Journal for Technology and Science
Homepage : https://journal.antispublisher.com/index.php/IPTEKS
Email : admin@antispublisher.com

e-ISSN : 3047-4337
JOTECH, Vol. 3, No. 4, October 2026
Page 58-71
© 2026 JOTECH :
Journal for Technology and Science

Best Source Of Precipitation Data As An Alternative To Ground Station Monitoring: (Dhi Qar Governorate – Iraq) Case Study

Mohammed Azeez[1], Hisham M.Jawad Al Sharaa[2], Abdul Razzak T. Zboon[3]
[1] Department of Surveying, Shatrah Technical Institute (STI), Southern Technical University (STU), Shatrah, Iraq
[2] Department of Civil Engineering, College of Engineering, University of Technology, Baghdad, Iraq
[3] Department. Of Building and Construction Technology, Al-Esraa University, Baghdad, Iraq

DOI : https://doi.org/10.61796/ipteks.v3i4.585

Sections Info

Article history:
Submitted: May 07, 2026
Final Revised: June 26, 2026
Accepted: July 18, 2026
Published: August 16, 2026

Keywords:
Precipitation data
TRMM
IMERG
PERSIANN-CDR
GSMaP
ERA5
Dhi Qar-Iraq

ABSTRACT

Objective: *In this research, six sources (TRMM, IMERG, PERSIANN-CDR, GSMaP, and ERA5) of precipitation data collected by satellites/global reanalysis were evaluated to find the best source of precipitation data as an alternative method to monitoring from GWS.* ***Method:*** *The evaluation was based on two methods; the first is the use of statistical metrics (Pearson's Correlation Coefficient (CoC), Mean Error (ME), mean absolute error (MAE), Root Mean Square Error (RMSE), and Bias (BIAS) and the second is the use of precipitation data quality metrics Probability of Detection (POD), the False Alarm Ratio (FAR), and the Critical Success Index (CSI). In both methods, monitoring adopted precipitation data from GWS as the source data (the most accurate), and compared it with estimation data (extracted from remote sensing (RE) techniques /reanalysis data).* ***Results:*** *Based on the results of the quality metrics, it was found that CHIRPS is the most reliable alternative to GWSs for precipitation data, followed by TRMM and IMERG. However, the statistical metrics results indicated that ERA5 outperformed the other data sources.* ***Novelty:*** *The study concludes that quality measures are better at verifying the validity of data when it comes to temporal and numerical discrepancies between GWSs and RE techniques/reanalyzed data, as these measures are not sensitive to the number of observations. Therefore, it was suggested to use CHIRPS data as an alternative source to study drought and hydrology instead of relying exclusively on GWS.*

INTRODUCTION

Precipitation is an essential component of the global water cycle and significantly impacts the diversity of life on Earth. Recording the amounts of precipitation is extremely important to studying the region's climate history and changes. Precipitation data is of high value as it is used as primary data in studying drought[1–12] agricultural, hydrological, and natural disaster assessments[13–17].

Many studies have shown the effect of precipitation on vegetation throughout Iraq and its impact on vegetation, especially in semi-arid areas[18]. On the other hand, precipitation data in Iraq and the effects of climate change on food and water security are important and sensitive issues with the increasing population growth[19]. In hydrological studies, precipitation data were critical, and many researchers in Iraq presented their results based on it[20,21].

There are two methods for recording and estimating precipitation data. The first method involves direct measurement using gauges at ground weather stations (GWSs). The second method utilizes satellites and re-analysis data derived from various sources, including global GWSs, satellites, and auxiliary data such as temperature, humidity, and vegetation cover. This approach is often referred to as the downscaling method. The accuracy of the data obtained from GWSs depends on the station's spatial spread in the region[14,15,22] and the possibility of daily recording without malfunctions. Even with the quality of GWS data, it will still represent a specific point. However, unobserved data interpolation methods still need to be used, especially in hydrological studies where data covering a wider area are needed [23].

Estimating precipitation amounts and timing using remote sensing (RE) techniques may be a better alternative to GWS data, especially given its poor spatial distribution in the study area. Furthermore, GWS data may be subject to human error (such as a lack of regular rain gauge maintenance). Although the spatial and temporal coverage of RE data is superior to GWS data, RE data are not free from errors and bias[13,23].

Evaluating bias in precipitation data can be done using statistical measures [24–29]. On the other hand, some studies presented the hydrological model as a model for evaluating bias in precipitation data [13,23,27,30] . Chen et al. used the Standardized Precipitation Index (SPI), a drought indicator, to evaluate the performance of Tropical Rainfall Measuring Mission (TRMM). Chen et al.'s approach is a step different from previous contexts [31].

In Iraq, Kadhim et al. presented a recent study to evaluate rainfall data estimated from remote sensing techniques. Although their study covered all regions of Iraq, they focused on evaluating the Integrated Multi-Satellite Retrievals (IMERG) dataset only [25]. In previous studies, researchers evaluated the reliability of precipitation data collection sources derived from RE, assuming numerical consistency between GWS observations, which are generally more accurate, and these RE sources. In this research, we present an investigation into the validity of six precipitation data datasets that were collected and analyzed by different methods. The validity investigation is carried out according to two methods, a statistical method and a quality method, to investigate in depth the best alternative to GWSs in conditions of temporal and numerical inconsistencies.

MATERIALS AND METHODOLOGY

Study area

Dhi Qar is located approximately 450 kilometers south of the capital city, Baghdad. It is bordered to the south by Al-Basrah and to the north by Wasit. To the east and west, it is surrounded by Maysan and Muthanna, respectively. The area of Dhi Qar city is estimated to cover 12900 square kilometers, and it features diverse environmental conditions. In the southeastern part of Dhi Qar, there are about eight marshes with various names, including "Al-Himar," "Al-Wasat," "Al-Qurnah," "Al-Sanaf," "Abu Zarq," "Al-Adl," "Cheetahs," and "Al-Ghamouka." Dhi Qar is characterized by moderate terrain, with elevation changes ranging from about 10 meters between the northernmost and southernmost points. The city has a population of approximately 2095172 and is classified administratively as a governorate, with Nasiriyah serving as its center. The geographical coordinates of Dhi Qar are approximately 45°-47° E longitude and 30°-32° N latitude. See Fig. 1.

Dhi Qar is classified as an arid to semi-arid region. It has recorded a maximum rainfall of approximately 30 mm from 2008 to 2024. The highest average temperature noted was 42 °C, while the lowest was 3 °C. The region experienced solar radiation levels ranging from a maximum of 33 W/m^2 to a minimum of 1 W/m^2. The highest average wind speed recorded was 7 m/s, compared to a minimum of 1 m/s. Lastly, the maximum value of evaporation (ET) measured was around 14 mm, with the lowest recorded ET value being 1.5 mm.

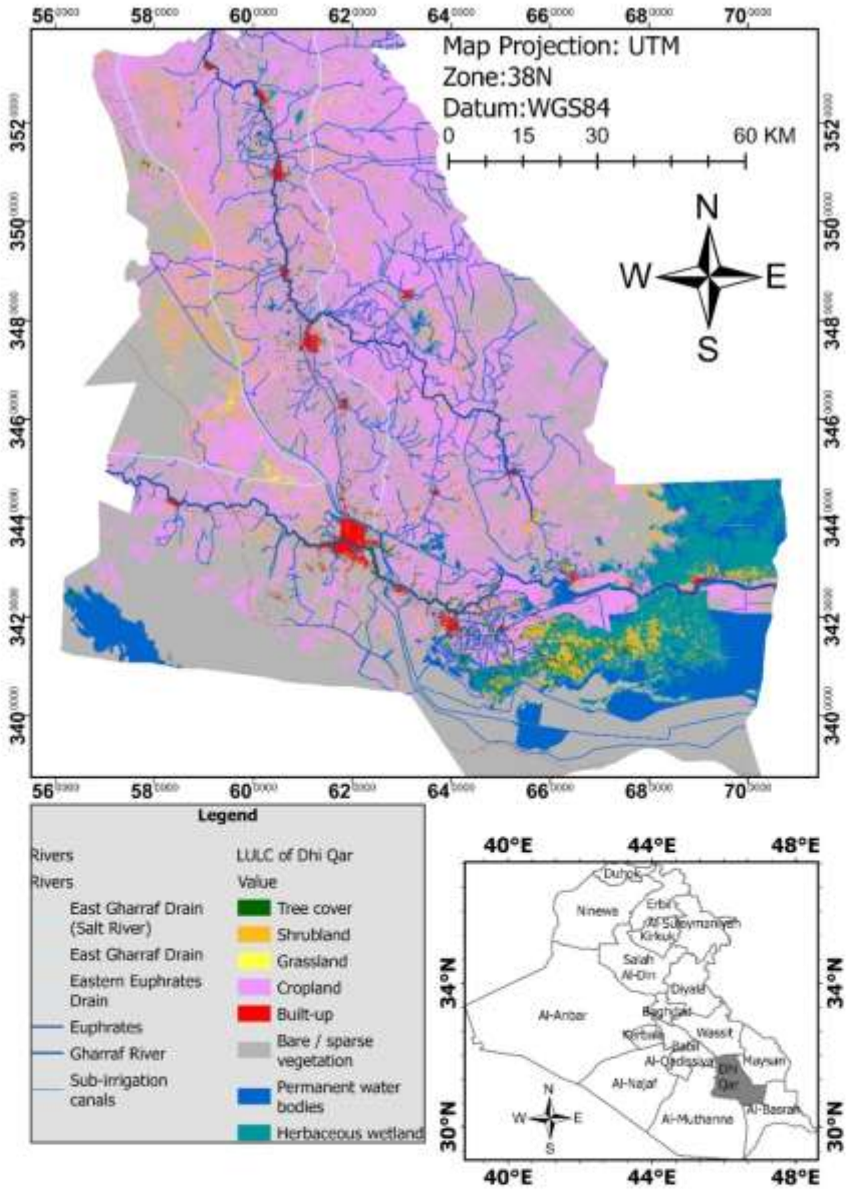

Figure1. Study area, LULC from (32)

Data

Precipitation data from GWSs

The climate data for the Dhi Qar study area were collected from four GWSs managed by the Iraqi Ministry of Agriculture - Meteorological Center(http://www.agromet.gov.iq/). These stations are distributed throughout the area, as illustrated in Fig.2 . Al-Faier station is located in the northern part of the study area at coordinates 31.85° north latitude and 45.78° east longitude. Al-Shatra station is situated in the central section of the study area at coordinates 31.45° north latitude and 46.16° east longitude. Both Suq Al-Soyokh and Al-Chibayish stations are found southeast of the study area. The coordinates for Suq Al-Soyokh station are 30.96° north latitude and 45.57° east longitude, while Al-Chibayish station is located at 30.94° north latitude and 47.07° east longitude. A different department of the Meteorological Center manages each of these stations. Please refer to Table 1 for more details.

Table 1. Coordinates of GWS, their operating dates, and the departments responsible for managing them.

GWS Name	coordinates		startup date	Managed by
	Latitude	Longitude		
Al-Faier	31.85° N	45.78° E	2013	F.C.D
Al-Shatra	31.45° N	46.16° E	2008	A.G.T
Suq Al-Soyokh	30.96° N	45.57° E	2014	A.G.T
Al-Chibayish	30.94° N	47.07°	2011	A.DQ

NOTES:
Agricultural Guidance and Training (A.G.T) Department.
Forestry and Combating Desertification (F.C.D) Department.
Agriculture Dhi-Qar (A.DQ) Department.

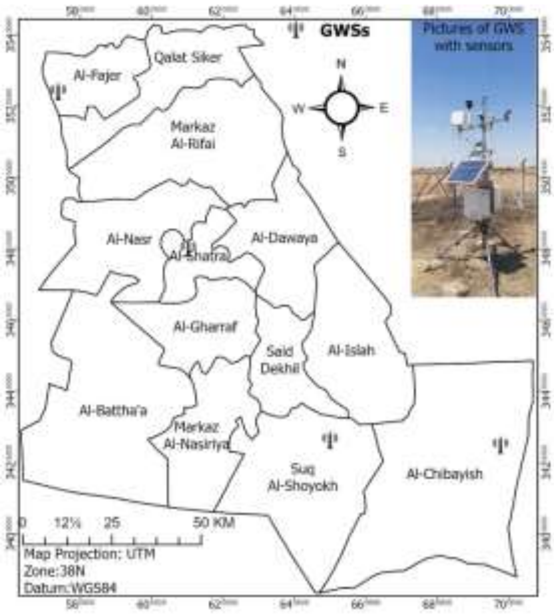

Figure 2. The locations of GWSs in the study area.

There is a significant amount of missing data across the four GWSs, especially regarding rainfall measurements. The Al-Shatra station has six years of missing rainfall data. In comparison, the Al-Fajer station also reports approximately six years of data gaps. The Al-Chibayish station has about four years of missing rainfall data. In contrast, the Suq Al-Soyokh station has the least amount of missing data, with only about four months of gaps. In addition to the extensive missing data, the stations have inconsistent operating times. Al-Shatra station is the oldest, while Suq Al-Soyokh station is the newest. See Fig.3.

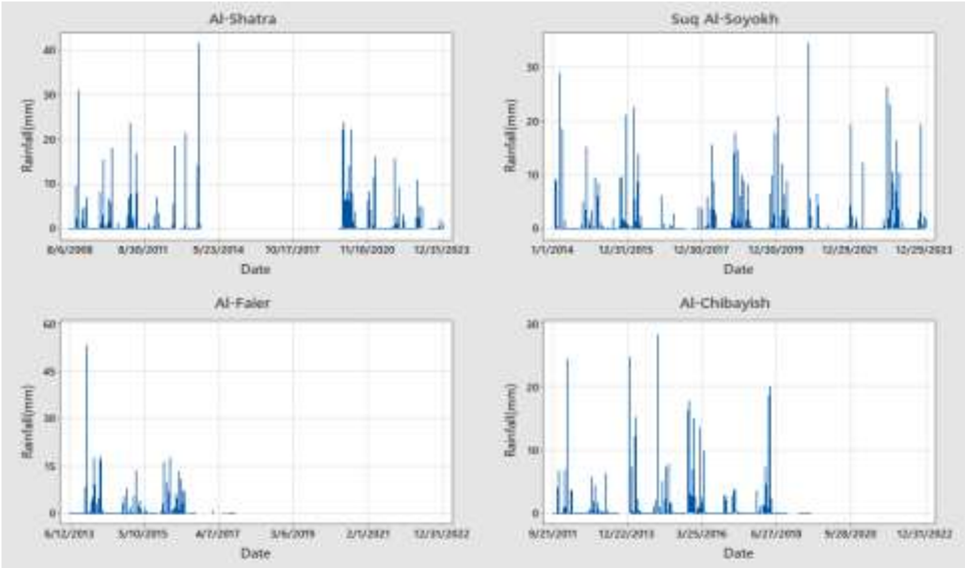

Figure 3. Daily precipitation data measured from GWSs

Precipitation data from remote sensing techniques

The sources of precipitation data are diverse: observations from a single satellite or a group of satellites, and precipitation data extracted from reanalysis of auxiliary data. See Table 2.

Table 2. Abbreviations and names of the precipitation data evaluated in our research, and the organizations publishing/producing this data

Abbreviated	Full name	Agency
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station Data(https://chc.ucsb.edu/about)	USAID, NASA, and NOAA
TRMM	The Tropical Rainfall Measuring Mission (TRMM)(https://gpm.nasa.gov/missions/trmm)	NASA, JXAX
PERSIAN-CDR	Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Climate Data Record(https://climatedataguide.ucar.edu/climate-data/persiann-cdr-precipitation-estimation-remotely-sensed-information-using-artificial)	NCAR
IMERG	Integrated Multi-satellitE Retrievals for GPM(https://gpm.nasa.gov/data/imerg)	NASA
GSMaP	Global Satellite Mapping of Precipitation(https://sharaku.eorc.jaxa.jp/GSMaP/)	JXAX
ERA5	European Centre for Medium-Range Weather Forecasts(ECMWF) (https://cds.climate.copernicus.eu/)	C3S

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between two agencies, the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA). It is the first mission to detect rainfall in tropical and subtropical regions. It was launched in November 1997 at an altitude of 350 kilometers[33,34].TRMM covers parts of the world between 50°N and 50°S, with a spatial coverage accuracy of (0.25°X 0.25°)and a temporal resolution of (3h). There is much research on this mission, and the reader may find it useful to review this research[33–35]. IMERG data is the integration of several weather monitoring satellites, covering large parts of the world(90° N-S)[36] .IMERG is particularly valuable over areas of Earth's surface that lack ground-based precipitation-measuring instruments, including oceans and remote areas. IMERG is especially valuable in areas of the Earth's surface that lack terrestrial precipitation measuring instruments, including oceans and remote areas, as it gives weather readings in near real-time (0.5 hours) and the spatial resolution is (0.1° x 0.1°). A full description of this task and the method of processing and producing data has been published by [37,38].

PERSIANN-CDR covers from 60° S to 60° N and 0° to 360° longitude at 0.25-degree spatial resolution. PERSIANN-CDR is generated from the PERSIANN algorithm using GridSat-B1(https://www.ncdc.noaa.gov/gridsat/) infrared data. It is adjusted using the Global Precipitation Climatology Project (GPCP) monthly product to maintain consistency of the two datasets at a 2.5° monthly scale throughout the entire record[39]. CHIRPS covers parts of the world between 50° N and 50°S and has different spatial resolutions. The available spatial resolution is between 0.05° and 0.01°,depending on the region and the period (40). This data can be reviewed in [41].

GSMaP is a combined dataset from a group of satellites; the first group is low earth orbit(LEO) satellites, and the second is geostationary orbit(GEO) satellites. The LEO satellites provide measurements using the infrared radiometer (IR), while the GEO satellites provide measurements using the microwave radiometer (MWR)(42). The spatial resolution of GSMaP reaches(0.1°X0.1°)and the temporal resolution is up to an hour, and the global coverage is 40 ° N and 40 ° S [43]. More details about this data can be found at[44].

ERA5 is the last generation reanalysis from ECMWF, with spatial resolution (0.1°X0.1°)and temporal accuracy reaching up to hours [45]. ERA5 data covers the whole world and has been available since 1940. More information can be found at[46].

The six precipitation data sources (CHIRPS, TRMM, IMERG, GSMaP, PERSIANN-CDR, and ERA5) were accessed using the Google Earth Engine (GEE) platform (https://earthengine.google.com/).

Accuracy Evaluation

Statistical Metrics

Precipitation data from six global databases were evaluated using statistical metrics, including the Pearson's Correlation Coefficient (CoC), Mean Error (ME), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Bias (BIAS). They are the most commonly used statistical measures in many studies[24,25,29,31,47] . Note equations Eq.1 through Eq.5.

$$CoC = \frac{\sum_{i=1}^{n}(P-p^{-})(O-O^{-})}{\sqrt{\sum_{i=1}^{n}(P-p^{-})^{2}\ \sum_{i=1}^{n}(O-O^{-})^{2}}} \quad (1)$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}(P-O) \quad (2)$$

$$RESE = \sqrt{\frac{\sum_{i=1}^{n}(P-O)^{2}}{n}} \quad (3)$$

$$\mathrm{MAE} = \frac{1}{n}.\sum_{i=1}^{n}|P-O| \quad (4)$$

$$\mathrm{BIAS} = \frac{\sum_{i=1}^{n}(P)}{\sum_{i=1}^{n}(O)} \quad (5)$$

The symbols P and O refer to precipitation observations from satellites or reanalysis data, while the symbol O indicates precipitation observations from gauges at GWSs.

Data Quality Metrics

Statistical measures, as the above equations clearly show, are sensitive to the number of observations. Another alternative to evaluate the accuracy of precipitation measurements from RE techniques/reanalyzed data is to use the Probability of Detection (POD), the False Alarm Ratio (FAR), and the Critical Success Index (CSI). Note the equations Eq.6 to Eq. 8.

$$POD = \frac{a}{a+c} \quad (6)$$

$$FAR = \frac{b}{a+b} \quad (7)$$

$$CSI \frac{a}{a+b+c} \quad (8)$$

Where **a** represents the number of times or events that rainfall occurred and was measured from the ground station and satellite/reanalysis data. The symbol **b** indicates the number of times or occurrence of rain recorded by satellite/reanalysis data only, while the symbol **c** indicates the number of times that GWSs record rainfall only, without being recorded by RE/reanalysis data [48,49]. See Table 3.

POD, FAR CSI are measures of the quality of precipitation data obtained from RE/reanalysis data. Their value ranges from zero to one. When the POD value approaches one, it means that the RE/reanalysis data is good at estimating the occurrence of rain. And vice versa, if the FAR value approaches zero, this means that the RE/reanalysis data is good at capturing the occurrence of rain. When the value of CSI approaches one, this means that the RE/reanalysis data is better at assessing the occurrence of precipitation. CSI is an index that can be used to compare the quality of the six precipitation data collected in the Dhi Qar Governorate, in addition to using the rest of the quality measures to review the quality of that data.

Table 3. shows the meanings of the symbols used in the precipitation data quality metrics.

The symbol	Rainfall was measured at GWSs	Rainfall measured by RE/reanalysis
a	Yes	Yes
b	NO	Yes
c	Yes	No

Results and Discussion

The comparison of monitoring dates between GWSs and RE/reanalyzed data resulted in 2,529 matched observations of TRMM at Al-Chibayish, marking the highest number of matched observations for this station. Other stations recorded fewer matches, with 2,100 observations at Suq Al-Shuyoukh, 1,083 at Al-Fajer, and 784 at Al-Shatra. See Fig.4.

Comparing the rest of the precipitation data obtained from satellites/reanalyzing data, CHIRPS showed the lowest number of matching observations, which were 634 observations with the highest value at Suq Al-Soyokh station and 214 as the lowest value at Al-Fajer station. The number of matching observations in Al-Shatra, close to Suq Al-

Soyokh station, was 612. While in Al-Chibayish Station, only 520 observations were matched.

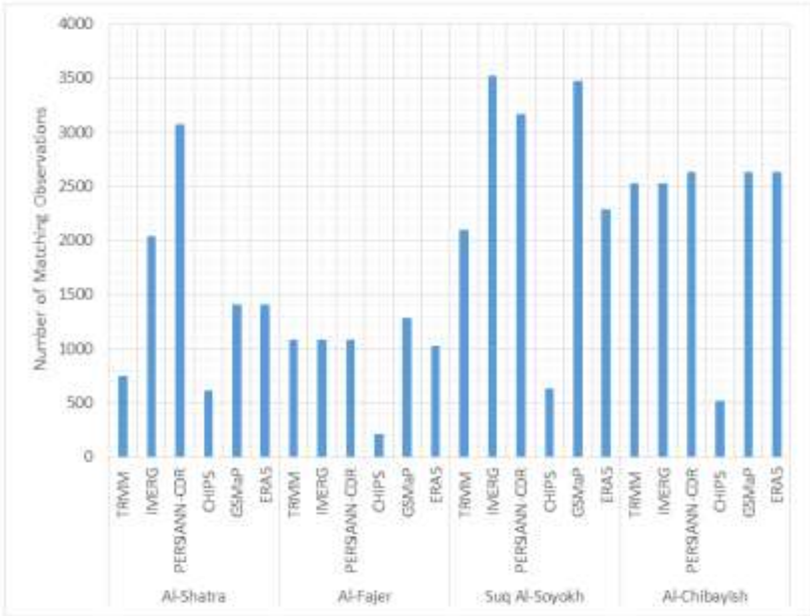

Figure 4. Number of time-matched observations between GWSs and RE/reanalysis data.

IMERG, PERSIANN-CDR, and ERA5 had nearly 2,000 observations at Al-Chibayish Station. On the other hand, Al-Shatra station recorded several similar observations for GSMaP and ERA5 only, with around 1400 observations, while IMERG and PERSIANN-CDR recorded 2037 and 3069 observations, respectively. At Al-Fajr station, the number of IMERG and ERA5 observations is similar and is about one thousand. While GSMaP and PERSIANN-CDR, the number of their observations was 1278 and 1083, respectively, at the same station. Finally, at Suq Al-Soyokh station, the number of observations was 3527, 3164, 3478, and 2291 for IMERG, PERSIANN-CDR, GSMaP, and ERA5, respectively.See Table 4.

GSMaP recorded the lowest RMSE at two stations: 1.52 mm at Suq Al-Soyokh and 1.39 mm at Al-Chibayish. In contrast, ERA5 had the lowest RMSE at the Al-Shatra station, with a value of 1.34 mm. CHIRPS recorded the lowest RMSE at the Al-Fajr station, measuring 0.03 mm. For further details, refer to Fig.5.

The MAE for TRMM, IMERG, and PERSIANN-CDR was 0.57 mm at the Al-Fajr station. Meanwhile, GSMaP showed MAE values ranging from 20 mm to 30 mm at four different stations. CHIRPS had the lowest MAE at the Al-Fajr station, while MERG recorded the highest MAE at Al-Chibayish, with values of 0.03 mm and 1.63 mm, respectively.

Table 4. shows the meanings of the symbols used in the precipitation data quality metrics

GWS	Rainfall data source	RMSR	CoC	N	ME	MAE	BIAS
Al-Shtraa station	TRMM	2.18	0.50	748	-0.19	0.34	0.42
	IMERG	3.37	0.60	2037	0.61	0.73	3.51
	PERSIANN-CDR	1.87	0.45	3069	0.17	0.42	1.71
	CHIPS	3.08	0.85	612	1.19	1.35	7.04
	GSMaP	1.60	0.52	1406	0.00	0.30	1.00
	ERA5	1.34	0.52	1406	0.00	0.16	1.00
Al-Fajr station	TRMM	3.72	0.32	1083	0.45	0.57	2.63
	IMERG	3.72	0.32	1083	0.45	0.57	2.63
	PERSIANN-CDR	3.72	0.32	1083	0.45	0.57	2.63
	CHIPS	0.03	0.30	214	0.03	0.03	7.14
	GSMaP	2.11	0.48	1287	-0.30	0.30	0.00
	ERA5	0.95	0.78	1020	0.04	0.08	1.16
Al-Shuyoukh station	TRMM	1.79	0.29	2100	0.13	0.53	1.46
	IMERG	5.22	0.52	3527	0.94	1.06	4.43
	PERSIANN-CDR	2.57	0.40	3164	0.26	0.52	2.02
	CHIPS	3.29	0.25	634	1.45	1.62	7.19
	GSMaP	1.52	0.60	3478	-0.01	0.28	1.01
	ERA5	1.76	0.55	2291	-0.29	0.29	0.00
Al-Chibaish Station	TRMM	1.96	0.20	2529	0.50	0.80	3.42
	IMERG	4.89	0.40	2529	1.56	1.63	8.48
	PERSIANN-CDR	2.36	0.39	2631	0.40	0.53	2.53
	CHIPS	2.65	0.14	520	1.18	1.33	7.73
	GSMaP	1.39	0.52	2631	-0.06	0.22	0.70
	ERA5	1.55	0.60	2631	-0.16	0.16	0.00

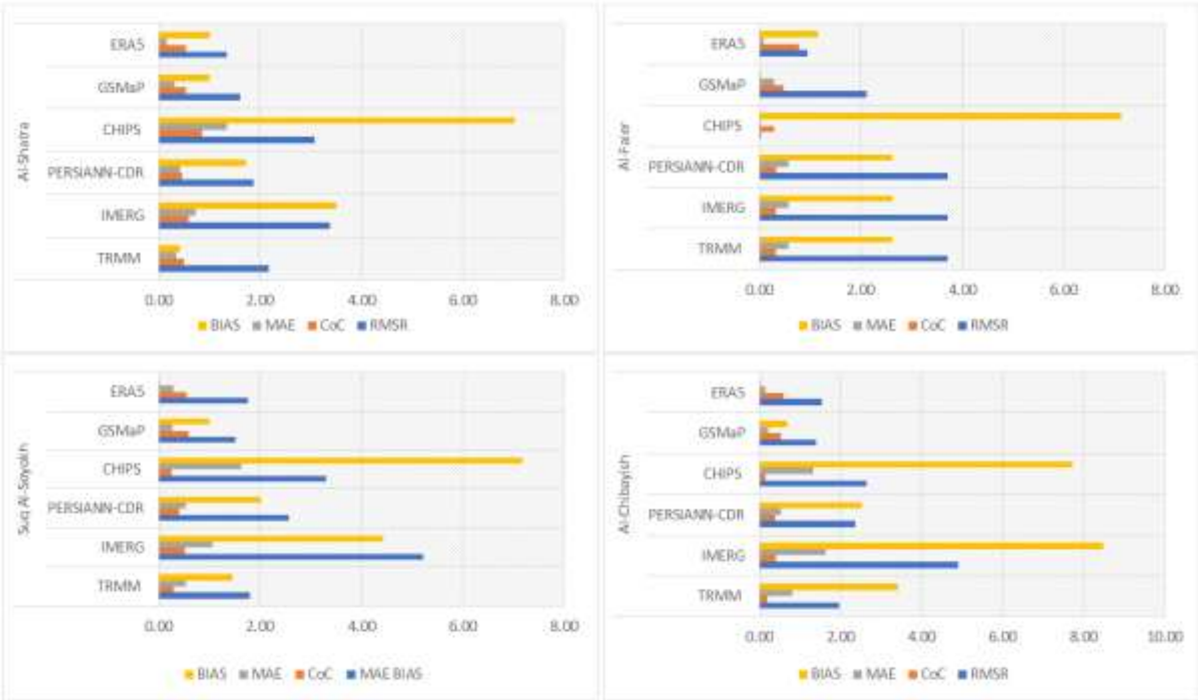

Figure 5. Statistical metrics for different precipitation data sources in four GWSs

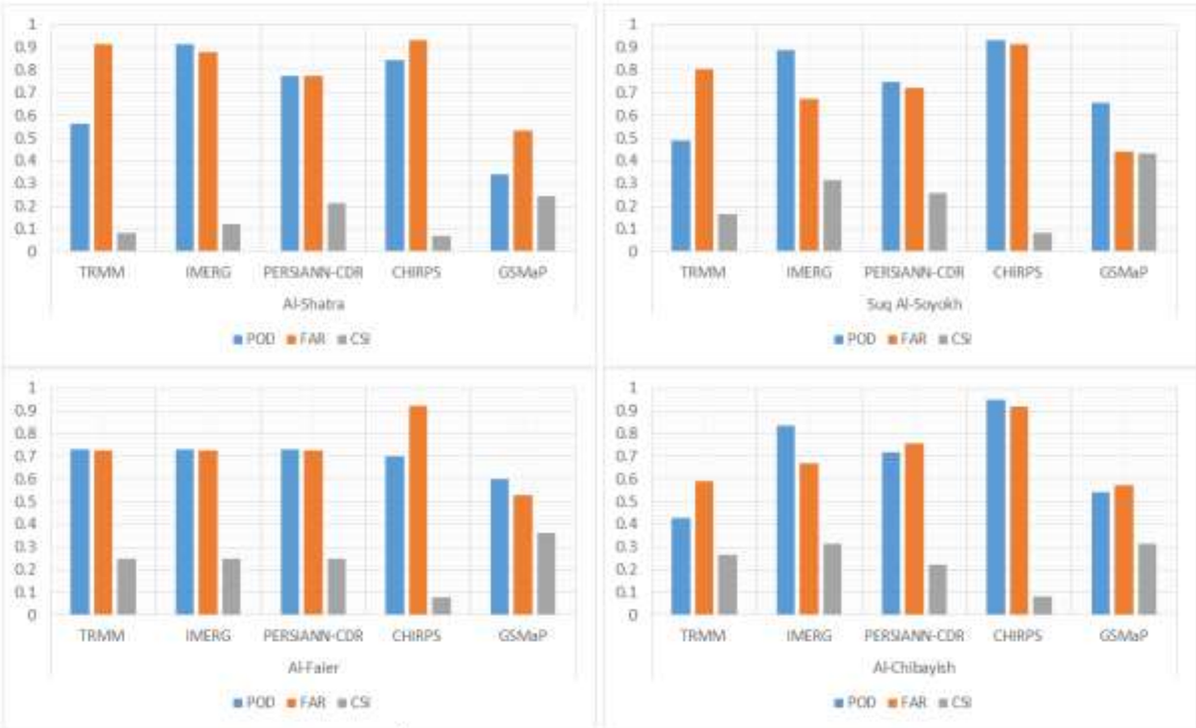

Figure 5. Quality metrics for different precipitation data sources in four GWS

The best CoC value was for CHIRPS at Al-Shatra station, ERA5 at Al-Fajr, Al-Chibayish, and GSMaP at Suq Al-Soyokh. The ERA5 precipitation reading bias value is close to zero at the Suq Al-Soyokh and Al-Chibayish stations. On the other hand, the value of the bias precipitation reading was one for GSMaP and ERA5 at Al-Shatra station. Unlike Al-Shatra station, GSMaP recorded a bias value approaching zero at Al-Fajr station.

In four GWSs, ERA5 did not record any quality measure. The value of CSI varied across the five data sets, with the highest value recorded at Suq Al-Soyokh station (0.41

for GSMaP) and the lowest at Al-Shatra station (0.07 for CHIRPS). The highest FAR was observed with CHIRPS data at Al-Shatra station, reaching a value of 0.92, while the lowest FAR was noted at Suq Al-Soyokh station for GSMaP data, which had a value of 0.44.CHIRPS demonstrated the highest POD compared to the other data sets at both Suq Al-Soyokh and Al-Chibayish stations. IMERG achieved the best POD at Al-Shatra station, while POD values were equal for TRMM, IMERG, and PERSIANN-CDR at Al-Fajr station. See Fig.5.

CONCLUSIONS

Fundamental Finding: The findings indicate that CHIRPS data can serve as an effective alternative to GWSs for studying drought and hydrology. In this context, CHIRPS ranks first, followed by TRMM and then IMERG. This validation was based on quality metrics rather than purely statistical metrics. While ERA5 statistically achieves the best results, it has the lowest quality in terms of precipitation data. **Implication:** Based on the above, we conclude that quality measures are better at verifying the validity of data when it comes to temporal and numerical discrepancies between GWSs and RE techniques/reanalyzed data, as these measures are not sensitive to the number of observations. **Limitation:** Data validation using statistical measurements conducted under conditions of variability and unequal observations at the four precipitation measuring stations provides an inaccurate representation of the rainfall data from RE techniques/reanalyzed data. **Future Research:** For future work and to verify the results in other Iraqi regions, and to integrate with hydrological models, we recommend following the statistical method and quality metrics ،and use CHIRPS in national drought monitoring programs, integrating with Iraqi meteorological services.

REFERENCES

[1] M. Aboukota, H. Hassaballa, M. Elhini, and G. Shimaa, "Land degradation, desertification & environmental sensitivity to climate change in Alexandria and Beheira, Egypt," *Egypt. J. Soil Sci.*, vol. 64, pp. 167–180, Mar. 2024.

[2] F. Paredes *et al.*, "Impact of drought on land productivity and degradation in the Brazilian semiarid region," *Land*, vol. 12, no. 5, p. 954, Mar. 2023.

[3] R. M. Brasil Neto, C. A. G. Santos, R. M. da Silva, C. A. C. dos Santos, Z. Liu, and N. W. Quinn, "Geospatial cluster analysis of the state, duration and severity of drought over Paraíba State, northeastern Brazil," *Sci. Total Environ.*, vol. 799, p. 149492, 2021.

[4] D. C. Refati *et al.*, "Influence of drought and anthropogenic pressures on land use and land cover change in the brazilian semiarid region," *J. S. Am. Earth Sci.*, vol. 126, p. 104362, 2023.

[5] A. M. El Kenawy *et al.*, "Evidence for intensification of meteorological droughts in Oman over the past four decades," *Atmos. Res.*, vol. 246, p. 105126, 2020.

[6] A. H. A. Suliman, T. A. Awchi, M. Al-Mola, and S. Shahid, "Evaluation of remotely sensed precipitation sources for drought assessment in Semi-Arid Iraq," *Atmos. Res.*, vol. 242, p. 105007, 2020.

[7] L. Diaz, A. Romero, and J. Vega, "Drought assessment in the northern region of Colombia using the Standardized Precipitation Index (SPI): A case study in the department of La Guajira," 2021.

[8] S. Chen, T. Y. Gan, X. Tan, D. Shao, and J. Zhu, "Assessment of CFSR, ERA-Interim, JRA-55, MERRA-2, NCEP-2 reanalysis data for drought analysis over China," *Clim. Dyn.*, vol. 53, Mar. 2019.

[9] R. Albarakat, M. H. Le, and V. Lakshmi, "Assessment of drought conditions over Iraqi transboundary rivers using FLDAS and satellite datasets," *J. Hydrol. Reg. Stud.*, vol. 41, p. 101075, 2022.

[10] I. Alwan, A. Ziboon, A. Khalaf, Q. Pham, D. Tran Anh, and K. Khedher, "Monitoring agricultural and meteorological drought using remote sensing," *Arab. J. Geosci.*, vol. 15, Apr. 2022.

[11] N. Muhaisen, T. Khayyun, and M. Al-Mukhtar, "Drought forecasting model for future climate change effects in a regional catchment area in northern iraq," *Eng. Technol. J.*, vol. 42, no. 5, pp. 525–539, 2024.

[12] I. Alwan, A. R. Ziboon, and A. Khalaf, "Monitoring of agricultural drought in the Middle Euphrates area, Iraq using Landsat dataset," *Eng. Technol. J.*, vol. 37, no. 7A, pp. 222–226, 2019.

[13] A. M. Dehaghani, A. Gohari, M. J. Zareian, and A. Torabi Haghighi, "A comprehensive evaluation of the satellite precipitation products across Iran," *J. Hydrol. Reg. Stud.*, vol. 46, p. 101360, 2023.

[14] H. Jiang *et al.*, "Characterizing precipitation uncertainties in a high-altitudinal permafrost watershed of the Tibetan plateau based on regional water balance and hydrological model simulations," *J. Hydrol. Reg. Stud.*, vol. 47, p. 101445, 2023.

[15] Q. You, K. Fraedrich, G. Ren, B. Ye, X. Meng, and S. Kang, "Inconsistencies of precipitation in the eastern and central Tibetan Plateau between surface adjusted data and reanalysis," *Theor. Appl. Climatol.*, vol. 109, no. 3, pp. 485–496, 2012, doi: 10.1007/s00704-012-0594-1.

[16] N. Rasheed, M. Al-Khafaji, and I. Alwan, "Variations of streamflow and sediment yield in the Mosul-Makhool Basin, North of Iraq under climate change: A pre-dam construction study," *H2Open J.*, vol. 7, Apr. 2023.

[17] Z. Kadhim, T. Khayyun, and I. Alwan, "Impact of climate change on crops productivity using MODIS-NDVI time series," *Civil Eng. J.*, vol. 8, p. 1136, Jun. 2022.

[18] I. Hatem, I. Alwan, A. Ziboon, and A. Kuriqi, "Assessment of agricultural drought in Iraq employing Landsat and MODIS imagery," *Open Eng.*, vol. 14, p. 20220583, Apr. 2024.

[19] M. M. Al-Mukhtar and G. S. Mutar, "Modelling of future water use scenarios using WEAP model: A case study in Baghdad City, Iraq," *Eng. Technol. J.*, vol. 39, no. 3A, pp. 488–503, 2021.

[20] B. Nabit, R. Al-Anbari, and I. Alwan, "Identifying suitability rainwater harvesting zones in Diyala Watershed, Iraq, using multi-criteria analysis and GIS modelling," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1158, p. 022036, Apr. 2023.

[21] B. Al-Shammari, R. Al-Anbari, and I. Alwan, "Analysis of water harvesting structures sites appropriateness using GIS-based methodology: Diyala, Iraq, as a case study," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1215, p. 012048, Apr. 2023.

[22] J. Ma, H. Li, J. Wang, X. Hao, D. Shao, and H. Lei, "Reducing the statistical distribution error in gridded precipitation data for the Tibetan Plateau," *J. Hydrometeorol.*, vol. 21, no. 11, pp. 2641–2654, 2020, doi: 10.1175/JHM-D-20-0096.1.

[23] M. W. Lubczynski, M. Leblanc, and O. Batelaan, "Remote sensing and hydrogeophysics give a new impetus to integrated hydrological models: A review," *J. Hydrol.*, vol. 633, p. 130901, 2024.

[24] J. Ma, H. Li, J. Wang, X. Hao, D. Shao, and H. Lei, "Reducing the statistical distribution error in gridded precipitation data for the Tibetan Plateau," *J. Hydrometeorol.*, vol. 21, no. 11, pp. 2641–2654, 2020.

[25] Z. Kadhim, T. Khayyun, and I. Alwan, "Integrated approach for precipitation assessment in different topography of Iraq," vol. 2, pp. 1–22, Mar. 2023.

[26] X. Xu, S. K. Frey, and D. Ma, "Hydrological performance of ERA5 and MERRA-2 precipitation products over the Great Lakes Basin," *J. Hydrol. Reg. Stud.*, vol. 39, p. 100982, 2022.

[27] G. Tang, M. P. Clark, S. M. Papalexiou, Z. Ma, and Y. Hong, "Have satellite precipitation products improved over last two decades? A comprehensive comparison of GPM IMERG with nine satellite and reanalysis datasets," *Remote Sens. Environ.*, vol. 240, p. 111697, 2020.

[28] H. L. Shah and V. Mishra, "Uncertainty and bias in satellite-based precipitation estimates over Indian subcontinental basins: Implications for real-time streamflow simulation and flood prediction," *J. Hydrometeorol.*, vol. 17, no. 2, pp. 615–636, 2016.

[29] F. Peng, S. Zhao, C. Chen, D. Cong, Y. Wang, and H. Ouyang, "Evaluation and comparison of the precipitation detection ability of multiple satellite products in a typical agriculture area of China," *Atmos. Res.*, vol. 236, p. 104814, 2020.

[30] Y. Yang *et al.*, "Assessing satellite and reanalysis-based precipitation products in cold and arid mountainous regions," *J. Hydrol. Reg. Stud.*, vol. 51, p. 101612, 2024.

[31] S. Chen, L. Zhang, Y. Zhang, M. Guo, and X. Liu, "Evaluation of Tropical Rainfall Measuring Mission (TRMM) satellite precipitation products for drought monitoring over the middle and lower reaches of the Yangtze River Basin, China," *J. Geogr. Sci.*, vol. 30, pp. 53–67, Mar. 2020.

[32] D. Zanaga *et al.*, "ESA WorldCover 10 m 2020 v100," Zenodo, 2021, doi: 10.5281/zenodo.5571936.

[33] C. Kummerow, W. Barnes, T. Kozu, J. Shiue, and J. Simpson, "The Tropical Rainfall Measuring Mission (TRMM) sensor package," *J. Atmos. Ocean. Technol.*, vol. 15, pp. 809–817, Mar. 1998.

[34] J. Simpson, R. F. Adler, and G. R. North, "A proposed Tropical Rainfall Measuring Mission (TRMM) satellite," *Bull. Amer. Meteorol. Soc.*, vol. 69, no. 3, pp. 278–295, 1988.

[35] H. H. Gu, Z. B. Yu, C. G. Yang, Q. Ju, B. H. Lu, and C. Liang, "Hydrological assessment of TRMM rainfall data over Yangtze River Basin," *Water Sci. Eng.*, vol. 3, no. 4, pp. 418–430, 2010.

[36] S. H. Jiang, L. Y. Wei, L. L. Ren, L. Q. Zhang, M. H. Wang, and H. Cui, "Evaluation of IMERG, TMPA, ERA5, and CPC precipitation products over mainland China: Spatiotemporal patterns and extremes," *Water Sci. Eng.*, vol. 16, no. 1, pp. 45–56, 2023.

[37] G. J. Huffman *et al.*, "Integrated multi-satellite retrievals for the Global Precipitation Measurement (GPM) Mission (IMERG)," in *Satellite Precipitation Measurement: Volume 1*, V. Levizzani, C. Kidd, *et al.*, Eds. Cham, Switzerland: Springer, 2020, pp. 343–353, doi: 10.1007/978-3-030-24568-9_19.

[38] A. Y. Hou *et al.*, "The Global Precipitation Measurement Mission," *Bull. Amer. Meteorol. Soc.*, vol. 95, no. 5, pp. 701–722, 2014.

[39] H. Ashouri *et al.*, "PERSIANN-CDR: Daily precipitation climate data record from multisatellite observations for hydrological and climate studies," *Bull. Amer. Meteorol. Soc.*, vol. 96, no. 1, pp. 69–83, 2015.
[40] D. Touma, "The Climate Data Guide: CHIRPS: Climate Hazards InfraRed Precipitation with Station data (version 2)," 2023.
[41] C. Funk *et al.*, "The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes," *Sci. Data*, vol. 2, no. 1, p. 150066, 2015, doi: 10.1038/sdata.2015.66.
[42] Q. Fu, R. Ruan, and Y. Liu, "Accuracy assessment of Global Satellite Mapping of Precipitation (GSMaP) product over Poyang Lake Basin, China," *Procedia Environ. Sci.*, vol. 10, pp. 2265–2271, 2011.
[43] K. Okamoto, T. Ushio, T. Iguchi, N. Takahashi, and K. Iwanami, "The Global Satellite Mapping of Precipitation (GSMaP) project," in *Proc. IEEE Int. Geosci. Remote Sens. Symp. (IGARSS)*, 2005, pp. 3414–3416.
[44] T. Kubota *et al.*, "Global precipitation map using satellite-borne microwave radiometers by the GSMaP project: Production and validation," *IEEE Trans. Geosci. Remote Sens.*, vol. 45, no. 7, pp. 2259–2275, 2007.
[45] D. Dalla Torre, N. Di Marco, A. Menapace, D. Avesani, M. Righetti, and B. Majone, "Suitability of ERA5-Land reanalysis dataset for hydrological modelling in the Alpine region," *J. Hydrol. Reg. Stud.*, vol. 52, p. 101718, 2024.
[46] H. Hersbach *et al.*, "ERA5 hourly data on single levels from 1940 to present," ECMWF Climate Data Store (CDS), 2023.
[47] A. H. A. Suliman, T. A. Awchi, M. Al-Mola, and S. Shahid, "Evaluation of remotely sensed precipitation sources for drought assessment in Semi-Arid Iraq," *Atmos. Res.*, vol. 242, p. 105007, 2020.
[48] E. E. Ebert, "Methods for verifying satellite precipitation estimates," in *Measuring Precipitation From Space: EURAINSAT and the Future*, V. Levizzani, P. Bauer, and F. J. Turk, Eds. Dordrecht, Netherlands: Springer, 2007, pp. 345–356.
[49] D. S. Wilks, *Statistical Methods in the Atmospheric Sciences*, 3rd ed. San Diego, CA, USA: Academic Press, 2011.

Mohammed Azeez
Department of Surveying, Shatrah Technical Institute (STI), Southern Technical University (STU), Shatrah, Iraq
Email: mohammed.aziz@stu.edu.iq

Hisham M.Jawad Al Sharaa
Department of Civil Engineering, College of Engineering, University of Technology, Baghdad, Iraq
Email: Hisham.M.AlSharaa@uotechnology.edu.iq

Abdul Razzak T.Zboon
Department. Of Building and Construction Technology, Al-Esraa University, Baghdad, Iraq
Email: dr.abdulrazzak@esraa.edu.iq