Exp. Theo. NANOTECHNOLOGY 10 (2026) 185-196 https://doi.org/10.56053/10.S.185

Nano impact of rainfall on soil temperature and soil moisture in Iraq for the period 2000-2022

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Received 17/11/2025, *Received in revised form* 15/12/2025, *Accepted* 28/12/2025, *Published* 15/2/2026

The high rainfall increases the water content in the upper and lower layers of the soil, while low rainfall decreases the water content and reduces the water potential. Data from the European Centre for Medium-Range Weather Forecasts (ECMWF) are used to measure soil temperature (ST), soil moisture (SM), and total precipitation (TP). Stations in Iraq are selected for the period 2000-2022 at latitudes (29.55°-37.225°) north of the equator and longitudes (38.455°-48.548°) east. The behavior of monthly, seasonal, and annual averages of ST, SM, and TP, as well as annual average TP data over Iraq from 2000 to 2022, are calculated. It is found that Emadiya station had the highest value and Najaf station had the low value of TP during the study period. The highest SM value is at Zakho station during the study period, while Basra station had the lowest SM. It appears that Nasiriyah had the highest ST value and Emadiya station had the lowest ST value during this period. This is due to various climatic factors.

Keywords: Nanotechnology; Soil temperature; Soil moisture; Total precipitation.

1. INTRODUCTION

The Soil temperature affects the physical, chemical, and microbial Mechanics that take place there. The use of cover crops, crop rotation, grazing crop residues or cover crops, crop residue clearance, and tillage are among the cropping methods that have an impact on soil temperature [1]. Most underground ecosystem functions, including root growth, respiration, decomposition, and nitrogen mining, depend on soil temperature [2]. However, most weather stations do not capture soil temperature as a standard variable [3]. An 11-day running average air temperature, adjusted by daily precipitation and overstory LAI, is used to predict soil temperatures at 10 cm depth since soil temperature is dependent on the net effect of the daily surface energy balance and can be estimated by computing a running average of air temperature, with increasingly longer integration times as soil depth increases [4]. Estimated soil temperatures are in close agreement with observed values when tested on locations throughout the United States (r2 = 0.86–0.95) [5]. Although it exhibits significant spatiotemporal fluctuation, soil temperature is essential for physical, hydrological, and biogeochemical processes. The rates and directions of physical processes in the soil as well as the exchange of mass and energy with the atmosphere are largely determined by the temperature of the soil, which fluctuates across time and space [6]. The types and rates of chemical reactions that occur in the soil, as well as evaporation and aeration, are all influenced by temperature [7]. Lastly, biological processes like root development, microbial activity, germination seed, and seedling emergence and growth are all significantly impacted by soil temperature. Changes in the radiative, thermal, and latent energy exchange processes-which mostly occur through the soil surface-affect the temperature of the soil [8]. Time-variable and space-variable soil parameters influence the rates of a complex series of transport mechanisms that spread the effects of these phenomena into the soil profile [9]. The temperature of the soil varies greatly throughout the day and throughout the seasons [10]. The type of soil (light or heavy, with or without leaf litter) and the current climate both affect how much the changes occur. Furthermore, there are typically quite significant temperature differences with depth. Once more, these will rely on the soil type [11]. The amount of water in the soil, the conditions under which water evaporates from the soil, the texture and structure of the soil, and the amount of plant cover all affect soil temperature [12]. The soil's top layers typically exhibit significant variations, and as depth increases, the year-round conditions become increasingly consistent [13]. Temperature has an impact on soil microbial activity and dispersal. The combination of incident solar radiation and a number of other variables determines the temperature of the soil [14].

Reflectance, or the quantity of incident solar energy reflected by the soil-plant system, is one example [15]. which depends on the soil color and vegetation type [16]. Another is the soil moisture [17]. The amount that a unit net of radiation warms a unit of soil depends on the soil's specific heat capacity and moisture content. Furthermore, soil temperature is influenced by seasonal elements, such as vegetation type and edaphic parameters like soil type or depth [18]. Temperature is a powerful selective factor and a major driver of some physiological and physicochemical responses [19]. Within the usual mesophilic microbial communities, the metabolic activity doubles roughly every 10°C between 0°C and 30°C to 35°C [20]. Microbial physiology is directly impacted by soil temperature, while alterations in water activity, substrate transport, and nutrient changes are indirectly influenced [21].

1.1 Climate change impacts

There is a strong correlation between soil and air temperature, and rising air temperatures lead to higher soil temperatures [22]. Most soil activities are highly dependent on soil temperature, much like soil moisture [23]. Globally, warmer soil temperatures will speed up soil processes, resulting in faster organic matter breakdown, higher microbial activity, faster nutrient release, higher nitrification rates, and generally faster chemical weathering of minerals [24]. Although they are not entirely consistent, the soil temperature and greenhouse ambient temperature are connected. Furthermore, crops are significantly impacted by the temperature of the soil [25]. Crop development, trace elements, and enzymes will all be significantly impacted by soil temperature [26]. An excessively hot soil inhibits the growth of cool-season grasses. Crop productivity and physiological performance will both be enhanced by the right temperature [27]. demonstrated that under strip tillage, rising soil temperatures encouraged an increase in the plant emergence rate index (ERI) [28]. As the soil temperature rose, tomato resistance to Fusarium Wilt dramatically declined [29]. In greenhouses, a water bath pipe is frequently used to regulate the soil temperature [30]. It's expensive. To precisely manage temperature and cut costs, it is therefore essential to establish a water bath, send out information at extremely high or low temperatures, and keep an eye on the soil's temperature [31]. An IoT-based plant water stress warning system. to alert users when soil water levels are low. Solar radiation is the primary energy source used to raise ST [32,33]. Changes in soil temperature are influenced by the color of the soil surface, the number of plants, and the land's slope with respect to the sun. A soil's thermal capacity is the amount of heat it can absorb, while its thermal conductance regulates how much heat it can transport through the soil. The way the soil's temperature changes with depth is moderated by these two characteristics. Soil temperature fluctuation is most pronounced at the soil surface and diminishes with depth Figure 1. Due mainly to the soil's thermal conductivity, it is also evident that the change in soil temperature over a 24-hour period exhibits a lag with depth [6].

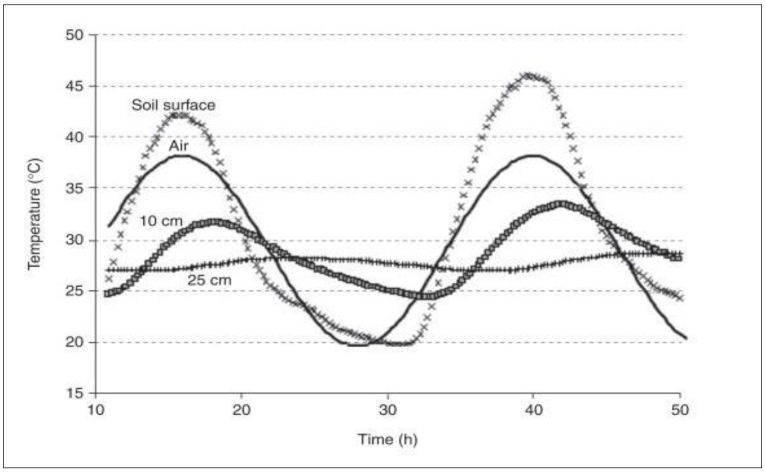

Figure 1 Soil temperature [6].

The total amount of water in unsaturated soil, including water vapor, is known as soil moisture (SM). SM, commonly referred to as soil water, is the water on land surfaces that is found in soil pores rather than in rivers, lakes, or groundwater. Numerous factors, including soil type and associated plants, affect SM content in addition to weather. SM levels therefore affect a range of soil and plant dynamics. Surface SM is the water found in the top 10 cm of soil, whereas root zone SM is the water that plants can reach and is generally believed to be in the top 200 cm of soil. The effects of SM can vary greatly depending on the kind of soil, depth, location, and season. The same absolute SM measurement, for instance, can signify average soil in the Southwest but a severe drought in the Southeast. It is necessary to evaluate and preserve a variety of different metadata, especially soil properties, in order to interpret soil moisture data. In addition, it implies that many units of measurement such as volumetric water (the amount of water present) as well as anomalies, daily ranking percentages, etc. may be required to fully characterize the situation. With the introduction of new proximal and in situ sensors, satellite and other distant sensing technologies, and improved modeling capabilities, SM monitoring methods are expanding and evolving quickly. As a result, more and more SM data products are being developed. SM is the quantity of water in the soil. It can be expressed in terms of volume or weight. SM can be measured using remote sensing methods or in situ probes (like neutron or capacitance probes). Water that enters a field is released through runoff, drainage, evaporation, or transpiration. Runoff is the water that flows from the field's surface to its edge; drainage is the water that flows through the soil underground or downward toward the field's edge; evaporative water loss is the part of the field's water that evaporates directly into the atmosphere; and evaporation from the plant itself is the water that leaves the field through transpiration. The primary focus is on plant development, even if water affects soil formation, structure, stability, and erosion [6]. Additionally, water changes the soil profile through a process known as leaching, which dissolves and re-deposits organic and mineral solutes and colloids, frequently at lower depths. Only half of the volume of loam soil—which varies greatly depending on matric potential—will be accessible to most plants. Solids make up half of the volume, gas 25%, and water 25%. Gravity, osmosis, and capillarity all affect how water travels through soil. Slaking occurs when water enters the soil and uses buoyancy to push air out of interconnecting macropores and break up air-entrapped aggregates. The soil and other factors determine how quickly a soil can absorb water. The largest pores (macropores) are the first to lose water when a plant grows. Only the intermediate- and smallest-sized pores (micropores) contain the residual water, as the bigger pores soon contain only air [3]. Plant roots are unable to remove the water from the smallest pores because it is so firmly attached to the particle surfaces. As a result, not all soil water is accessible to plants, and texture plays a significant role. As the water drains from the soil, nutrients may be lost. In a draining field, where the soil is locally saturated, water flows under the influence of pressure and is drawn to drier areas of the soil by capillarity. The suction generated by evaporation from plant leaves (transpiration) provides the majority of the water required by plants, while a smaller portion is provided by suction resulting from osmotic pressure differentials between the soil solution and the interior of the plant. Plant roots must actively seek for water and preferentially grow in moist soil microsites, even though certain root system components can remoisten dry soil regions. Insufficient water will reduce crop productivity. Transpiration consumes most of the available water to deliver nutrients to the plant. Soil water is also essential for climate modeling and numerical weather forecasting. The Global Climate Observing System identified soil water as one of the 50 Essential Climate Variables (ECVs Since every approach has advantages and disadvantages, combining many approaches may lessen a method's shortcomings [6].

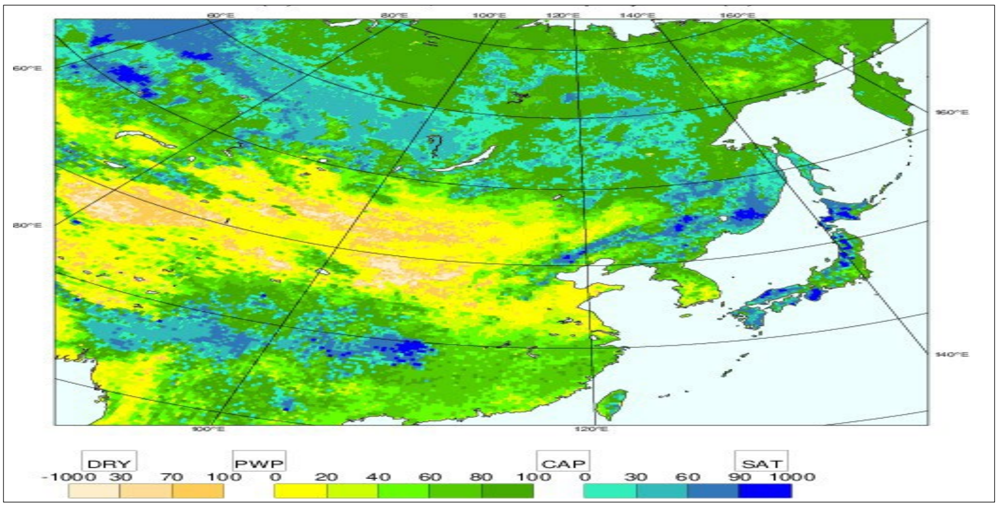

Figure 2 This is based on the legend showing categories like DRY, PWP (Permanent Wilting Point), CAP (Field Capacity), and SAT (Saturation), along with the color scale indicating soil moisture conditions [7].

SM is the quantity of water in the soil's active layer, which is typically the top 1-2 meters. It is extremely important because it is the main supply of water for agriculture and natural vegetation. By regulating the distribution of available energy at the surface into sensible and latent heat exchange with the atmosphere, near-surface soil moisture also connects the water and energy balances through the soil's temperature and moisture conditions [7]. The water that penetrates and evaporates from the soil and vegetation into the atmosphere is known as SM, and it has an impact on the distribution of precipitation and clouds. Because a wetter surface will be cooler and more of the available energy will be directed toward evapotranspiration (evaporation and transpiration) rather than surface heating, soil moisture regulates surface temperature. Runoff is also influenced by SM, which determines how much snowmelt or precipitation enters rivers and streams right away or, in severe situations, causes flooding. Drought is frequently linked to a lack of soil moisture, and interactions between soil moisture and the atmosphere may play a significant role in sustaining droughts. The most crucial element of the meteorological memory for the land-based climate system is soil moisture, combined with snow cover. Soil moisture status is therefore a significant indicator of monthly to seasonal climate fluctuations [34]. There are several methods for measuring SM, ranging from the straightforward gravimetric method to more sophisticated electronic devices. In the midlatitudes of the Northern Hemisphere, the temporal scale of soil moisture variation for the top 1 m of soil layers is 1.5 to 2 months, while the spatial scale is roughly 500 km. When forced with either model-generated or observed meteorology, parameterization approaches used in weather predictions and climate simulation models generally fail to capture the observed fluctuations in soil moisture, despite the importance of SM. Summer drying in the midlatitudes may pose a major threat to human society in the twenty-first century. However, observations over the last few decades indicate that while surface temperatures have climbed, summer soil moisture in the top 1 m has increased for the stations with the oldest records. The increased evaporation has so far been more than offset by the increasing trend in precipitation. The quantity of water in the soil's top layer that interacts with the atmosphere is known as SM. This active layer's depth varies depending on the plant and soil type, although it is usually within the first 1 m. There are various units used to express SM [35].

1.2 Nontechnique

Nanotechnology can greatly enhance photovoltaic cells by boosting their efficiency, lowering production expenses, and improving their lifespan. Solar cells at the nanoscale exhibit greater light absorption capabilities compared to traditional ones. Additionally, nanostructure-induced graded layers enable light to be absorbed instead of being repeatedly reflected. Despite the fact that current nanoscale solar cells are less efficient than traditional types, they may offer reduced thermal production costs [7].

2. MATERIALS AND METHODS

2.1 Data source and study Station

Soil temperature (ST), total precipitation (TP), and soil moisture (SM) data from the ECMWF are used in the work [21]. To explain seasonal influences, this data is transformed into month average. SigmaPlot is used to draw the data after it had been analyzed by MATLAB. Additionally, Iraq is mapped using the Surfer 13 program to gather information on soil moisture, rainfall, and temperature. The selection of Iraq Stations over 2000–2022 It stretches between two longitudes (38.455 - 48.548) east of the Corniche line and between two latitudes (29.55 - 37.225) north of the equator [20].

3. RESULTS AND DISCUSSION

3.1 Analysis of behavior of annual rate of total precipitation over Iraq

The yearly average precipitation data over Iraq from 2000 to 2022 is displayed in Figure 3. Additionally, it demonstrates that Emadiyah had the highest precipitation value within this time frame, whereas Al-Najf had the lowest. As a result of its geographic location, which is marked by numerous atmospheric depressions, low air temperatures, and high humidity, the Emadiyah station is regarded as a northern station. These elements contribute to more rainfall throughout the year, which promotes the growth of tall and short plants.

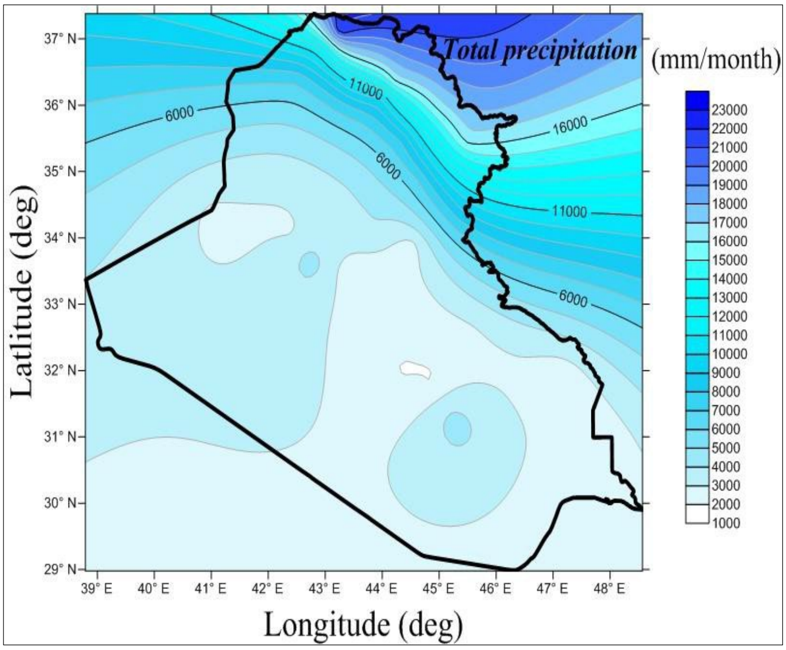

Figure 3 Annual average of total precipitation for the period 2000-2022 over Iraq.

3.2 Examination of patterns of yearly soil moisture rate over Iraq

The yearly average soil moisture data over Iraq from 2000 to 2022 is displayed in Figure 4. Because Zakho station is regarded as a northern station and Basrah station as a southern station—the northern stations are distinguished by cold weather, low temperatures, and high humidity, in contrast to the southern stations—it also demonstrates that during this time, the highest amount of rain that reached the earth's surface occurred at Zakho station, while the lowest amount occurred at Basrah station. The majority of water enters the soil through precipitation. The size of the pore spaces that exist between the soil particles is dictated by the soil's particle size distribution. The most significant force acting on the water in large pore spaces is gravity, which causes the water to flow through the soil vertically and downward. Until water hits a barrier, which could be a zone where the soil is already saturated or a band of impermeable rock or soil, it will continue to drain downward and possibly into whatever substrate is underneath the soil. Water that hits such a barrier will either find a lateral pathway and move horizontally through the soil, or it may amass to produce or prolong a saturated zone because it cannot drain vertically. If the rain keeps coming, the saturated zone can rise to the point where it touches the surface, creating puddles. In addition to being influenced by the weather, the infiltration capacity of soil is determined by its characteristics. Long periods of hot, dry weather can cause some soils to build a crust, which can restrict infiltration, while other soils may break, allowing water to swiftly reach the subsurface and avoid typical infiltration pathways. Extreme cold can cause soils to freeze, which significantly reduces or completely stops infiltration.

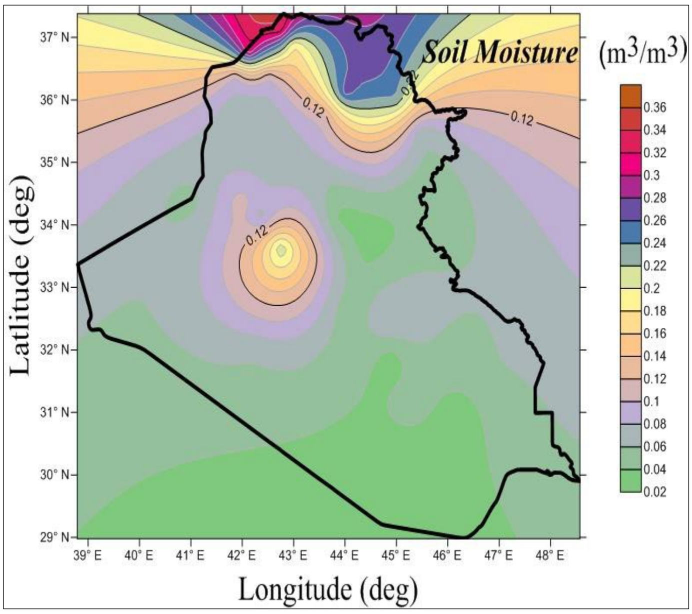

Figure 4 Annual average of soil moisture for period 2000-2022 over Iraq.

3.3 Examination of how yearly rate of soil temperature changes over Iraq

Figure 5 shows the annual average soil temperature data from 2000 to 2022 over Iraq. It also shows that during this period, Nasiriyah obtained the highest value for ST and the lowest value for ST Emadiyah. This is because the Emadiyah station is considered a northern station; due to its geographical location, it is characterized by abundant rainfall, low air temperature, and high humidity. These factors cause a decrease in the soil temperature, which causes desertification and a lack of plant growth.

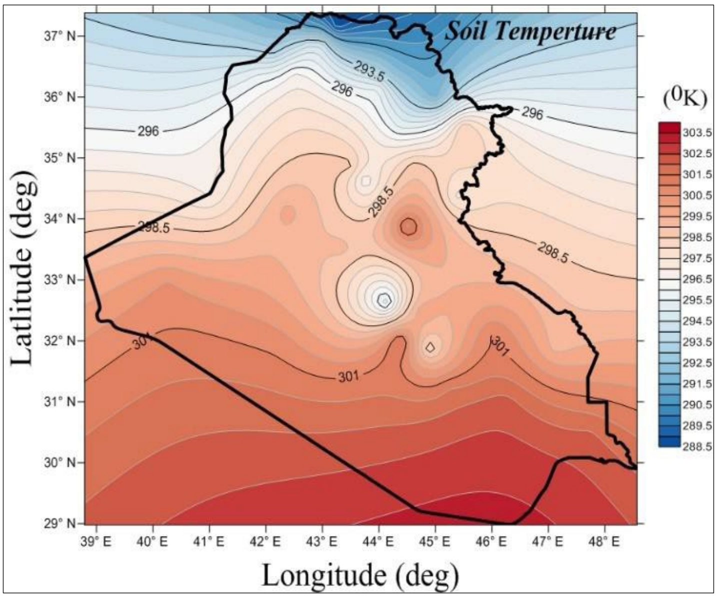

Figure 5 Annual average of soil temperature for the period 2000-2022 over Iraq.

3.4 Examination of Iraqi stations' seasonal averages for type precipitation

Figure 6 shows the highest total seasonal mean of Tp over Iraq for 23-year period, from 2000 to 2022. The largest amount of Tp occurred on Emadiyah station through 2000-2022, and a lesser amount of TP occurred on Dawaniya and Basrah station. where the spring and winter seasons are characterized by very high amounts of rain and very small amounts during the summer and fall in general, the northern regions, such as Emadiyah, are characterized by their high terrain. This helps in the formation of different types of clouds, including convective rains and terrain, while the Dawaniya and Basrah station, which crosses the regions of the south, is characterized by very high temperatures and little rainfall.

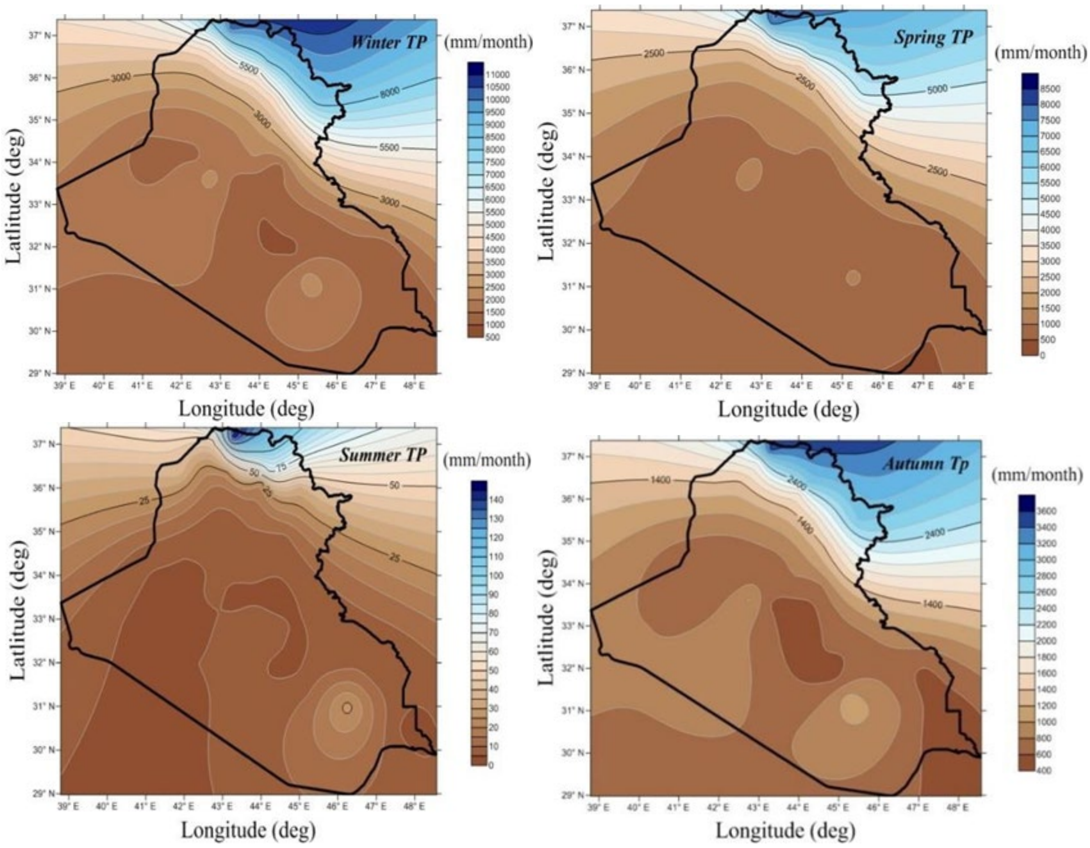

Figure 6 Analysis of the seasonal mean of TP Iraq for 23 years.

3.5 Examination of Iraqi stations' seasonal mean soil moisture

Figure 7 shows the highest total seasonal mean of SM over Iraq for 23 years, from 2000 to 2022. The largest amount of SM occurred on Zakho station from 2000-2022, and a lesser amount of SM occurred on the Basrah station. where the spring and winter season are characterized by very high amounts of rain and very small amounts during the summer and Autumn in general, Where the abundance of rain makes the soil moisture high and suitable for growing plants, especially in the northern regions such as Zakho, and on the contrary, in the southern stations such as Basrah, the very high temperature causes little rainfall and little soil moisture, as most of the Southern regions suffer from desertification. As shown in the Figure.

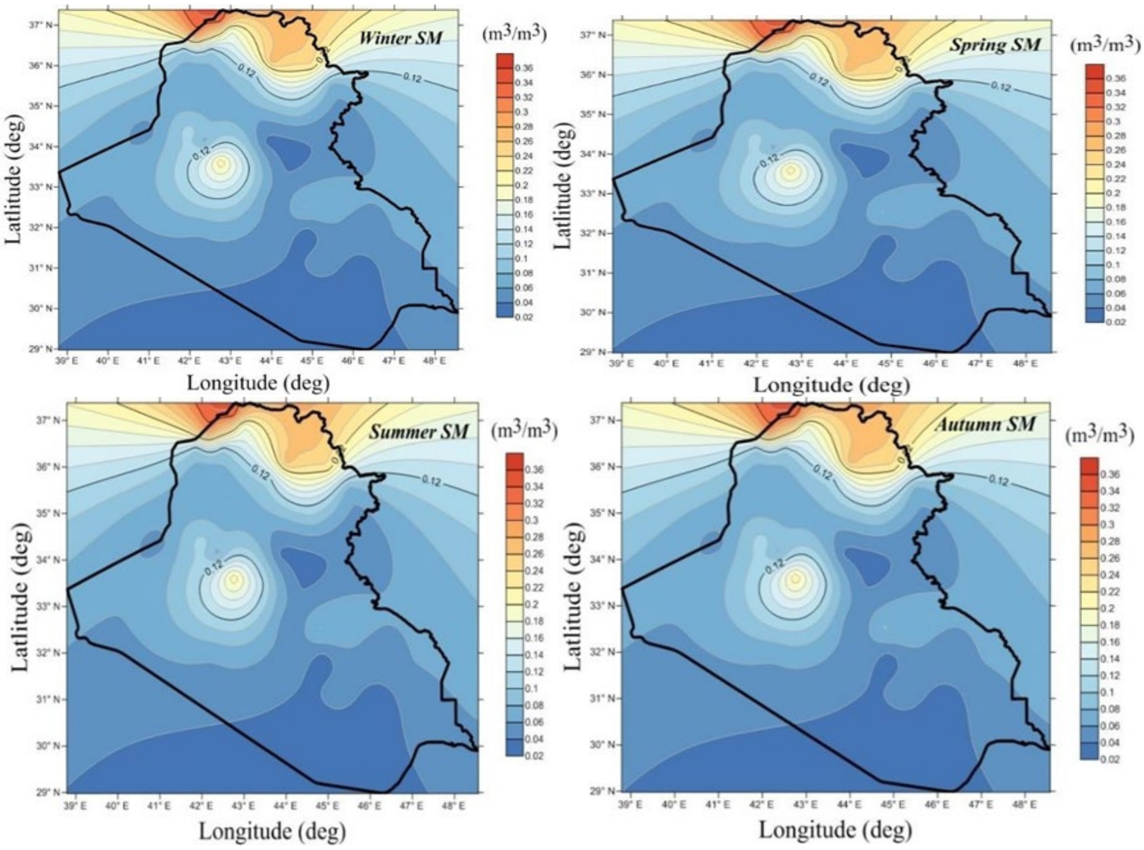

Figure 7 Analysis of seasonal mean of SM Iraq for 23 years.

3.6 Examination of Iraqi stations' seasonal average soil temperature

Figure 8 shows the highest total seasonal mean of ST over Iraq for 23 years, from 2000 to 2022. The largest amount of ST occurred on Nasiriya station from 2000-2022, and a lesser amount of ST occurred on Emadiyah station. The southern regions, such as Nasiriyah, are characterized by extreme heat. This is due to the high air temperature, which causes the soil temperature to rise, and the lack of rain. This causes an abundance of barren lands, unlike in the northern regions, such as Emadiyah.

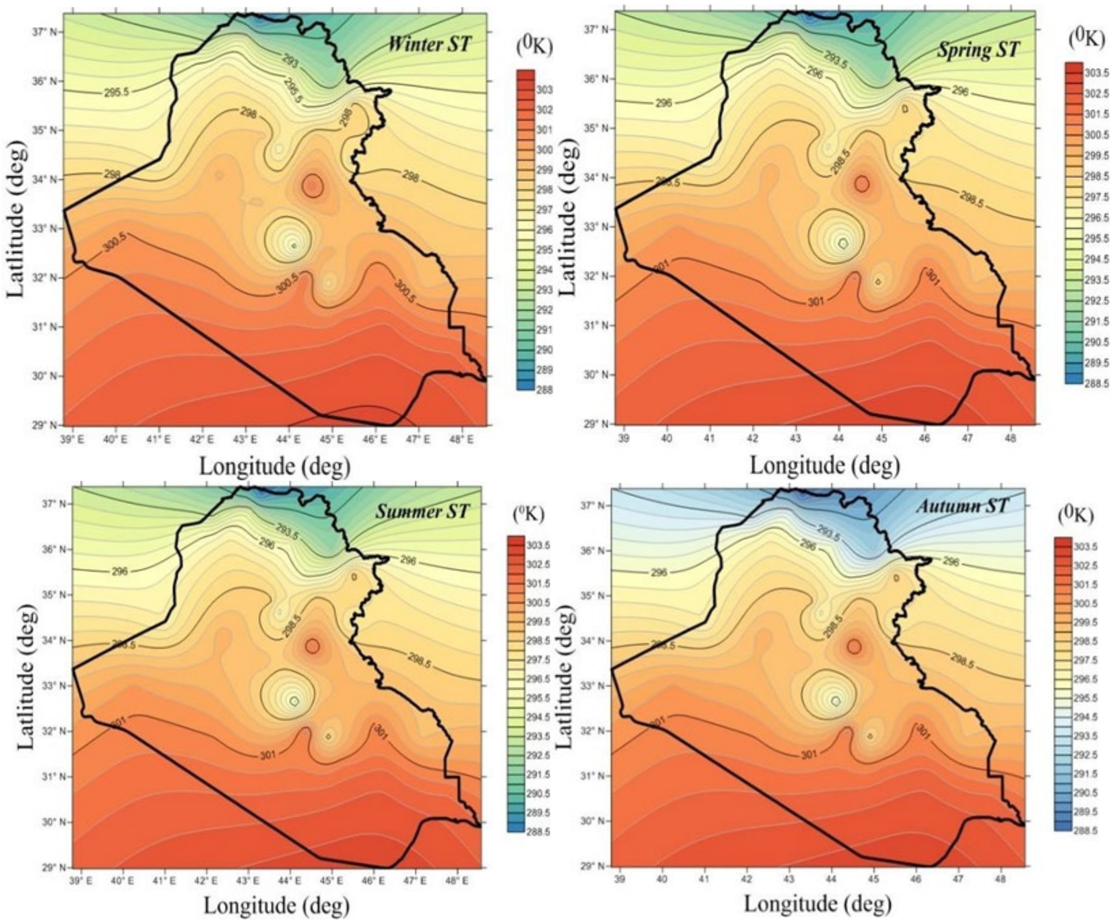

Figure 8 Analysis of the seasonal mean of ST Iraq for 23 years.

4. CONCLUSIONS

Emadiyah station obtained the highest value for precipitation and the lowest value in Al-Najf. It also shows that during this period, the highest amount of rain reaching the surface of the earth was at Zakho station, and the lowest amount was at Basrah station. It also shows that during this period, Nasiriyah obtained the highest value for soil temperature and the lowest value for ST Emadiyah. This shows the highest total seasonal mean of Tp over Iraq for 23 years, from 2000 to 2022. The largest amount of Tp occurred on Emadiyah station from 2000-2022, and a lesser amount of TP occurred on Dawaniya and Basrah stations. This shows the highest total seasonal mean of SM over Iraq for 23 years, from 2000 to 2022. The largest amount of SM occurred on Zakho station from 2000-2022, and a lesser amount of SM occurred on the Basrah station. The shows the highest total seasonal mean of ST over Iraq for 23 years, from 2000 to 2022. The largest amount of ST occurred on Nasiriya station from 2000-2022, and a lesser amount of ST and SM is high due to the increase in rainfall occurred on Emadiyah station. All these reasons are due to atmospheric factors such as temperature, humidity, solar radiation, wind, rain, and astronomical factors such as the nature of the surface, the angle of inclination of the sun's rays, latitude, etc.

Acknowledgment

We would like to thank Al-Mustansiriyah University and the European Centre for Medium-Range Weather Forecasts (ECMWF) for their contribution to the completion of this research paper.

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