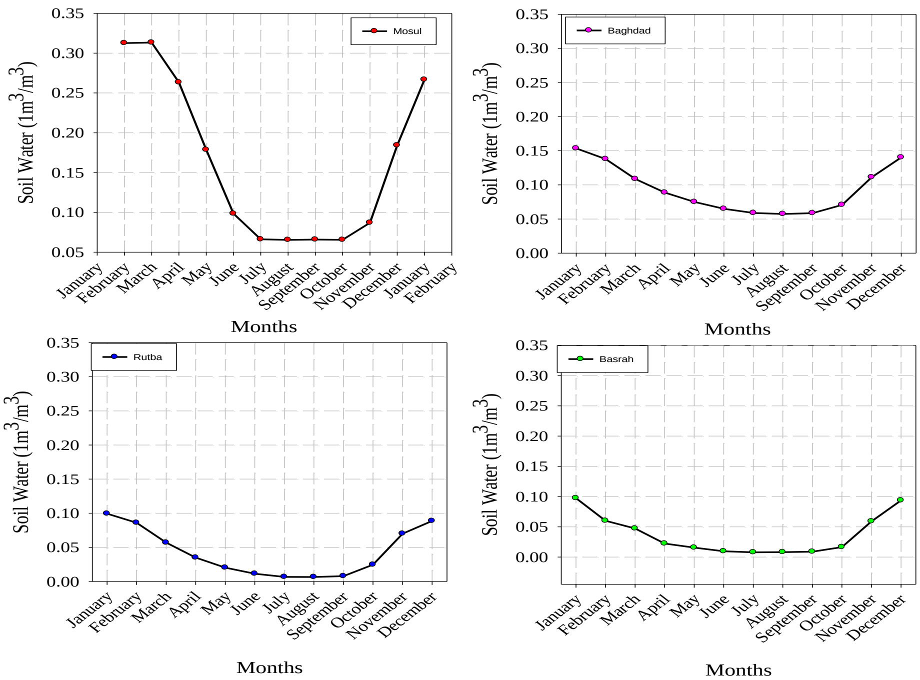


Figure 11 (a). Analysis of the monthly behavior of soil water for the period 1980-2022 over Iraq.

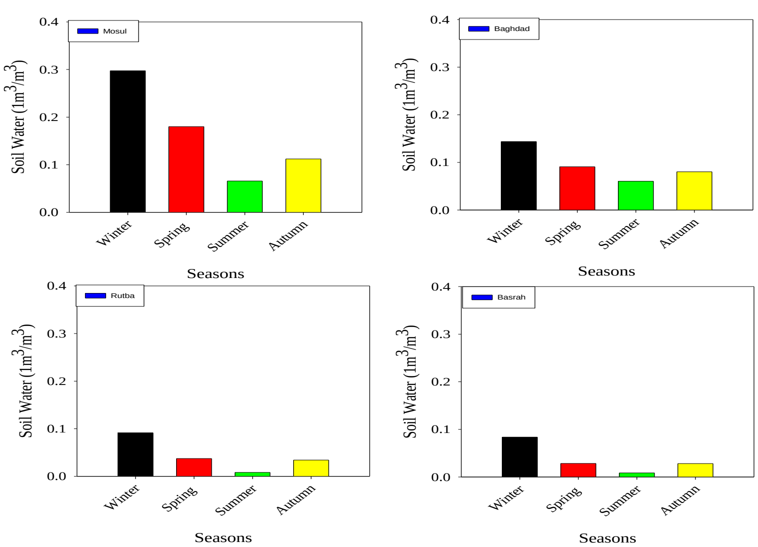


Figure 11 (b). Analysis of the seasonal behavior of soil water for the period 1980-2022 over Iraq.

Analysis of the monthly and seasonal behavior of total precipitation in Iraq

Figure 12 (a, b) shows the monthly and seasonal averages of soil water data for selected stations over Iraq, such as Mosul, Baghdad, Rutba, and Basra. It was found that there was a noticeable increase in January, February, and December (Winter season) and a decrease in June, July, and August (Summer season). This is due to the frequent rainfall and low temperature during the winter, which makes the soil moisture high and increases in soil water. It was noted that the Mosul station had the highest soil water, while the Basra station had the lowest soil water. This is because the Mosul station is considered a mountainous northern region with a lot of rainfall, while the Basra station is very hot in the south.

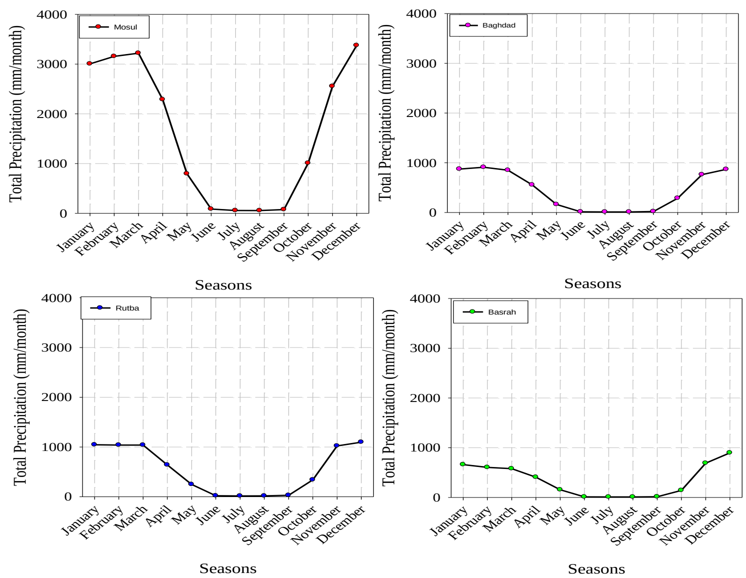


Figure 12 (a). Analysis of the monthly behavior of total precipitation for the period 1980-2022 over Iraq.

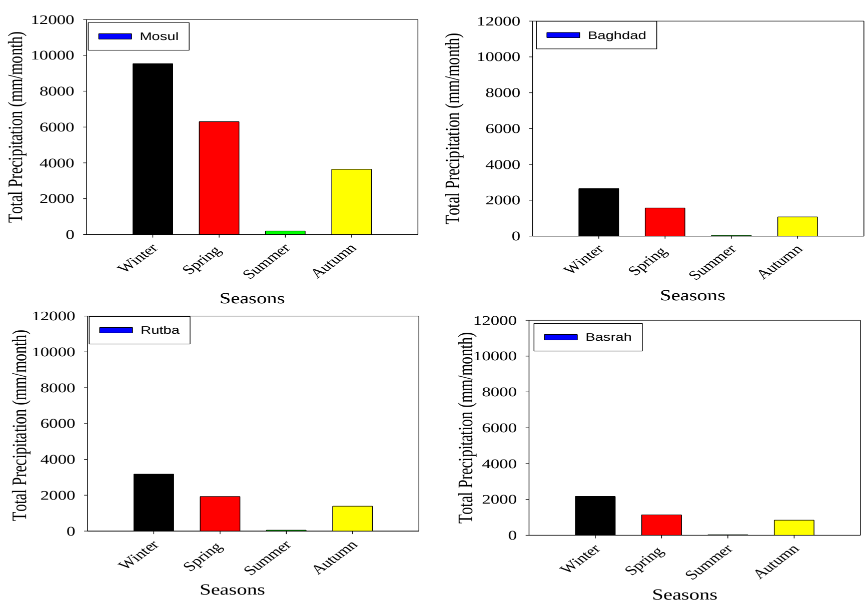


Figure 12 (b). Analysis of the seasonal behavior of total precipitation for the period 1980-2022 over Iraq.

CONCLUSIONS

The annual rate of high vegetation cover data for the period 1980-2022 over Iraq shows that during this period Mosul had the highest value of vegetation cover, while the lowest values for vegetation cover were in Sinjar, Makoor, Qaim, Anah, Haditha, Ramadi, Kerbela, Nukhen, Najaf, Dawaniya, Amara, Samawa, and Kahalis. The annual average soil temperature data for the period 1980-2022 over Iraq. It also shows that during this period, Nasiriyah obtained the highest value for soil temperature, while the lowest value of soil temperature was in Emadiyah. The annual average soil water data for the period 1980-2022 in Iraq. It also shows that during this period, the Basra station obtained the lowest value for soil water, while the highest value of soil water was in Zakho. The annual average of temperature data for the period 1980-2022 in Iraq. It also shows that during this period, the Nasiriyah station obtained the highest temperature, while the lowest temperature value was in Emadiyah. The annual sum of precipitation data for the period 1980-2022 in Iraq. It also shows that during this period, Najaf station obtained the lowest precipitation, while the highest value of precipitation was in Emadiyah. It was found (TP) that there was a noticeable increase in January, February, and December (Winter season) and a decrease in June, July, and August (Summer season). It was noted that the Mosul station had the highest soil water, while the Basra station had the lowest soil water. It was found (SW) that there was a noticeable increase in January, February, and December (Winter season) and a decrease in the months of June, July, and August (Summer season). It was noted that the Mosul station had the highest soil water, while the Basra station had the lowest soil water. It was found (ST) that there was a noticeable increase in June, July, and August (Summer season) and a decrease in the months of January, February, and December (Winter season). It was found (HVC) that there was a noticeable increase in the months of February, March, and April, and a decrease in the months of June, July, and August. In addition, the Mosul station witnessed a high vegetation cover, while the Basra station witnessed a very low vegetation cover. It was found (T) that there was a noticeable increase in the months of June, July, and August and a decrease in the months of January, February, and December. In addition, the Rutba station witnessed low temperatures, while the Basra station witnessed a significant rise in temperatures.

Acknowledgment
An acknowledgment to the European Centre for Medium-Range Weather Forecasts (ECMWF), and an acknowledgment to Mustansiriyah University.

REFERENCE

1. Onwuka, B. and B. Mang, *Effects of soil temperature on some soil properties and plant growth.* Adv. Plants Agric. Res, 2018. 8(1): p. 34-37.
2. Pregitzer, K. and J. King, Effects of soil temperature on nutrient uptake, in Nutrient acquisition by plants: an ecological perspective. 2005, Springer. p. 277-310.4. Noh, Y., et al., Improvement of the K-profile model for the planetary boundary layer based on large eddy simulation data. Boundary-layer meteorology, 2003. 107(2): p. 401-427.
3. Elshorbagy, A. and K. Parasuraman, On the relevance of using artificial neural networks for estimating soil moisture content. Journal of Hydrology, 2008. 362(1-2): p. 1-18.6. Xu, L. and P. Dirmeyer, Snow–atmosphere coupling strength. Part II: Albedo effect versus hydrological effect. Journal of Hydrometeorology, 2013. 14(2): p. 404-418.
4. Musacchio, C., G. Coppa, and A. Merlone, An experimental method for evaluation of the snow albedo effect on near-surface air temperature measurements. Meteorological Applications, 2019. 26(1): p. 161-170.
5. Gardner, C.M., et al., Soil water content. Soil analysis: physical methods, 2000: p. 1-74.
6. Paul, K.I., et al., Soil temperature under forests: a simple model for predicting soil temperature under a range of forest types. Agricultural and Forest Meteorology, 2004. 121(3-4): p. 167-182.

7. Qian, B., et al., Observed soil temperature trends associated with climate change in Canada. Journal of Geophysical Research: Atmospheres, 2011. 116(D2).
8. Bilgili, M., Prediction of soil temperature using regression and artificial neural network models. Meteorology and atmospheric physics, 2010. 110: p. 59-70.
9. Al-Taai, O.T. and Z.M. Abbood, Analysis of convective available potential energy by convective and total precipitation over Iraq. Indian Journal of Ecology, 2020. 47: p. 263-269.
10. Al-Behadili, A.A., Al-Taai, O.T., Al-Muhyi, A.H.A., Analysis of ship accident resulting from bad weather conditions in the port of Khor Al-Zubair, Iraqi crane accident Aba Thar: a case study. Bionatura, 2023, 8(1), 49.
11. Salman, A.D., Al-Taai, O.T., Association Between Precipitable Water Vapor and Evaporation Over Iraq During the Period (1979-2019). IOP Conference Series: Earth and Environmental Science, 2022, 1060(1), 012021.
12. Jawad, T.K., Al-Taai, O.T., Al-Timimi, Y.K., Evaluation of drought in Iraq using DSI by remote sensing. Iraqi Journal of Agricultural Sciences, 2018, 49(6), pp. 1132–1145.
13. Wallentin, C. and U. Nilsson, Storm and snow damage in a Norway spruce thinning experiment in southern Sweden. Forestry, 2014. 87(2): p. 229-238.
14. Halos, S.H., Al-Taai, O.T., Al-Jiboori, M.H.. Impact of dust events on aerosol optical properties over Iraq. Arabian Journal of Geosciences, 2017, 10(12), 263.
15. Abbood, Z.M. and O.T. Al-Taai, Data analysis for cloud cover and rainfall over Baghdad city, Iraq. Plant Archives, 2020. 20(1): p. 822-826.
16. Maan, H., Al-Taai, O.T., Halos, S.H., Calculating the Environmental Drought Index using the de Martonne Equation for the Rainy Months in Iraq. IOP Conference Series: Earth and Environmental Science, 2024, 1371(2), 022001.
17. Maan, H., Al-Taai, O.T., Halos, S.H., Estimate the drought in some Iraqi meteorological stations using the de Martonne Aridity index. AIP Conference Proceedings, 2024, 3229(1), 050014.
18. Yau, M.K. and R. Rogers, A short course in cloud physics. 1979: 2nd edition, Pergamon Press, Oxford.
19. Wallace, J.M. and P.V. Hobbs, Atmospheric science: an introductory survey. Vol. 92. 2006: Elsevier.
20. O. T. Al-Taai and Z. M. Abbood, "Analysis of convective available potential energy by convective and total precipitation over Iraq," Indian Journal of Ecology, 47, 2020; 263-269.
21. Hashim, S.A., Tawfeek, Y.Q., Al-Taai, O.T., Abbood, Z.M., "Spatiotemporal Distribution of the Monthly and Seasonal Mean of High Vegetation Cover, Total Precipitation, and Temperature in Iraq for the Period (1950-2022)," IOP Conference Series: Earth and Environmental Science, 2024, 1371(2), 022008.
22. Z. S. Mahdi, Z. M. Abbood, and O. T. Al-Taai, "Thunderstorm Dynamic Analysis Based on Total Precipitation over Iraq." Journal of Engineering Science and Technology, 16, 2021; 62-70.
23. Z. M. Abbood and O. T. Al-Taai, "Data analysis for cloud cover and rainfall over Baghdad city, Iraq," Plant Archives, 20, 2020; 822-826.
24. W. G. Nassif, O. T. Al-Taai, and I. H. Abdalkareem, "Analysis of the Aerosol Optical Thickness and Winds Over Selected Stations in Iraq," AIP Conference Proceedings, 2021; 2372, p. 030008.
25. Abd, N.M., Abbood, Z.M., Mohammed, N.A., Al-Taai, O.T., Nassif, W.G. Impact of Acid Gases on Total Precipitation Over Iraqi Stations. Nature Environment and Pollution Technology, 2025, 24, pp. 439–448.
26. Hassan, A.S., Kadhum, J.H., Alsalhy, S.N., Al-Taai, O.T., "Nanosensor-based satellite images and GIS filter for urban expansion analysis and its impact on climate change," Experimental and Theoretical Nanotechnology, 2025, 2025(Special Issue), pp. 335–346.
27. Yehia, M.A., Al-Taai, O.T., Ibrahim, M.K., The Chemical Behavior of Greenhouse Gases and its Impact on Climate Change in Iraq," Egyptian Journal of Chemistry, 2022, 65, pp. 1373–1382.
28. W. G. Nassif, O. T. Al-Taai, and Z. M. Abbood, "The Influence of Solar Radiation on Ozone Column Weight Over Baghdad City," IOP Conference Series: Materials Science and Engineering, IOP Publishing, vol. 928, no. 7, p. 072089, 2020.

29. Z. M. Abbood, and O. T. Al-Taai, "Data Analysis for Cloud Cover and Rainfall over Baghdad City, Iraq," Plant Archives, vol. 20, no. 1, pp. 822-826, 2020.
30. Z. M. Abbood, and O. T. Al-Taai, "Calculation of Absorption and Emission of Thermal Radiation by Clouds Cover," ARPN Journal of Engineering and Applied Sciences, vol. 13, no. 24, pp. 9446-9456, 2018.
31. S. A. Hashim, W. G. Nassif, B. I. Wahab, Z. M. Abbood, O. T. Al-Taai, and Z. S. Mahdi, "Impact of COVID-19 on Aerosol Optical Depth and Particulate Matter over Iraq," Journal of Engineering Science and Technology, vol. 17, pp. 12-20, 2022.
32. O. T. Al-Taai, Z. M. Abbood, and J. H. Kadhum, "Determination Stability Potential Energy of Thunderstorms for Some Severe Weather Forecasting Cases in Baghdad City," Journal of Green Engineering, vol. 11, no. 1, pp. 779-794, 2021.
33. S. A. Hashim, J. H. Kadhum, Z. M. Abbood, O. T. Al-Taai, and W. G. Nassif, "Determination of the Dynamics of Thunderstorms Through the Dry Adiabatic Lapse Rate and Environmental Lapse Rate," Nature Environment and Pollution Technology, vol. 22, no. 3, pp. 1447-1455, 2023.
34. W. G. Nassif, F. H. Lagenean, and O. T. Al-Taai, "Impact of Vegetation Cover on Climate Change in Different Regions of Iraq," Caspian Journal of Environmental Sciences, vol. 21, no. 2, pp. 333-342, 2023.
35. R. S. Al-Awadi, O. T. Al-Taai, and S. A. Abdullah, "Assessment of Outer Space Events on Troposphere and Climate Change over Iraq," Iraqi Journal of Science, vol. 64, no. 8, pp. 4278-4289, 2023.
36. G. A. Redah, M. H. Al-Jiboori, and O. T. Al-Taai, "Turbulent Diffusion Effect on PM2.5 Concentration Above an Urban Canopy," IOP Conference Series: Earth and Environmental Science, IOP Publishing, vol. 1223, no. 1, p. 012005, 2023.
37. Z. M. Abbood, M. H. Al-Jiboori, and O. T. Al-Taai, "Temporal and Spatial Analysis of Particulate Matter Concentrations in Iraq," IOP Conference Series: Earth and Environmental Science, IOP Publishing, vol. 1215, no. 1, p. 012018, 2023.
38. O. T. Al-Taai, S. A. Hashim, W. G. Nassif, and Z. M. Abbood, "Interference between Total Solar Radiation and Cloud Cover over Baghdad City," Journal of Physics: Conference Series, vol. 2114, no. 1, p. 012070, 2021.
39. A. Al-Behadili, A. H. A. Al-Muhyi, and O. T. Al-Taai, "Analyzing the Oil Pollution Resulting from the Iraqi Oil Ports in the Northern Arabian Gulf Using the GNOME Model," AIP Conference Proceedings, AIP Publishing, vol. 2830, no. 1, p. 050004, 2023.
40. G. A. Redah, M. H. Al-Jiboori, and O. T. Al-Taai, "A Study of Turbulent Fluctuation of Three-Component Wind and Air Temperature in the Surface Layer of Baghdad Urban," IOP Conference Series: Earth and Environmental Science, IOP Publishing, vol. 1223, no. 1, p. 012005, 2023.
41. Z. M. Abbood, O. T. Al-Taai, and W. G. Nassif, "Impact of Wind Speed and Direction on Low Cloud Cover over Baghdad City," Current Applied Science and Technology, vol. 21, no. 3, pp. 590-600, 2021.
42. O. T. Al-Taai, "Preface," IOP Conference Series: Earth and Environmental Science, vol. 1223, no. 1, p. 011001, 2023.
43. W. G. Nassif, I. K. Al-Ataby, O. T. Al-Taai, and Z. M. Abbood, Impact of Soil Temperature and Precipitation on Vegetation Cover Over Selected Stations in Iraq, Asian Journal of Water, Environment and Pollution, 2024, 21(1), pp. 25–33.
44. W. G. Nassif, A. A. Hashim, S. A. Muter, and O. T. Al-Taai, Relationship Between Winds with Surface Roughness and Carbon Dioxide Concentrations Over Iraq, Asian Journal of Water, Environment and Pollution, 2024, 21(1), pp. 89–96.
45. R. M. Ibrahim, Z. M. Abbood, O. T. Al-Taai, and M. M. Ahmed, The Influence of Ozone Depletion Potential Weighted Anthropogenic Emissions of Nitrous Oxide, Asian Journal of Water, Environment and Pollution, 2024, 21(2), pp. 65–73.
46. W. G. Nassif, F. H. S. Lagenean, and O. T. Al-Taai, Impact of vegetation cover on climate change for different regions in Iraq, Journal of Agrometeorology, 2022, 24(2), pp. 138–145.
47. W. G. Nassif, F. H. Jasim, and O. T. Al-Taai, Analysis of air temperature, relative humidity and evaporation over Iraq using ECMWF reanalysis, Indian Journal of Ecology, 2021, 48(2), pp. 446–452.

48. S. J. Al-Jaf, and O. T. Al-Taai, Impact of carbon dioxide concentrations on atmospheric temperature changes over Iraq and some neighboring countries, Plant Archives, 2019, 19, pp. 1450–1456.
49. Z. M. Abbood, and O. T. Al-Taai, Data analysis for cloud cover and rainfall over Baghdad City, Iraq, Plant Archives, 2020, 20(1), pp. 822–826.
50. Z. M. Abbood, O. T. Al-Taai, and W. G. Nassif, Impact of wind speed and direction on low cloud cover over Baghdad city, Current Applied Science and Technology, 2021, 21(3), pp. 590–600.
51. Yehia, M.A., Al-Taai, O.T., Ibrahim, M.K. Spatiotemporal Distribution of Minimum-Maximum Temperature over Iraq for the Period (1980-2017). IOP Conference Series: Earth and Environmental Science, 2022, 1060(1), 012026.
52. Yehia, M.A., Al-Taai, O.T., Ibrahim, M.K. Spatiotemporal Distribution of Mean Temperature and Total Precipitation over Iraq for a Period (1980-2017). IOP Conference Series: Earth and Environmental Science, 2023, 1158(3), 032004.
53. Ibrahim, R.M., Zahraa S., M., Nassif, W.G., Al-Taai, O.T. Relationship Between Short and Long Wave Radiation with Cloud Cover in Baghdad City. Asian Journal of Water, Environment and Pollution, 2024, 21(5), pp. 65–71.
54. Al Rukabie, J.S.A., Abbood, Z.M., Mahmood, D.A., Al-Taai, O.T. Relationship Between Greenhouse Gases Emissions with Some Meteorological Variables Over Baghdad City. Asian Journal of Water, Environment and Pollution, 2024, 21(5), pp. 27–36.
55. Abdalfatah, F.S., Abbood, Z.M., Muttalib, A.M.A., Al-Taai, O.T., Al-Jiboori, M.H. Evaluation of the impact of global warming on mean sea level in Basrah city, Iraq. AIP Conference Proceedings, 2024, 3249(1), 030005.
56. Al-Behadili, A.A., Al-Taai, O.T., Al-Muhyi, A.H.A. Analysis of ship accident resulting from bad weather conditions in the port of Khor Al-Zubair, Iraqi crane accident Aba Thar: a case study. Bionatura, 2023, 8(1), 49.
57. Al-Taai, O.T. Preface. IOP Conference Series: Earth and Environmental Science, 2023, 1223(1), 011001.
58. Al-Awadi, R.S., Al-Taai, O.T., Abdullah, S.A. Assessment of X-Ray Effects on HF Radio Communications. IOP Conference Series: Earth and Environmental Science, 2023, 1223(1), 012003.
59. Nassif, W.G., Lagenean, F.H.S., Al-Taai, O.T. Impact of vegetation cover on climate change for different regions in Iraq. Journal of Agrometeorology, 2022, 24(2), pp. 138–145.
60. Redah, G.A., Al-Jiboori, M.H., Al-Taai, O.T. Turbulent Diffusion Effect on PM2.5 Concentration above an Urban Canopy. IOP Conference Series: Earth and Environmental Science, 2023, 1223(1), 012005.
61. Al-Amery, H.A., Al-Taai, O.T. Effect of Nitrogen Oxides on Shortwave Solar Radiation in Atmosphere for Selected Iraqi Stations. IOP Conference Series: Earth and Environmental Science, 2021, 722(1), 012024.
62. Nassif, W.G., Al-Taai, O.T., Mohammed, A.J., Al-Shamarti, H.K.A. Estimate Probability Distribution of Monthly Maximum Daily Rainfall of Iraq. Journal of Physics: Conference Series, 2021, 1804(1), 012078.
63. Al-Kaissi, S.M., Al-Taai, O.T. Prediction of Global Solar Irradiation by Using Fuzzy Logic. 1st Babylon International Conference on Information Technology and Science 2021, BICITS 2021, 2021, pp. 92–97.
64. Al-Amery, H.A., Al-Taai, O.T. The ozone effect on shortwave solar radiation in the atmosphere over Iraq. AIP Conference Proceedings, 2020, 2290, 0027825.
65. Al-Jaf, S.J., Al-Taai, O.T. Impact of Ozone gas on Air Temperature Change in Iraq and Some Surrounding Countries. Journal of Physics: Conference Series, 2020, 1660(1), 012074.
66. Salman, A.D., Al-Taai, O.T. Association between pwv, water vapor and their influence on climate change over iraq using gis. Journal of Green Engineering, 2020, 10(11), pp. 10388–10402.
67. Mahdi, Z.S., Hashim, S.A., Al-Taai, O.T. Assessment of daily and monthly behavior of some meteorological factors and atmospheric gases in four iraqi stations. Journal of Green Engineering, 2020, 10(11), pp. 11289–11305.

68. Muter, S.A., Nassif, W.G., Al-Ramahy, Z.A., Al-Taai, O.T. Analysis of seasonal and annual relative humidity using GIS for selected stations over Iraq during the period (1980-2017). Journal of Green Engineering, 2020, 10(10), pp. 9121–9135.
69. Al-Taai, O.T., Nassif, W.G. Impact Rainfall on the Aerosols Optical Thickness over Selected Stations in Iraq. IOP Conference Series: Materials Science and Engineering, 2020, 928(7), 072053.