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ORIGINAL STUDY

Decadal Climate and Landform Variables Analysis in Iraq Using Remote Sensing Datasets

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ABSTRACT

Iraq has experienced record-breaking temperatures, making it one of the hottest places on Earth. It is also ranked among the world's top five most climate-vulnerable nations. Climate change is a hazard to Iraq's people and may cause societal disintegration, instability, and displacement. Therefore, it is important to assess Iraq's decadal climate and landform variables analysis. In the present study, the Climate Hazards Center InfraRed Precipitation with Station (CHIRPS) data in the Google Earth Engine (GEE) platform from 2000 to 2022, as well as rainfall, anomaly, temperature, vegetation, and water, are used to analyse climate change in Iraq. As the land surface temperature (LST) rose by 2.63 °C, the data show that rainfall dropped by 61.45 mm in just 22 years of observation and by 2.79 mm yearly. Additionally, some urban expansion and climatic change have reduced the areas of water bodies and vegetation. The correlation matrix shows a higher negative association between the vegetation and LST indices, with R^2 values of −0.58 (2022), −0.56 (2006), −0.60 (2012), −0.55 (2016), and −0.59 (2000), respectively. Iraq, extremely sensitive to climate change, is implementing several adaptation measures, including early warning systems, reforestation and mangrove planting, water management, a national adaptation plan (NAP), and a reforestation program. Due to vulnerabilities in vital areas including water, agriculture, health, and natural resources, Iraq is prioritizing adaptation to climate change.

Keywords: CHIRPS data, Climate change, Precipitation, Temperature, Iraq

1. Introduction

Intergovernmental Panels on Climate Change (IPCC) scenarios, both regional and global, depend on the results produced by General Circulation Models (GCMs). To forecast how global warming would affect both natural and human systems, they are regarded as crucial instruments [1]. Depending on their physical foundation and experimental connections, GCMs are mathematical representations of the weather, seas, and surface processes. That being said, their poor (course) resolution limits their capacity to preserve the spatial information of climatic variables needed at a local or regional level. One of the Middle Eastern nations most impacted by climate change and global warming is said to be Iraq [2].

The impacts of climate change on Iraq have been analysed in several studies, highlighting critical vulnerabilities in water resources, agriculture, and social stability. Researcher emphasizes that declining flows in the Tigris and Euphrates rivers, compounded by rising temperatures, are causing severe water shortages and salinity issues, directly threatening Iraq's agricultural productivity [3]. Similarly, reports by

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the United Nations Environment Programme (UNEP) identify Iraq as one of the world's most climate-vulnerable nations, with increasing temperatures and desertification exacerbating food insecurity and displacement risks.

Studies on the impacts of climate change on Iraq's rainfall and temperature reveal significant shifts in climatic patterns, threatening its ecosystems and livelihoods. Researcher highlights a marked temperature increase over recent decades, with projections indicating continued warming, particularly in southern Iraq [3]. These rising temperatures exacerbate evaporation rates, further stressing already scarce water resources. A study shows that rainfall patterns have become increasingly erratic, with reduced precipitation in key agricultural areas contributing to prolonged droughts [4]. The UNEP also underscores that these changes in rainfall and temperature have led to declining river flows, intensifying water shortages, and desertification [5]. Collectively, this body of research illustrates the urgency for Iraq to adopt robust climate adaptation measures, particularly in managing water resources and mitigating agricultural risks.

Sandstorms and desertification are rising, and extreme climatic events are occurring more frequently and with greater intensity. It is clearer how temperature, water demand, and rainfall are affected by regional climate change. Thus, it is now crucial to investigate the spatial-temporal aspects of local and regional climate change and how it affects adaptation. Iraq ranks 33rd out of 220 nations in terms of global emissions rankings, accounting for about 0.63% of global greenhouse gas (GHG) emissions [6]. According to the ND-Gain Index, Iraq is the least susceptible nation in terms of climate sensitivity, coming in at number 101 out of 182 [7]. Iraq has seen a decline in groundwater, particularly in arid regions, and the retreat of its major rivers and dam reservoirs resulting in the country's recent general rainfall fluctuations. There have been a lot of studies done to determine groundwater recharge in various parts of Iraq [8].

Due to the dry and semi-arid conditions of the Middle East, which would experience a lack of water if temperatures increase significantly and precipitation decreases, the region is thought to be among those most affected by global climate change [9]. Iraq is thought to be among the most climate change-vulnerable countries in the region [10]. As a result, it will have to deal with environmental problems such as a shortage of readily available water, population growth, and the resulting demand for water as well as rising temperatures. This will also be made worse by a rise in extreme weather occurrences that harm the country's ecosystem. Recent studies by several scholars have addressed this particular combination of conditions in Iraq and other neighbouring Middle Eastern countries, including Turkey, Saudi Arabia, Iran, and Syria [11, 12]. Several arid regions will see a 10–30% reduction in runoff resulting in the anticipated drop in rainfall and increased evaporation rates. It is predicted that global warming will persist throughout this century across all representative concentration pathways (RCPs) as a result of rising greenhouse gas emissions (GHG) brought on by human activity, the burning of fossil fuels, and changes in land use [13]. Unfortunately, the country's semi-arid environment puts it at considerable risk from the effects of climate change [14]. Iraq ranks sixth globally in terms of vulnerability to the effects of climate change, according to the United Nations Environment Program [15]. However, the future trends of climate change and their implications for Iraq's PV generation capacity have received very little attention until this point. The purpose of this study is to evaluate how local climate patterns are affected by climate change and the threats that these patterns pose to Iraq's future PV potential. The findings may help discern the potential hazards of PV module deterioration and failure, directing the creation of appropriate material choices and more potent technological fixes.

Increases in greenhouse gas emissions caused variations in average precipitation and evaporation, which had a substantial effect on Iraq's water balance. Issues with water distribution and ownership will undoubtedly worsen as a result of climate change [16]. One of the countries which is the most vulnerable to the physical and economic impacts of climate change can be described (or defined, explained) as Iraq [17]. Iraq ranks sixth globally in terms of vulnerability to the consequences of climate change, according to the UNEP [18]. Drought, desertification, heat waves, increasing temperatures, and sea level rise are some of the recent effects of climate change observed in Iraq. Forecasting the future of Earth's climate is the most popular use of climate models. The US Geological Survey and the University of California, Santa Barbara's Climate Hazards Group (CHG) collaborate to create CHIRPS v2.0 [19]. Indexes that are crucial for early warning of climate fluctuation, such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI), might accurately capture the total impact of temperature and rainfall variance. Spatial information on the amount of water and vegetation on the ground is provided by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite series pictures. To determine the climatic fluctuation from 2000 to 2022, the current study used land surface

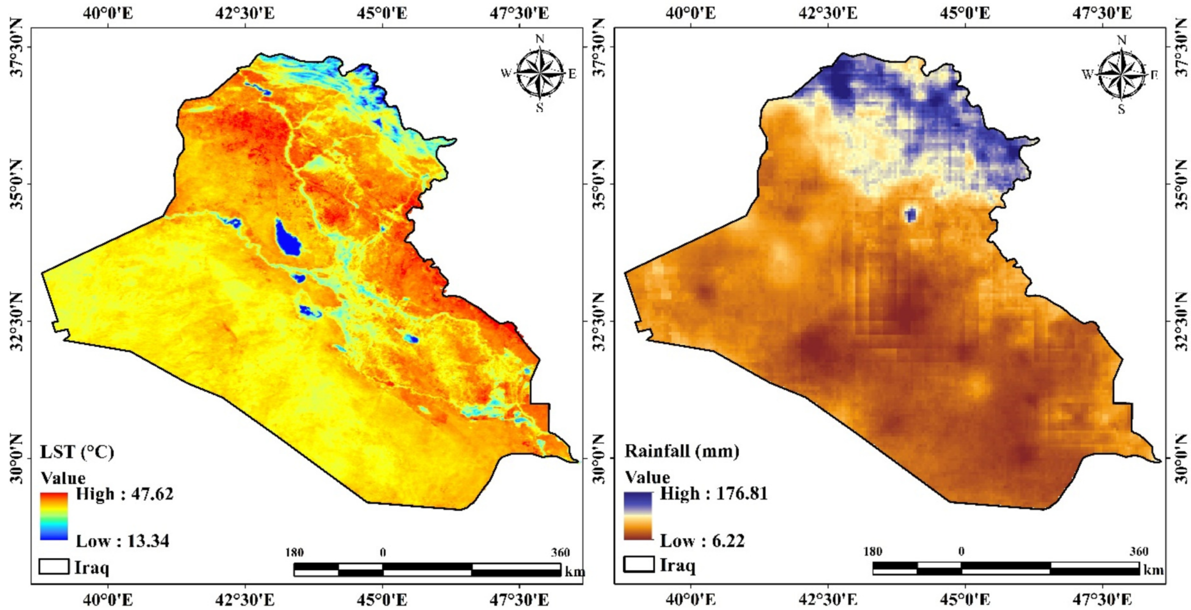

Fig. 1. Study location of Iraq with LST and rainfall in the year 2022.

temperature (LST), rainfall, anomaly, evapotranspiration (ET), and geospatial indicators. For future planning, management, and the creation of innovative adaption techniques, planners, climate scientists, legislators, and other stakeholders can benefit from this study.

2. Study area

The Middle Eastern nation of Iraq contains both semi-arid and desert regions. The southern portion of Iraq has seen the highest temperatures in recent years, making it one of the world's hottest locations. The coldest month is January as usual. August is the warmest month with temperatures of at least 45 °C, with the lowest temperatures between 5 °C and 10 °C. The rainy season, which lasts until May, begins in October. Particularly in the studied region, the agricultural sector is one of the most vital resources that the nation depends on (Fig. 1). The satellite data used in this study was reliant on a trustworthy alternative source, which was the Prediction of Worldwide Energy Resource (NASA-POWER) dataset. In general, Iraq may be divided into four climatic zones. About 21% of the land area is in Region I, which has a climate typical of the Mediterranean region with mountains in the north and northeast. Region II: The south and west portions of the submerged zone, which make up around 9.6% of the entire land area, have the steppe's climate. Nearly 30.2% of the total land is in Region III, which has a subtropical climate in the central and southern Mesopotamian Plain areas. Finally, the area is area IV: The continental desert climate is found in the western parts of the area, which make up around 39.2% of the entire region [20]. Extreme temperatures and a broad daily and yearly thermal range define Iraq's climate since no bodies of water to soften the winter's cold and the summer's heat (http://moen.gov.iq/). Iraq has arid conditions in the majority of its central and southern regions, with annual rainfall of less than 400 mm, and semi-arid conditions in its northern regions [21]. Consequently, Iraq is situated inside the decertified regions [22].

3. Materials and methods

3.1. Data used

To analyse climate indicators, the GEE platform was used to calculate the annual mean rainfall and rainfall anomaly using the CHIRPS Pentad dataset (UCSB-CHG/CHIRPS/PENTAD). This study used the MODIS datasets, namely the MODIS/061/MOD11A2 dataset, using the Google Earth Engine (GEE) platform to assess the geographical and temporal patterns of temperature variance (Fig. 2).

3.2. Rainfall and anomaly

The hydrological cycle depends heavily on rainfall, which also has a wide range of cultural effects on people, including agricultural activities [23], vegetation phenology [24], hydropower generation [25],

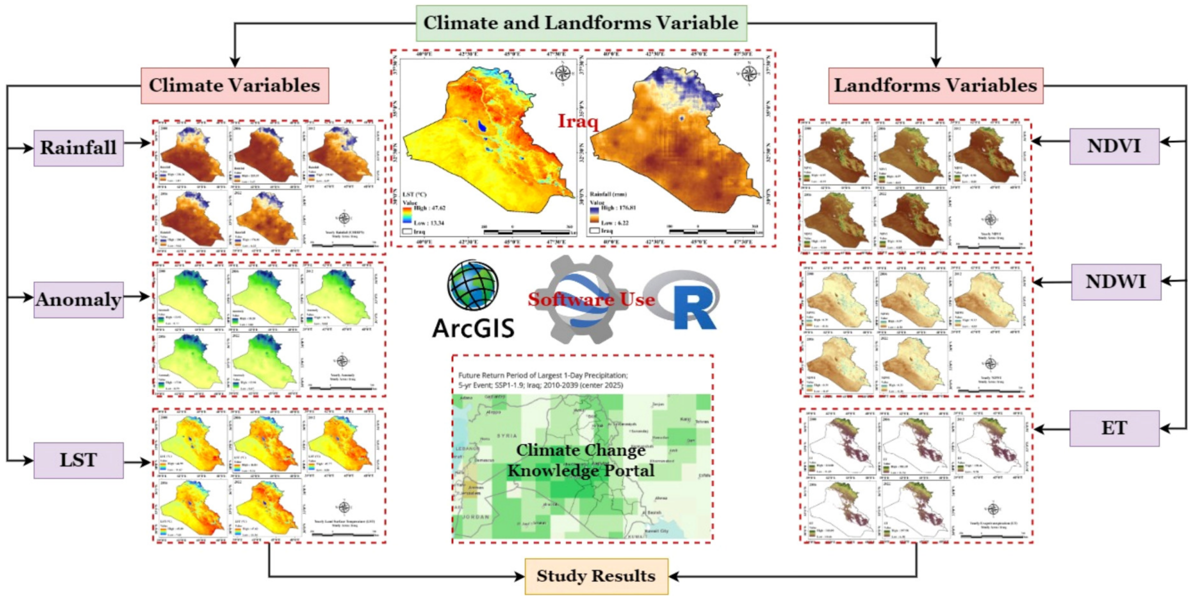

Fig. 2. Adopted methodology of the climate variation analysis in Iraq from 2000 to 2022.

and the biodiversity's continued existence. It is well acknowledged that the seasonal and yearly patterns of rainfall, along with its spatial distribution, have been impacted by recent climate change. One month before each image was taken from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) collection, a survey was conducted to confirm the impact of precipitation on the study locations [26]. Within the 50 °S and 50 °N zones, all longitudes are included in the CHIRPS products. In CHIRPS, satellite imagery and indoor climatology are combined with a daily precipitation record spanning over 35 years, from 1981 to the present, with a spatial resolution of 0.05 × 0.05 ° (5.55 × 5.55 km). The NEB has properly validated the data from CHIRPS [27]. The CHIRPS gridded daily rainfall output is noteworthy since it combines satellite and observed rainfall and has a long record span free of systematic bias.

3.3. LST calculation

Calculations based on satellite imagery and remote sensing data are examples of analytical steps. To compute and handle data, we utilized the cloud computing platform GEE. LST was determined using MODIS images. Environmental parameter (soil, biological, and atmospheric) data is available in the GEE raster library at many time scales (https://developers.google.com/earth-engine/datasets/catalog/). Each dataset's monthly and annual mean values were calculated for analysis and display. Calculations for LST were performed.

$$T_s = \frac{BT}{\left\{1 + \left[\frac{\lambda BT}{\rho}\right] \cdot \ln \varepsilon\right\}} - 273.15 \tag{1}$$

Here, BT represents At-sensor brightness temperature, $\lambda =$ The wavelength of emitted radiance, $\rho = 1.438 \times 10^{-2}$mK, ε represents Land surface emissivity [28]. The monthly LST statistics were created by averaging 8-D pictures throughout a given month. The "SummaryQA" and "QC_day" flags of MOD13Q1 and MOD11A2 pixel reliability bands were utilized to exclude or determine the weight of cloud-affected pixels before data reconstruction. No additional geometric or radiometric adjustments were made; the MOD13Q1 and MOD11A2 data layers were used precisely as provided [29].

3.4. Geospatial indices

The planet's surface vegetation is its most significant characteristic as it regulates temperature fluctuations, surface runoff, infiltration rates, drought control, and water levels throughout the land surface [30]. Urbanization is increasing evapotranspiration, causing temperature fluctuations, and causing droughts in many areas by causing vegetation to disappear [31]. This study calculates the NDVI [32] and NDWI [33] for vegetation and water value fluctuation.

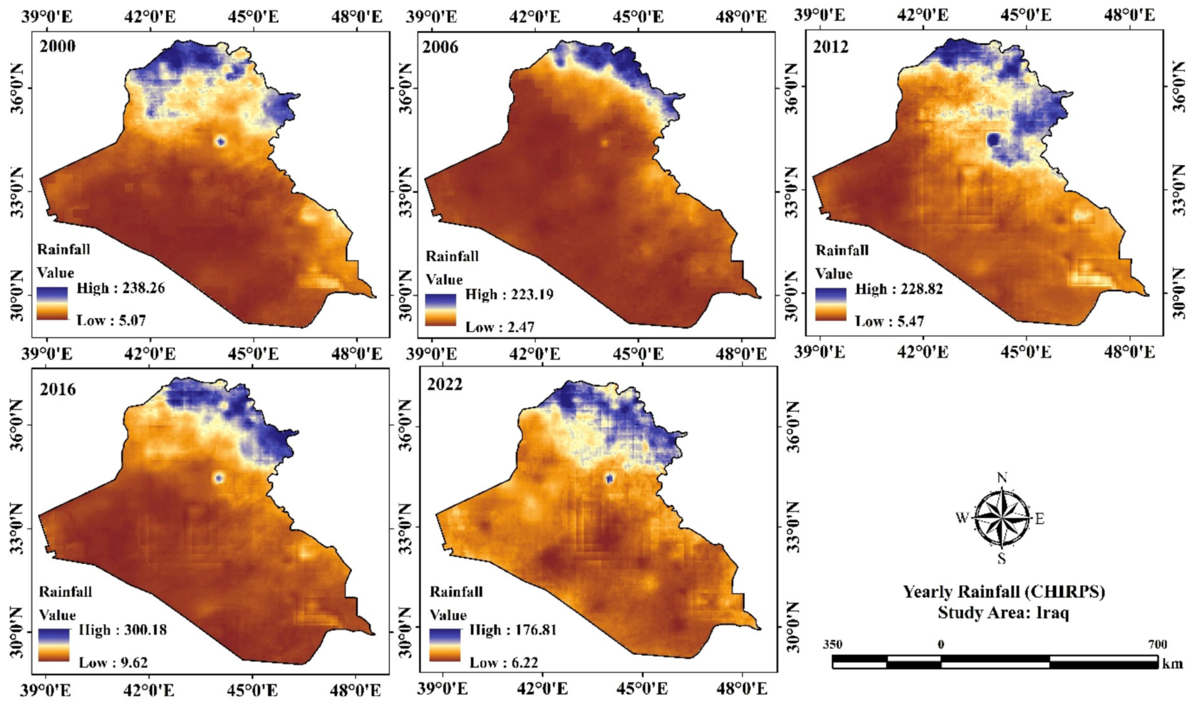

Fig. 3. Yearly mean Rainfall variation in Iraq from 2000 to 2022 with CHIRPS data.

3.5. Evapotranspiration

Researchers may upload a shape file and execute a script to use MODIS and Google Earth Engine to compute evapotranspiration (ET). A time series of the monthly mean daily ET for six internationally accessible ET products will be generated by the script. A 500-meter pixel resolution composite output that takes 8 days to complete. It uses the Penman-Monteith equation with inputs from MOD16A2.061, including dynamics of plant properties, albedo, and land cover. Together, evaporation and plant transpiration from the Earth's surface to the atmosphere make up evapotranspiration. The impacts of land use, ecological disturbances, and climate change may all be measured with the use of long-term ET data.

4. Modeling result and discussion

4.1. Rainfall and anomaly

The rainfall variation in Iraq is calculated through CHIRPS data and the GEE platform where five years like 2000, 2006, 2012, 2016, and 2022 are taken. The result indicates that year-wise high rainfall is 238.26 mm (2000), 223.19 mm (2006), 228.82 mm (2012), 300.18 mm (2016), and 176.81 mm (2022), respectively (Fig. 3). In the year 2016, received high rainfall and an average of 61.45 mm of rainfall decreased throughout the study years and annually decreased by 2.79 mm. Similarly. Rainfall anomaly recorded 13.93 (2000), 18.20 (2006), 14.76 (2012), 17.96 (2016), and 12.94 (2022), respectively (Fig. 4). Variability in Iraq's rainfall patterns may have a big influence on the nation's general stability, water supply, and agricultural production. Iraq suffers from persistent water scarcity as a result of poor rainfall and significant unpredictability. This issue is made worse by excessive usage, poor water resource management, and reliance on river flows (the Tigris and Euphrates) that come from nearby nations like Syria and Turkey [4]. Agricultural production has significantly decreased, desertification has developed, and rural populations have been displaced resulting in frequent droughts. In addition to affecting food security, drought may lead to unstable economies. Weather patterns are becoming more intense due to climate change, which is increasing the frequency of heavy rainfall events and extending droughts. Water management and agricultural planning are made more difficult by this uncertainty. An important source of income for many people in northern Iraq is rain-fed agriculture, which is impacted by rainfall fluctuations [34]. Unpredictable rainfall can impact the nation's food supply by causing crop failures and output reductions. Iraq has been investigated the diverse ways to improve water storage capabilities, update antiquated infrastructure, and implemented

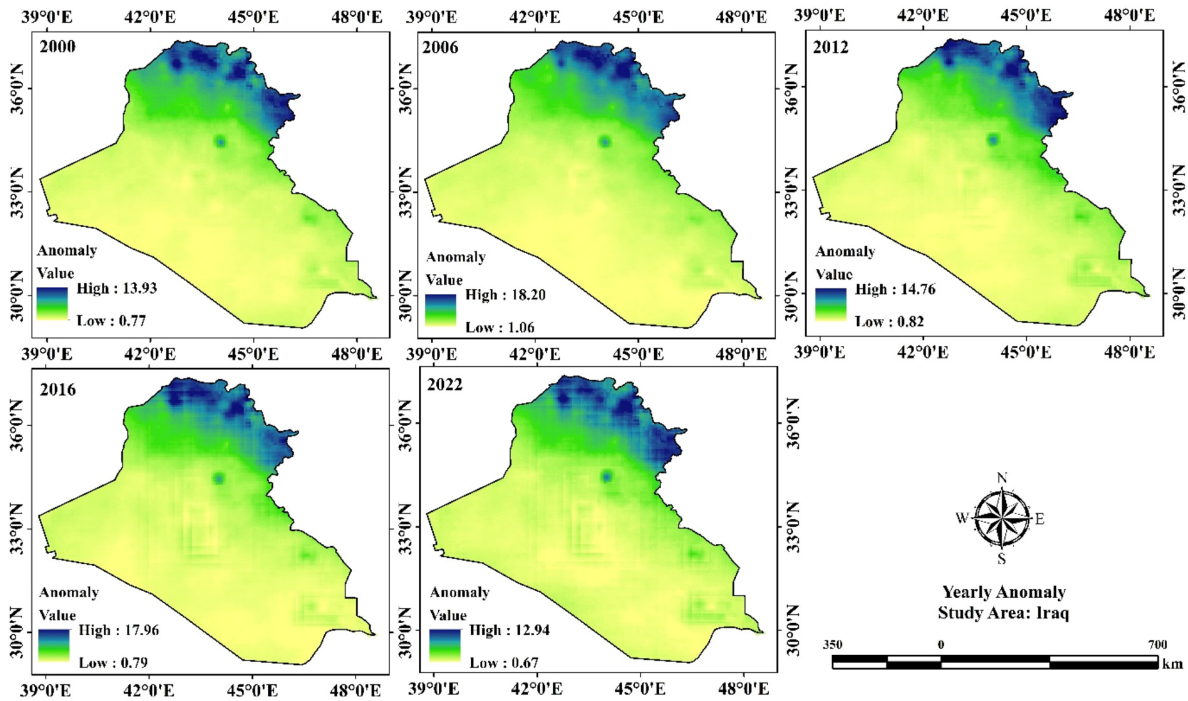

Fig. 4. Yearly mean Anomaly variation in Iraq from 2000 to 2022 with CHIRPS data.

more effective irrigation methods. There's a growing focus on sustainable water management. Iraq constructed dams and reservoirs to control its limited water supplies. However, these solutions are frequently constrained by financial, political, and technological issues. The rain in Iraq has influenced on Iraq's water availability, agricultural productivity, and general socioeconomic stability significantly. Resolving the issues related to rainfall unpredictability would need improved water management techniques, infrastructure spending, global collaboration, and climate change adaptation [35].

4.2. LST analysis

The surface temperature increased in the south, and western parts of Iraq and increased by 2.63 °C throughout the study periods and 0.12 °C annually. The highest LST of the study years observed like 44.99 °C (2000), 46.04 °C (2006), 45.77 °C (2012), 45.89 °C (2012), and 47.62 °C (2022), respectively (Fig. 5). An essential metric for assessing climate, land use, and environmental conditions in Iraq is the land surface temperature (LST). Depending on the kind of soil, vegetation cover, urbanization, and season, the temperature of the land's surface, which is measured by LST, can vary greatly. LST is associated with several environmental, social, and economic problems in Iraq and has unique features [36]. High LST causes heat stress, which is harmful to the health of susceptible groups, including children, the elderly, and outdoor labourers. Climate change is making heat waves more often and powerful, which raises the risk of heat-related diseases. Increased LST has an impact on crop growth, evaporation rates, and soil moisture content. High temperatures can lower agricultural production, especially for heat-sensitive crops like barley and wheat. Restoring vegetation and planting trees can reduce LST by increasing evapotranspiration and shade. These initiatives can also help fight desertification. Cities may lessen the Urban Heat Island (UHI) effect by including green roofs, urban parks, and green corridors. Reflective materials, shade, and more vegetation can all help reduce excessive LST [37]. Drip irrigation and rainwater collection are two examples of water-saving methods that may be used to reduce surface temperatures and preserve soil moisture, especially in agricultural areas. Reducing the need for conventional cooling techniques and lowering total energy usage in response to warming temperatures can be achieved by investing in renewable energy sources like solar and wind. An important problem in Iraq is the rising LST, which affects urban life, agriculture, water resources, and health [38]. To offset the consequences of high LST and ensure sustainable development, a mix of adaptive methods such as forestry, water management, urban design, and renewable energy production are needed to address these concerns.

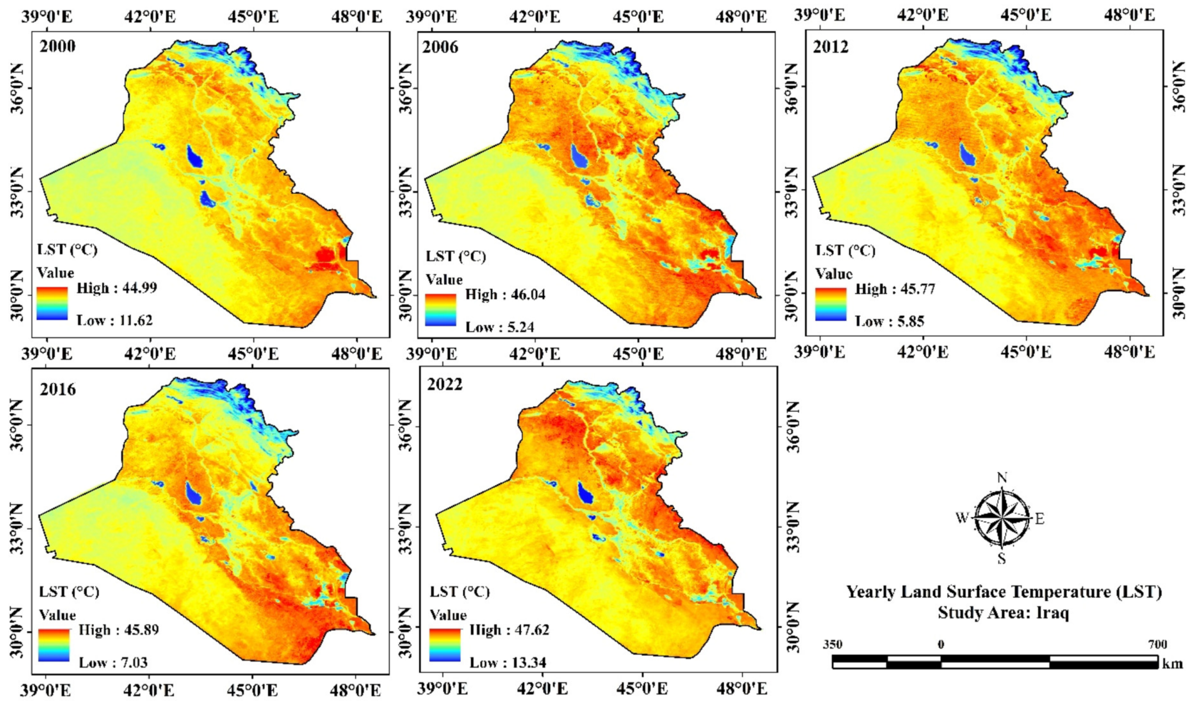

Fig. 5. Yearly mean LST variation in Iraq from 2000 to 2022 with MODIS data.

4.3. Geospatial indices analysis

The NDVI values fluctuate because of rainfall infrastructural development and urbanisation. Observed NDVI highest values are 0.95 (2000), 0.97 (2006), 0.98 (2012), 0.95 (2016), and 0.94 (2022), respectively (Fig. 6). The vegetation is only observed in the middle and northern parts of Iraq and mainly in the

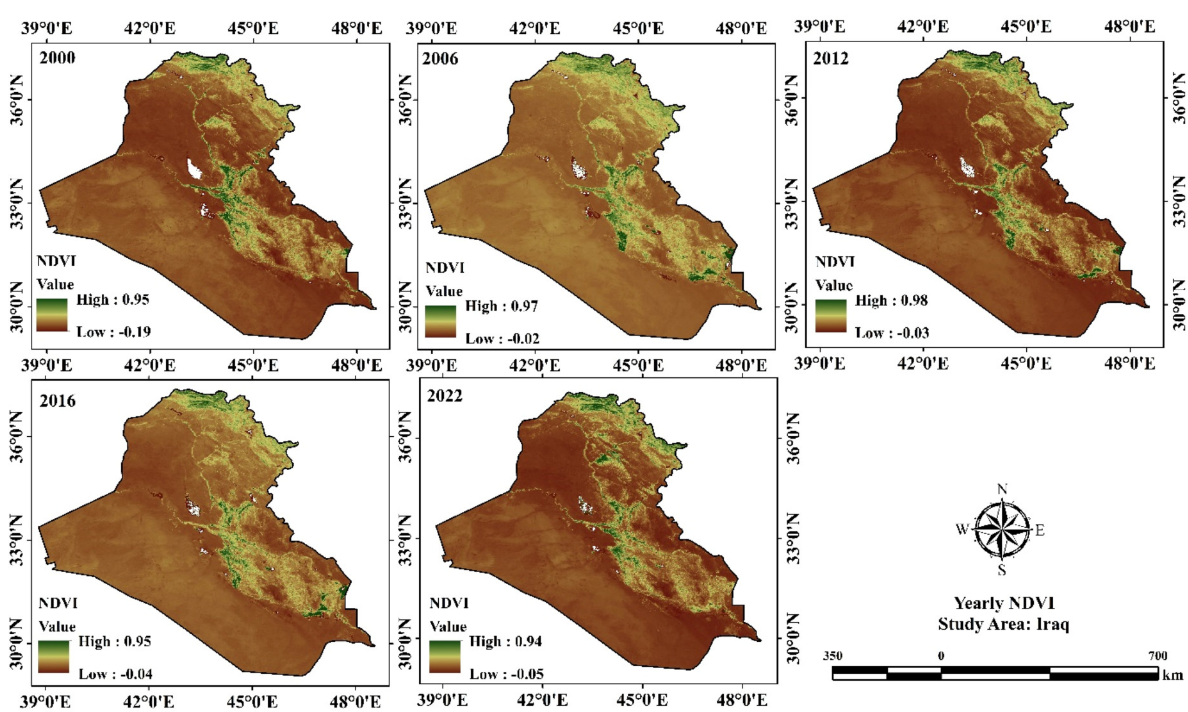

Fig. 6. Yearly mean NDVI variation in Iraq from 2000 to 2022 with MODIS data.

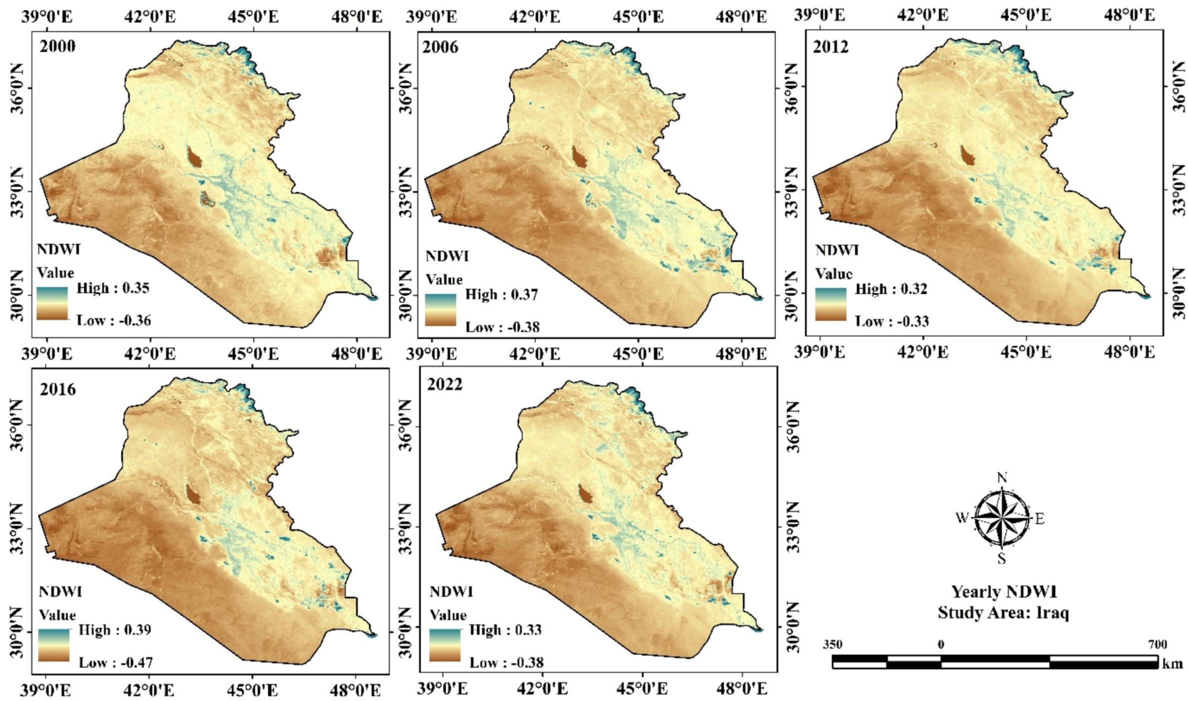

Fig. 7. Yearly mean NDWI variation in Iraq from 2000 to 2022 with MODIS data.

riverside of Iraq. Similarly, NDWI values are observed in the major reservoir and main river sides. The observed values are 0.35 (2000), 0.37 (2006), 0.32 (2012), 0.39 (2016), and 0.33 (2022), respectively (Fig. 7). An essential component of comprehending Iraq's environmental circumstances is the interplay of plant, water, and LST [39]. Agriculture, water availability, and the environment are all impacted by the vital roles that vegetation and water bodies play in controlling LST. The cooling of the surface is mostly attributed to vegetation, including grasslands, woods, and crops. Evapotranspiration is the process by which plants release moisture into the atmosphere, therefore reducing the ambient temperature [40]. In general, densely vegetated regions have lower LST than urban or arid ones. Better rainfall and steep terrain in northern Iraq have increased vegetation, which results in comparatively lower LST. The LST is greater in the central and southern areas, which are drier and have less vegetation. Seasonal variations in the LST can occur around bodies of water. Water bodies may help temper the cold in the winter and reduce excessive heat in the summer. LST in neighbouring areas of Iraq is significantly influenced by the Tigris and Euphrates rivers as well as reservoirs [41]. Reduced plant cover due to deforestation and soil degradation has led to higher LST in several places. Loss of vegetation, especially in southern Iraq, causes desertification, lowers soil fertility, and promotes soil erosion. Higher evaporation rates from water bodies caused by increased LST limit the amount of water available for industrial, drinking, and agricultural purposes. Additionally, this may result in decreased reservoir water levels, which might impact irrigation and hydroelectric power production. Plant and animal species sensitive to temperature fluctuations may become less common resulting in habitat changes brought on by rising temperatures. Ecosystem stability and agricultural resilience may be impacted by biodiversity loss. Iraq's land surface temperature is significantly regulated by vegetation and water. However, increasing LST has far-reaching effects on agriculture, water resources, human health, and biodiversity, and it is a result of deforestation, water shortages, climate change, and urbanization. For Iraq to have a more sustainable future and lessen the effects of high LST, effective management of water resources, forestry, sustainable agriculture, and urban planning will be crucial.

4.4. Evapotranspiration measurement

A crucial process in Iraq's hydrological and biological systems, evapotranspiration (ET) affects climate, water availability, and agriculture. It symbolizes the total amount of water lost from the surface resulting in transpiration (the release of water vapor from plants) and evaporation (the movement of water from soil, water bodies, and surfaces from liquid to vapor). The ET values are observed at 110.80 (2000),

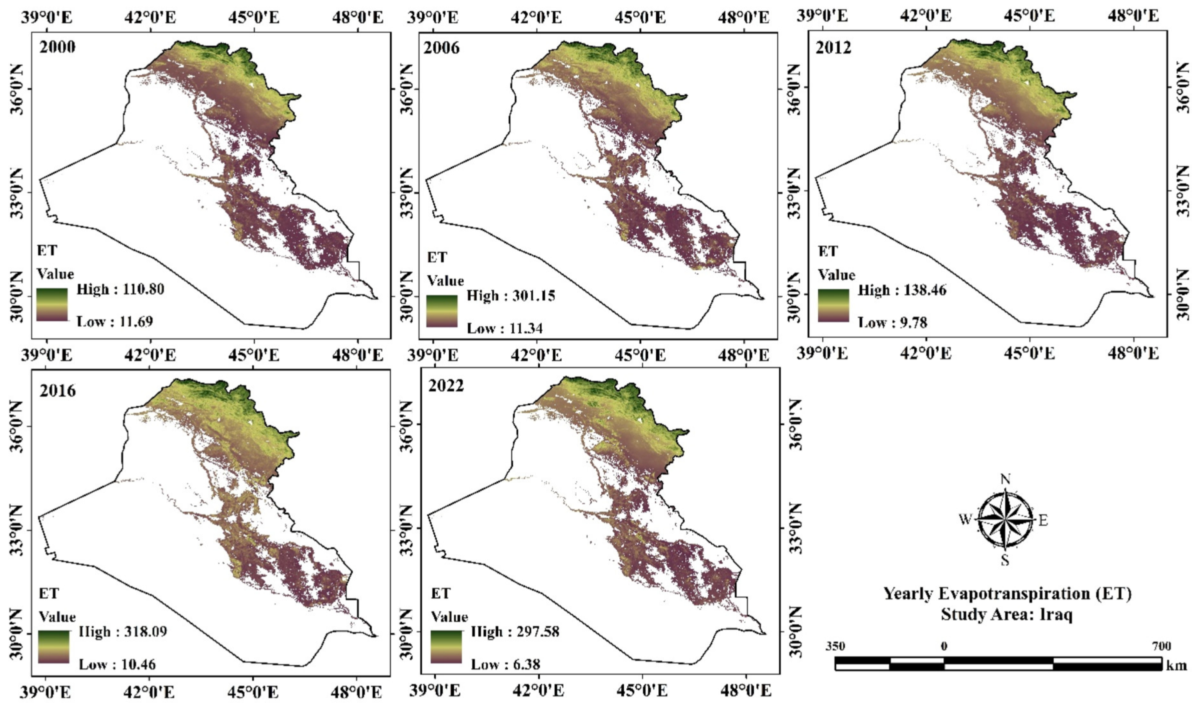

Fig. 8. Yearly mean ET variation in Iraq from 2000 to 2022 with MODIS data.

301.15 (2006), 138.46 (2012), 318.09 (2016), and 297.58 (2022), respectively (Fig. 8). The ET increased 186.78 throughout the study periods, and 8.49 annually. The main climates of Iraq are dry and semi-arid, especially in the central and southern parts of the country [40]. In this case, higher evapotranspiration rates are caused by high temperatures. As a result, soil moisture is decreased and the amount of water that is accessible is impacted. A considerable amount of water is lost to the atmosphere. In Iraq, evapotranspiration rates change with the seasons. ET peaks from June to September, when temperatures are high and the sun is shining brightly. The ET rates are lower during the winter months of November through February, however, because of the lower temperatures. Iraq's water shortage is largely caused by high ET. Freshwater availability is impacted by the rapid loss of moisture from soil and water bodies, which affects industrial usage, drinking water supply, and irrigation. High ET puts a burden on the nation's water resources by raising agricultural water demands. Ineffective irrigation systems make water loss worse, which reduces agricultural yields and raises farmer expenses. High ET exacerbates water competition, particularly in areas reliant on shared water supplies such as the Euphrates and Tigris rivers. This may result in disagreements between upstream and downstream areas as well as across sectors (households, industry, and agriculture). Iraq faces a serious problem with evapotranspiration, which has an impact on agriculture, the environment, and water supply. High ET rates worsen water shortages and lead to soil damage because of the nation's hot temperature and little rainfall [42]. Increased plant cover to lessen the effects of high ET, better irrigation, sustainable farming methods, and better water management are all necessary for adapting to these conditions. These actions will be essential to guaranteeing Iraq's long-term environmental sustainability, water security, and agricultural production.

In addition to the growing effects of climate change, Iraq's population is expected to exceed 80 million by 2050, and the nation's resources are depleting. As a result of temperatures by rising almost seven times faster than the world average in Iraq, water levels are being lowered by severe evaporation. With the Tigris and Euphrates rivers' water levels expected to drop by at least 30% and possibly as much as 70% by the end of the century, long-term resource management planning is required, especially in agricultural regions [43]. With rising temperature, altered climatic patterns, and catastrophic weather events, Iraq is suffering greatly as a result of climate change. Actually, according to some estimates, Iraq is the fifth most climate-vulnerable nation in the world. During the past 40 years, the Euphrates and Tigris rivers, which supply up to 98% of Iraq's surface water, have drastically reduced their water flows by 30–40%

[44]. Regretfully, Iraq has been suffered from low rainfall levels nationwide, with 2022 being the second year in a row below-average rainfall. The mean annual rainfall is predicted to keep declining, which will exacerbate desertification and water scarcity. In Iraq, riparian ecosystems flourish along the Tigris and Euphrates rivers, while the middle areas are home to grasslands and steppe flora, temperate forests and woods, and scant desert plants in the south [45].

Heat is expected to rise by 2–4 °C by 2050, worsening desertification, food insecurity, and social instability in Iraq. The country is already facing significant climate change effects, such as droughts, increasing heat, and water scarcity [46]. Except for the mountainous areas in the north and northeast, which have a Mediterranean climate, Iraq primarily experiences continental and subtropical semi-arid weather. In general, the nation sees dry summers with temperature swings between hot and severely hot, and winters that alternate between cool and cold. The majority of Iraq has seasonal rainfall from December to February during the winter months, except in the north and northeast, where the rainy season lasts from November to April. Sharqi, dry dust winds from the south and southeast that affect the nation from April to June and September to November, also have an impact on the climate. Significant surface warming is another effect of the north and northwest Shamal Winds on the climate. The current analysis indicates that the observed growing trends in Potential ET (PET) are expected to result in higher atmospheric evaporative loss, which in turn is anticipated to result in a significant rise in agricultural water demand and irrigation needs. A scientific reference for sustainable agriculture, precise hydrometeorology, and integrated water resources management in Iraq, the findings also provide a profound understanding of the intricate relationship between PET and its main climatic drivers in the area [40].

5. Correlation matrix analysis

The six climate and landforms variables are used for correlation analysis from 2000 to 2022. The rainfall and anomaly recorded a strong positive correlation and the R^2 values are 0.92 (2000), 0.86 (2006), 0.72 (2012), 0.76 (2016), and 0.69 (2022), respectively (Fig. 9). Similarly, rainfall and ET observed a strong positive correlation and the R^2 values are 0.60, 0.87, 0.72, 0.80, and 0.67 respectively. The LST with NDVI and NDWI R^2 values are observed strongly negative while NDVI and NDWI have a positive correlation. In Iraq, the relationship between rainfall, temperature, vegetation, and water resources is intricate, with one element having a major impact on the others. It is crucial to comprehend the relationships among these factors to manage Iraq's natural resources, agriculture, and environment as a whole. In Iraq, temperature and precipitation typically have an inverse

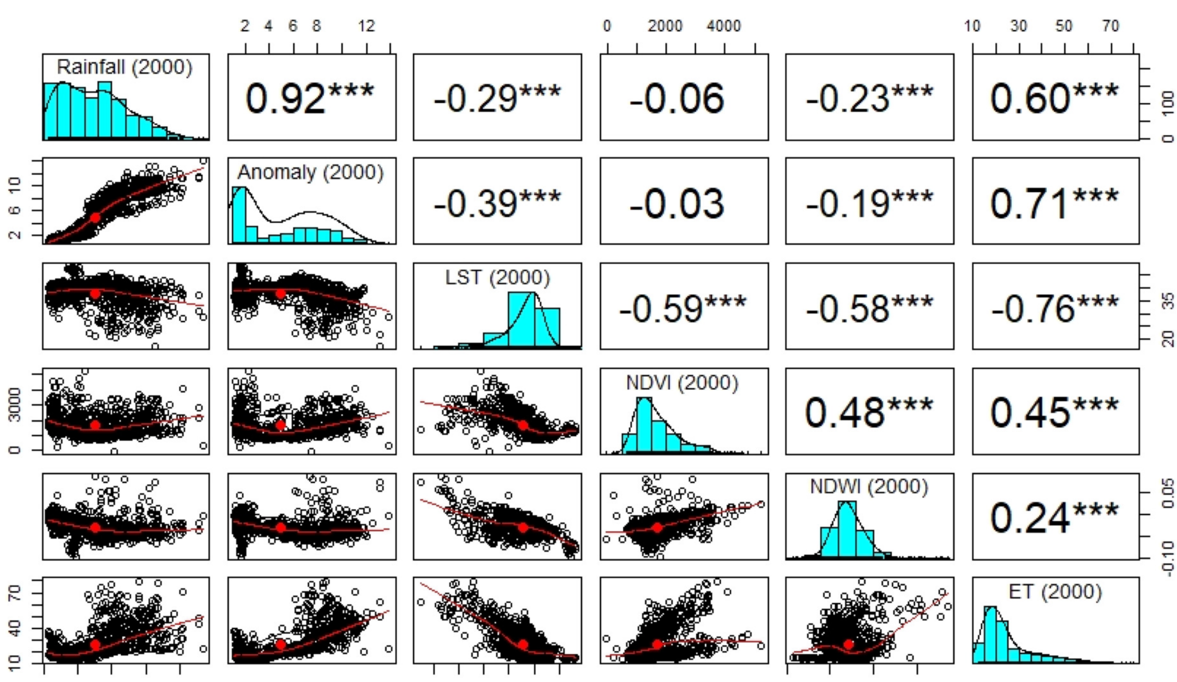

Fig. 9. Year-wise correlation matrix analysis in Iraq's different climate and landforms variables from 2000 to 2021.

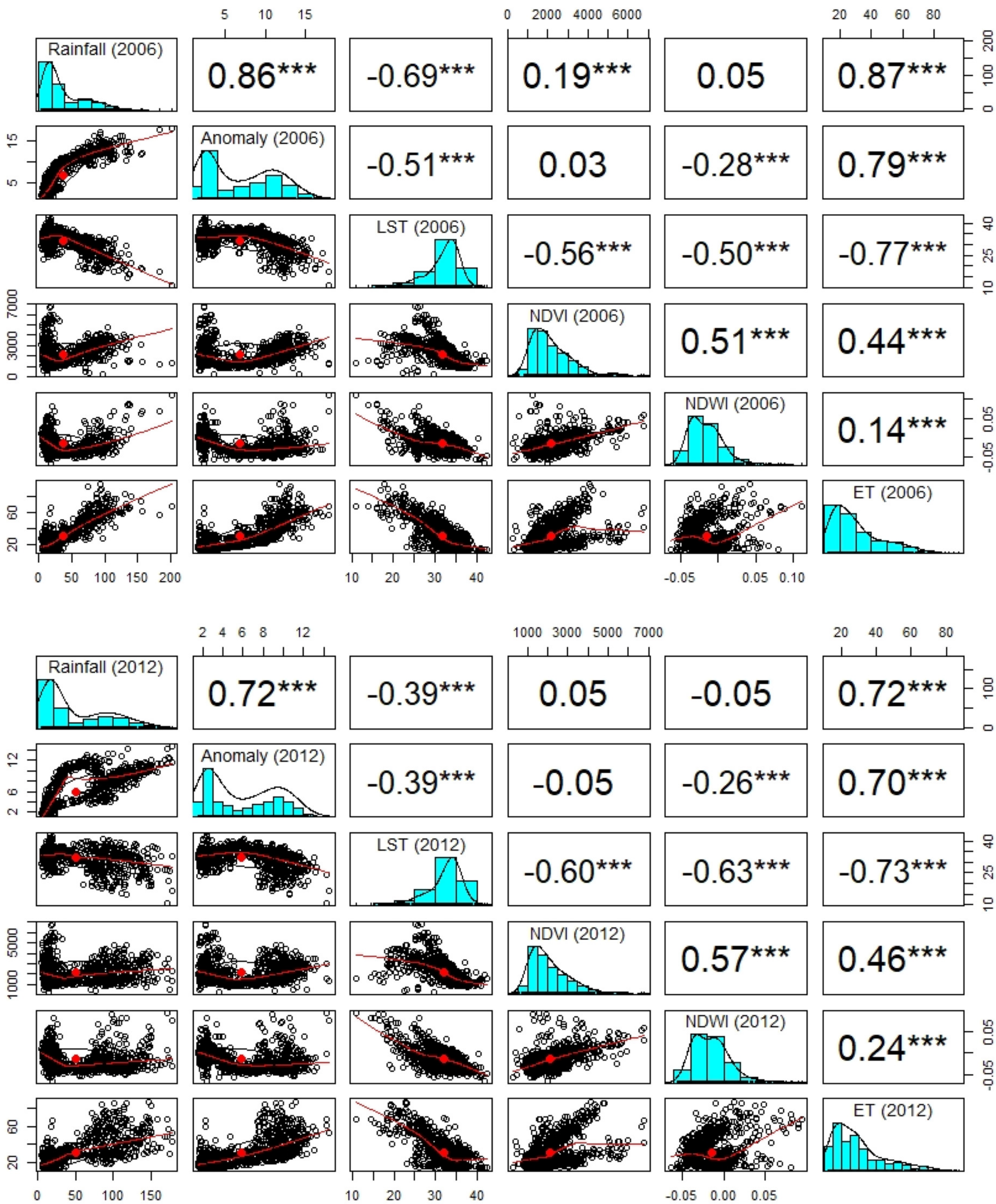

Fig. 9. Continued.

relationship. Temperatures are at their highest and rainfall is either very little or non-existent during the sweltering summer months, particularly in the central and southern areas. On the other hand, particularly in the northern and mountainous regions, wintertime brings lower temperatures and more rainfall. In Iraq, the amount of vegetation and rainfall are strongly positively correlated. Increased rainfall causes more vegetation to flourish, especially in the northern areas with a Mediterranean climate [47]. Mediterranean climate. By promoting agriculture, woodlands, and pastures, this improves the growing environment for plants. In Iraq, the development of the vegetation is seasonal, increasing from November to April during

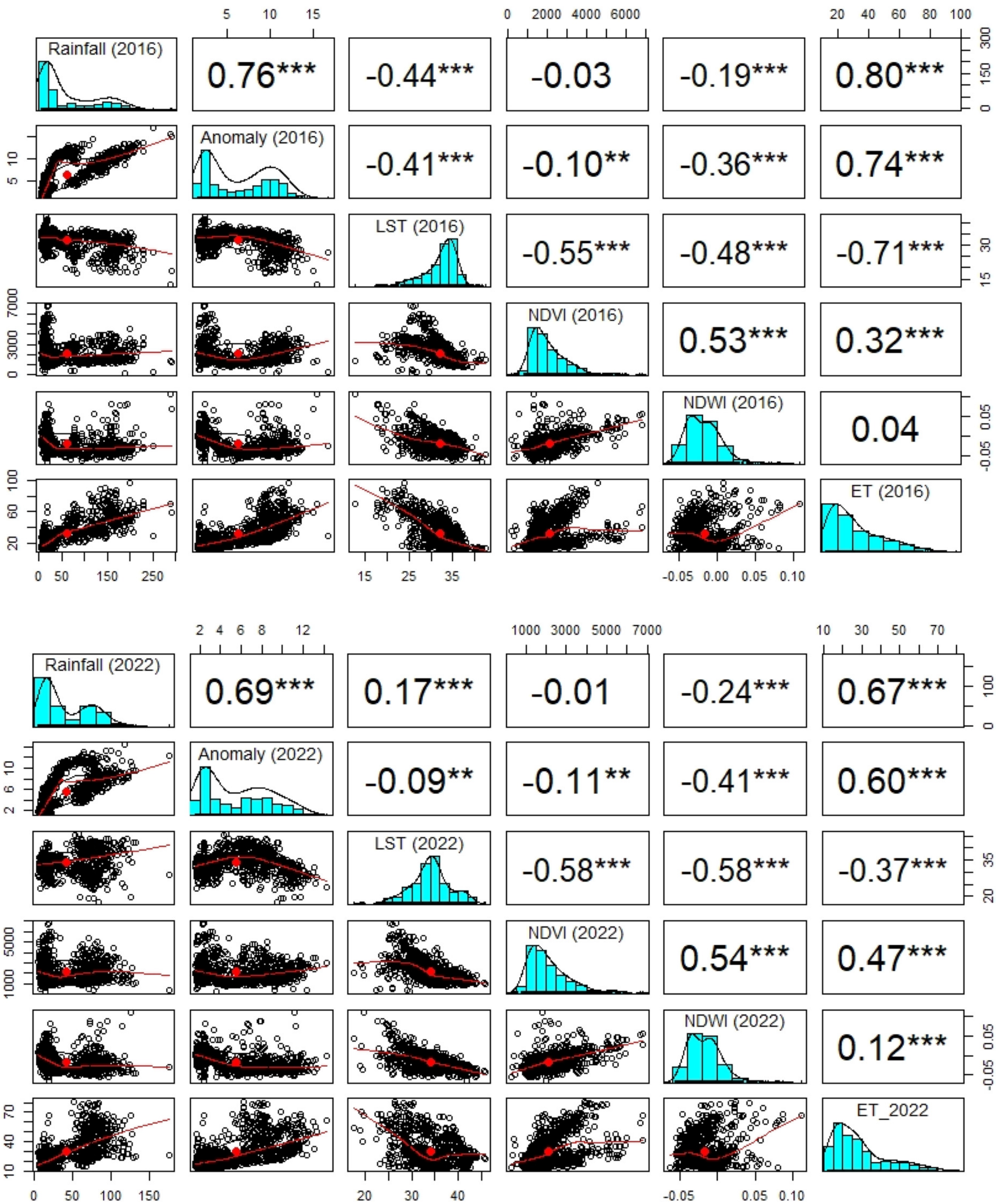

Fig. 9. Continued.

the rainy season and decreasing from May to October during the dry season [36]. The scant vegetation in dry and semi-arid regions, where rainfall is scarce, has evolved to withstand low water levels. Iraq's vegetation suffers from exceptionally high temperatures, particularly during the summer. In addition to limiting crop development, excessive heat can create water stress in plants and decrease photosynthesis. Additionally, evapotranspiration rises with high temperatures, causing the soil to lose moisture more quickly. Rainfall has a direct impact on the amount of water available in Iraq's aquifers, lakes, reservoirs, and rivers. More precipitation during the rainy season encourages river flows, raises groundwater levels, and replenishes reservoirs. Water shortage is made worse by decreasing water levels during dry spells due to less rainfall. Rainfall, temperature, vegetation, and water resources are all closely related in Iraq [48]. Modifications to one element frequently have a domino effect on the others, impacting water security, agriculture, and the ecosystem as a whole. To preserve the natural balance in the area, guarantee food and water security, and adapt to the difficulties presented by climate change, sustainable management of these factors is essential.

6. Conclusion

Iraq has several pressing issues, including climate change, and is among the top five countries in the world for susceptibility to its impacts. Iraq has to act now to adapt to and lessen the consequences of climate change, especially because the NDC was adopted in 2021 and there are ambitious plans to implement its provisions until 2030 with international and local funding. The current study's results will help policymakers integrate it into national initiatives to dismantle social barriers, promote growth opportunities, especially in southern Iraq, evaluate risks, and offer guidance for the future management of the most destitute and impoverished areas. Iraq needs help from other countries to combat climate change. Cooperation with international organizations, nearby nations, and regional projects will make sharing information, transferring technology, and finding financing possibilities easier. To estimate changes in temperature, precipitation, and other variables and ascertain the future implications of climate change over Iraq until the end of the present century, it is recommended that future research examine CMIP6 scenarios and assumptions. Iraq's adaptation plans for climate change demand urgent consideration and teamwork. These actions will guarantee sustainable development, lessen the effects of climate change, and increase Iraqi communities' resilience. Iraq's response to climate change will need perseverance, creativity, and teamwork. A sustainable future for Iraq's people, economy, and environment can be guaranteed by giving climate resilience priority.

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