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Trend and variability of rainfall in recent years in Iraq: A physical perspective

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Abstract

Iraq has experienced increased occurrences and elevated intensity of natural disasters focused on weather elements including droughts alongside floods and temperature fluctuations throughout the recent years. The research investigates rainfall pattern fluctuations and trends across Iraq but dedicates particular attention to the capital city Baghdad during the past decades.

Establishing intensity-duration-frequency curves requires the study to combine rainfall data obtained from ground-based measurements and satellite-derived estimates across major Iraqi cities. The curved models help the analysis reveal changes in how rainfall occurs through data on severe event magnitudes and their occurrences.

Studies indicate that Iraq traditionally showed varied rainfall patterns until recent times brought on distinct rainfall patterns displaying an elevated risk of dry periods and intense precipitation floods. This paper examines physical drivers of rainfall pattern changes along with their consequences for water resources management and agricultural practices and disaster prevention initiatives in Iraq.

Keywords: : Iraq; rainfall; intensity-duration-frequency; extreme events; climate change

1. Introduction

Iraq exists at the core of the Middle East where its landscape experiences arid to semi-arid conditions along with seasonal patterns of rainfall. Iraq has traditionally drawn most of its environmental support from seasonal precipitation which falls between November and April. The recent years have brought fundamental shifts to Iraqi rainfall patterns which demonstrate diminished total precipitation along with higher year-to-year variability and stronger rare weather occurrences [1].

The regional rainfall patterns are influenced by natural climate fluctuations and climate change-induced alterations of atmospheric forces and meteorological systems [2]. Iraq's water resources together with agricultural production and basic water access of millions of citizens face severe consequences due to these modifications [3].

The article examines physical patterns and fluctuations of Iraqi rainfall throughout recent years. A physical examination details the basis for rainfall pattern alterations through regional and global climatic factors while analyzing their environmental and socioeconomic effects within Iraq. After studying physical measurements of rainfall patterns we can strive to comprehend both the current climate evolution and future implications for Iraq [4].

2. Physical Factors Influencing Rainfall in Iraq

The climate of Iraq depends on physical elements which operate at three levels: local, regional, and global. Determining these factors enables better understanding of climate patterns both in the present and long-term future of Iraq [5].

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Geographical position along with topographical characteristics and climatic systems across the broad geography determine how much rainfall falls in the country and the degree of climate system variations. This analysis will examine the physical elements that affect rainfall distribution in Iraq based on studies in reference [6].

2.1. Geographical Location

Iraq exists in the Middle Eastern region where Turkey shares the northern border and Iran occupies the eastern sector while Syria holds the western boundary and Saudi Arabia controls the southern areas. The location between latitudes 29° and 37°N establishes Iraq in an area known for arid and semi-arid climate conditions [7]. The location between latitude 29° to 37°N leads to small rainfall amounts in the summer heat season. Natural aridity dominates Iraq because it exists close to significant desert areas such as the South Arabian Desert together with the Syrian Desert to its west [8].

The Mediterranean climate which affects the area displays wet winters alongside dry summers. The rainfall intensity and geographic distribution throughout Iraq shows significant variation because the country contains different geographical regions and climate zones [9].

2.2. Topography and the Orographic Effect

Varying terrains of Iraq form a major compositional factor that influences rain distribution throughout the country. Iraq presents different geographical areas that consist of mountain ranges in the northern section while its center displays flat terrain and the southern parts demonstrate desert plains [1].

- Northern Iraq (e.g., Kurdistan region) has more precipitation than other areas due to the orographic effect. The Zagros mountains in the north act as a barrier for moist air coming from the Mediterranean [7]. Rain occurs when moist air raises above mountains followed by air cooling and condensing processes. The northern highlands experience higher moisture levels because of the frequent rainfall which reaches 1,000 mm every year [10]. The combination of desert proximity and lack of topographical features makes Central and Southern Iraq areas that receive very little precipitation. The dryness from these areas exceeds 200 millimeters annually. [7].

2.3. Seasonal Wind Patterns and Atmospheric Circulation

Iraq's rainfall patterns mainly respond to seasonal winds that shift across the year according to various studies [7].

Wintertime rainfall between November and April brings the greatest precipitation to Iraq because of low-pressure systems and Mediterranean cyclones. The country's topography intersects with moist air transporting from the Mediterranean Sea and the Red Sea which results in rainfall deposit mainly in northern and central regions of Iraq [7]. The quantitative rainfall provides necessary water reserves for Iraq to maintain its resources and sustains farming activities particularly in rainfed agricultural zones [3].

Summer Drought lasts from May to September when Iraq falls under high-pressure systems which result in minimal precipitation levels [7]. Hot dry desert winds and winds from the Arabian Peninsula prevail through most of Iraq which intensifies its arid environmental conditions. The area undergoes severe evaporation while temperatures reach their annual peak during this time frame [11].

2.4. Influence of Global Climate Patterns

The annual rainfall patterns in Iraq are influenced significantly by global climate systems including El Niño and La Niña and by climate change patterns. Ocean temperature shifts coupled with atmospheric movement fluctuations generate extensive weather changes for this region [12].

El Niño and La Niña cause major changes in worldwide weather patterns because they alter Pacific Ocean sea surface temperature fluctuations [13]. Iraq typically sees dry weather conditions during El Niño years because the oceanic changes modify atmospheric patterns thus lowering rainfall-producing Mediterranean cyclone activity [7]. The La Niña cycle produces increased rainfall but its impact on Iraq is usually weaker than other regions according to research [14].

Global warming leads to rising temperatures in Iraq which rearranges when rain falls [11]. In recent years water scarcity had grown because rivers and lakes alongside soil lost more water through evaporation and faced reduced rainfall [15]. Global climate forecasting indicates Iraq will encounter an increase in severe weather occurrences throughout the next forty years known to cause extended dry seasons and flood events because of unusual rainfall distribution [16].

2.5. Proximity to Large Bodies of Water

The distance from Iraq to the ocean does not hinder its exposure to regional waters which include the Mediterranean Sea to the west and the Red Sea to the south [17]. The atmospheric moisture arriving from neighboring bodies of water provides winter precipitation most strongly to northern and central Iraq regions. The geographical formation of Iraq and its location from the seacoast reduce the water vapor uptake available for precipitation [18].

2.6. Human-induced Factors

Human activities are now on par with natural physical factors when it comes to altering rainfall patterns in Iraq [16]. Irrigation of major rivers Tigris and Euphrates by Turkey and Syria reduces the water volumes reaching Iraq [19]. The combined impact of declining rainfall became more severe as a result of these water diversion practices thereby creating a serious water scarcity emergency. Local weather patterns experience alterations through urbanization together with land-use changes which include deforestation and desertification processes that affect heat distribution and atmospheric moisture storage [20].

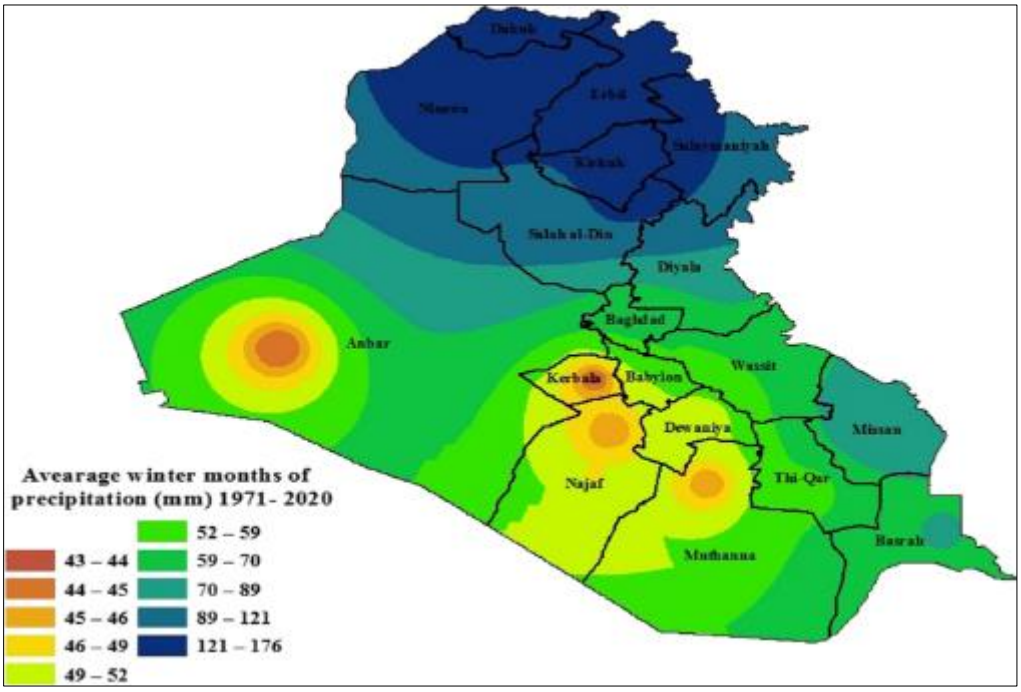

Figure 1 Temperature and precipitation trend analysis of the Iraq Region under SRES scenarios during the twenty-first century [20]

3. Trend Analysis of Rainfall Patterns

Tendencies in Iraq's rainfall during the past several decades appeared because of natural patterns plus the impact of climate change [16]. The country's agricultural productivity and water resources together with its environmental health face important consequences due to these patterns [21]. Knowledge of climate changes enables the development of strategic water management strategies together with agricultural plans to help face upcoming environmental conditions [22]. Rainfall in Iraq levels off each year according to official data report [23]. The southern and central parts of Iraq recorded major decreases in rainfall though southern areas saw this trend less before [24]. While Northern Iraq experiences more rainfall volatility its mountains and mountain effects provide more precipitation totals than other areas. Rainfall figures have decreased for many years throughout Northern Iraq according to reported studies [25]. The south of Basra and Nasiriyah experiences major rainfall drops that reach up to 50% to 70% fewer yearly totals compared to normal levels. Water scarcity becomes more severe because heavy rains have decreased throughout this part of the country [26]. The yearly rainfall pattern has shown both decreased water amounts and increased fluctuation between years. Droughts appeared in some years while heavy rainfalls took place during others according to official reports [28]. It becomes harder to plan water usage because rainfall shows unpredictable patterns across different areas and over multiple years [29].

Multiple short-term dry seasons intensified during the last five years especially from 2018 to 2019 [30].

When 2020 received more than expected rainfall during the year flooding happened but consistent moisture did not develop [31]. Heavy rainfall during storms delivers large amounts of water that produce swift floods which hurt buildings and disrupt activities in cities and farmlands [32]. Winter becomes the active season for rainfall in Iraq with the highest levels coming in December and January. New observations demonstrate that the rainy season now arrives earlier and lasts less time [7].

Rains occur less time during the normal wet season period [33]. The shortened period of winter rain hurts bread crop production because wheat and barley need continuous winter precipitation for growth [34]. Every year some areas face prolonged waiting between December and February that forces farmers to miss their viable planting dates [35]. The waiting period affects farmers the most because they operate under established climate conditions [36].

This abnormal weather leads rainfall to stop sooner than the forecasted window which ends normally in May. The early end of rainy days causes water problems at the time when crops need it most [37]. The number of extreme weather events like floods and dry conditions keeps growing in Iraq [26]. Heavy rain showers hit hard and quick but brief periods produce flash floods. Thunderstorms drop heavy rain in Iraqi cities like Baghdad and Basra which strains municipal drainage systems and hurts infrastructure plus personal lives [38].

Low rainfall during continued dry seasons causes major drought problems mainly in Southern and Central Iraq [39]. Dry seasons generate severe problems for farmers who lose their harvests and face food availability challenges throughout the nation [40]. The northern part of Iraq, particularly the Kurdistan region, relies on snowmelt from the Zagros Mountains for much of its water supply. Snowfall has decreased within these mountains which decreases water amounts flowing into Tigris and Euphrates rivers at spring period [41].

In Iraq the warm spring snowmelt serves as the main water source during hot summer seasons so less snow causes serious worries about water supply. The country's water shortage gets worse because snowfall decreases and rain slides down at a slower rate [42]**.**

Iraq records less rainfall but its regional patterns throughout the country differ from one another. Rainfall in the Northern Iraq region exceeds the rest of the nation's areas because of its higher elevations within the Zagros Mountains landscape [43]. The area still feels the impacts of snow loss and fewer seasonal rains even though it stands out from other Iraqi regions. The new weather patterns will weaken the available water for both human consumption and farming in coming years [44].

Southern Iraq cities like Baghdad and Basra along with Nasiriyah experience severe decreases in rainfall as compared to the rest of Iraq. The desert weather conditions and strong sun heat create a severe water shortage problem for these areas [45].

Current climate predictions show that rainfall trends from the past twenty years will keep expanding with more severe impacts in some parts of Iraq. The rise of temperatures will make it harder to store water during drought events because the hot sun makes water evaporate faster. This will create greater water demand problems especially throughout Iraq's southern and central areas [46].

- Scientific models show Iraq will see both longer dry spells and more powerful rainfall events which turn into flood situations [26]. Iraq needs to design better water storage systems and increase flood protection efforts to handle future weather threats [47].

The trend of decreased snowfall in northern Iraq will reduce Tigris and Euphrates river water amounts which impacts the availability of water downstream. Water management systems need to cover both rainfall and snowmelt due to snowfall changes [48].

4. Impacts of Climate Change on Rainfall Trends

Climate change ranks as the top international problem during the 21st century because Iraq and other regions are currently experiencing its detrimental consequences. The climate of Iraq struggles since it exists within a delicate environment which is mostly arid and semi-arid yet suffers additional challenges from climate warming that alter rainfall distributions [49]. Climate change yields major effects on water quantity along with impacts on agricultural production and people's standard of living in Iraq. This segment investigates the rainfall pattern modifications in Iraq caused by climate change with emphasis on rain reduction alongside precipitation becoming more extreme [26].

Iraq's rainfall has displayed a prominent change due to climate change through reduced total yearly precipitation. Iraq's southern and central regions together with their arid nature have witnessed decreasing rainfall levels throughout the last few decades [11]. Changes in global atmospheric circulation together with regional climate dynamics due to global warming are responsible for this pattern of reduction [24].

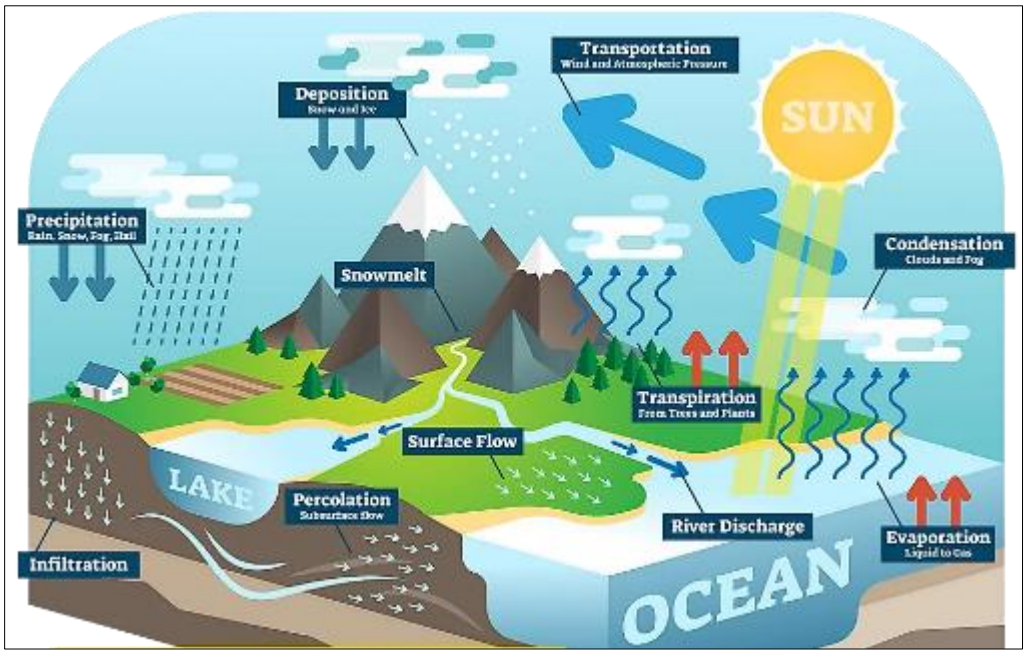

Figure 2 Climate Change Impacting The Water Cycle [50]

High variable rainfall patterns represent a major problem caused by climate change. The interannual (year-to-year) and seasonal precipitation changes result in an increase of extreme weather events like droughts and floods. Water management and agricultural practices become more challenging because farmers together with policymakers now struggle to forecast when rain will occur or where it will reach [51].

The southern and central regions of Iraq experience severe droughts which have grown more severe while occurring with greater frequency over the recent years. Rainfall during 2018, 2019 and 2020 fell at levels 50-70% lower than usual [11]. The current droughts have caused severe harm to agricultural production particularly because wheat and barley cultivation requires dependable rain patterns. The insufficient water supply has magnified Iraq's current water shortage problems because its reservoirs and rivers cannot properly replenish themselves [52].

Soil moisture levels decrease because of escalating temperatures that speed up evaporation rates thus resulting in more frequent drought occurrences. Agricultural productivity faces increasing risks because irrigation water availability decreases mostly in rain-fed farming areas [53].

Climate change has distorted the timing and length of Iraq's typical rainy period. The traditional rainfall pattern in Iraq operates during winter and early spring months between November and April with December along with January comprising the most rain. The recent climate trend indicates that Iraq's rainy season duration shortens while its patterns become more unpredictable [54].

The seasonal rainfall now appears in January or February before stopping prematurely in March or April. The shortened rainy season diminishes both agricultural planting time and the total amount of water resources in the country [55].

The Kurdistan region of Iraq along with other northern territories obtains water during spring mainly from the snowmelt on Zagros Mountains that feeds the Tigris and Euphrates rivers. The declining snow levels in the Zagros Mountains bring about less stream discharge into Iraq since snowmelt represents their main water source [56].

The snow melts earlier due to warmer temperatures and some years have observed substantial snow shortage which reduces summer river water levels. Reduced snowmelt volumes lead to reduced river flows which affects water quantity for households along with irrigation needs in southern and central areas [57].

Models forecast Iraq will encounter reduced river levels and more excessive weather patterns in future years. Some key projections include [58]:

The rise in average temperatures in Iraq will create more rapid evaporation together with worsening water shortages and increasing drought frequencies. Climate change will transform rainfall patterns throughout Iraq into less consistent and irregular rainfall patterns [59].

The prediction shows that climate change will lead to intensified occurrences and enhanced severity of both droughts and floods. A growing unpredictability in rainfall together with more severe weather events will create uncertainty for farmers regarding crop planting and harvest times leading to potential failures of their harvests and food shortages [60].

The water supply situation in Iraq will deteriorate due to both reduced rainfall amounts and more extreme droughts and less snowmelting. Iraq currently faces two primary threats to its Tigris and Euphrates rivers from upstream water management but the situation will probably worsen because of climate change [61].

5. Case Studies of Extreme Rainfall Events

The occurrence of extreme rainfall in Iraq grows more frequent because of natural climate patterns along with modern climate change factors. Heavy rains over short periods develop into major flooding that produces damage to infrastructure and destroys agriculture [11]. Better response plans for such extreme situations can be developed by local authorities and policymakers through acquiring knowledge about these events first-hand. Interested case studies about intense rainfall events in Iraq illustrate increasing difficulties for the country to handle these incidents [5].

5.1. Flooding in Baghdad and Central Iraq (December 2019)

The city of Baghdad together with multiple Iraqi central regions faced major flooding after heavy rainstorms occurred during December 2019. Exchange of multiple days of rain resulted in city flooding and transport problems and infrastructure destruction and took multiple human lives [62]. This storm existed among multiple Mediterranean cyclones that appeared in winter throughout the region [63].

5.1.1. Details of the Event

The storm brought excessive rainfalls exceeding 50 mm to various regions of Baghdad indicating substantial precipitation compared to the yearly average of 200 mm rainfall in the area [64].

Heavy rains exceeded the capacity of Baghdad's drainage network because the systems were built without considering such heavy rainfall rates. Flash floods occurred after the rains started and these floods washed away streets as well as destroyed property while slowing down public transportation [65].

Farm operations suffered major losses after the torrential downpour carried away agricultural goods throughout the surrounding land. The flood augmented concerns over water crisis in one hand and make agriculture sector sensitive to such a circumstance. [66].

5.2. Southern Iraq Flooding (November 2020)

A Mediterranean cyclone brought excessive rainfall to Basra and Nasiriyah as well as other regions of southern Iraq during November 2020 [26]. The dry weather pattern of southern areas took a surprise turn due to excessive precipitation. This rainfall episode became one of the most severe in the region since recent history [67].

5.2.1. Details of the Event

The cyclone produced rainfall of more than 60 mm across southern Iraq which matches the seasonal rainfall total of that region [7]. The southern Iraqi city of Basra witnessed its largest rainfall recorded in recent decades which caused flooding across low-lying regions [68]. Flooding occurred throughout both city and country areas when rivers that were already swollen after previous rains exceeded their banks [69].

The storm caused extensive damage to electrical facilities that led to power outages across the region while storms flooded sufficient areas to block numerous roads for multiple days [40].

5.3. Kurdistan Region Snowmelt and Heavy Rainfall (Spring 2019)

During spring 2019 the Kurdistan region of northern Iraq experienced an excessive rainfall together with intense snowmelt from the Zagros Mountains. Facets of extreme flooding as well as river surges led to substantial destruction of rural areas together with infrastructure within western Iraq's region [61].

5.3.1. Details of the Event

- Heavy rainfall in March accompanied with snowmelt of Zagros Mountains resulted in swift water level rises in Great Zab and Little Zab rivers that cross through Kurdistan. [70].Near-river settlements suffered extensive flooding while the disaster destroyed houses together with agricultural lands and road infrastructure [71]. The Tigris River became flooded due to rain and snowmelt processes that increased water levels throughout the affected downstream areas [48].

5.4. Flash Flooding in Baghdad and Northern Iraq (November 2020)

5.4.1. Event Overview

A severe flash flood outbreak happened in Baghdad and northern areas of Iraq during November 2020 [72]. Heavy Mediterranean cyclones deposited moisture in the region before this event took place. Heavy rain arrived swiftly and intensely leading to extensive destruction especially throughout cities as well as flat regions [73].

5.4.2. Details of the Event

A sudden storm dumped 30-40 mm of rainwater throughout several hours which resulted in excessive flooding of Baghdad's drainage infrastructure and led to multiple flash floods in city neighborhoods [41].

Significant water accumulation flooded both cities along with numerous other towns in the northern region of Iraq [7]. Heavy floods from excessive rainfall filled streets so rapidly that they disrupted road traffic and public systems and left damage to properties [62].

6. Conclusion and Recommendations

Due to climate change Iraq which exists in an already vulnerable climate zone experiences rising occurrence of severe rainfall incidents increasing their intensity. Recent extreme rainstorms hit Baghdad and southern Iraq and the Kurdistan region showing important shortfalls in Iraq's water management systems together with infrastructure and disaster preparedness operations. Future climate extremes are too strong to wait to act because their extreme events result in flooding, crop failure, and humanitarian or infrastructure catastrophes.

Both excessive water during intense rainfall and continuous drought conditions negatively affect Iraq's agriculture and water resources systems which represent vital components for the nation's economic well-being and food preservation capacity. The growing number of water-related disasters alongside damaged infrastructure prove that Iraq is becoming more susceptible to environmental threats which needs strategic plans combining climate adaptation with urban planning, agriculture and water resource management.

We recommendations implementing these action points to deal with present water problems.

- The nation should create new water rules and designs that teach people how to save water while also building additional water options like wells and beach water.
- East Iraq sees all rainstorm surplus water so we should spend funds on building storage units for this runoff.
- Establish a wide network of water-testing stations across Iraq to observe rainfall totals and measure water supplies in different spaces over time.
- Iraq should encourage farmers to grow plants and use irrigation methods that save water since agriculture needs more water than any other sector.
- The country should build stronger links with other nations to share their knowledge about how to manage shared water resources and create equal access to water resources sustaining all parties.

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