COMPARISON OF RAINFALL DATA FROM HYDROLOGICAL STATIONS AND SATELLITES ON HARRIROD-MORGHAB RIVER BASIN

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Abstract

Rainfall has direct impact on life and economy of the people in an agricultural country like Afghanistan. High amount of rainfall causes floods and as a result of that, destruction of houses and agricultural lands and low rainfall causes drought and loss of plants. Measurement of rainfall in a water zone is very important for studying of water cycle, water management, floods identification, agricultural activities and etc.

Due to economic and security problems in Afghanistan, there are no enough hydrological stations to measure the rainfall in the most parts of the country. Despite, most of the rainfall data from existing stations is not available from the years 1980 to 2008. Also, the data of the hydrological stations are not readily available publicly. Fortunately, with the advancement of science and technology, today there are several satellites that can accurately record information on rainfall and other atmospheric processes. Data from remote sensing method is freely available and easily accessible to everyone in the world. In this study, the accuracy and reliability of the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) has been investigated and further research has been done to investigate the cause of the errors in order to minimize the difference between satellite estimation and observed rainfall data in hydrological stations. As a result, it was found that there is a good relationship between the rainfall data that estimated by CHIRPS and the rainfall data from hydrological stations at monthly level in the Harrirod-Morghab river basin; but precipitation that has obtained from CHIRPS is slightly higher than obtained data from hydrological stations.

Keywords

Rain gauge observation, Satellite-based precipitation, Harrirod-Morghab River Basin

Introduction

Afghanistan is a land surrounded country with high mountains and having arid and semi arid climate. The annual precipitation in this country is little. In the last several years due to human activities the global climate has changed; because of this the type and amount of precipitations have changed as well. The accurate measurement of rainfall is much needed in the field of climate researches, draught forecasting, irrigation and natural disasters management. As Rain Gauge stations are outspreaded and its data is not easily available. So in this case; there should be another alternative for the estimation of the rainfall data. Nowadays this problem has solved by satellites or remote sensing methods. Satellites can estimate rainfall in mountainous and broad area that can motivate researchers more and more to use this method in their researches. Before the using of the satellites rainfall data in the specific part of the earth; the satellite data should be compared with observed data in the hydrological stations and it should be calibrated as much as possible. There are deferent satellites for the estimation of rainfall like: CHRIPS, MPE, TAMSAT, GPM, TRMM & CMORPH. Considering the importance of researches in the water sector and absence of enough rain gauges in the several parts of Afghanistan the using of satellite data is much needed. As the accuracy of the deferent satellites in the deferent basins is not the same; therefore it is required to check the accuracy of deferent models in deferent basins. In this research the accuracy of Climate Hazards Group InfraRed Precipitation with Station Data (CHRIPS) has been checked in Harrirod-Morghab River Basin of Afghanistan. The rainfall data from CHIRPS uses in the prediction of drought as well. Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) product is a 35+ year quasi-global rainfall data set that gives data since 1981. Estimating rainfall variations in space and time is a key aspect of drought early warning and environmental monitoring. An evolving drier-than-normal season must be placed in a historical context so that the severity of rainfall deficits can be quickly evaluated. However, estimates derived from satellite data provide areal averages that suffer from biases due to complex terrain, which often underestimate the intensity of extreme precipitation events. Conversely, precipitation grids produced from station data suffer in more rural regions where there are less rain-gauge stations. CHIRPS was created in collaboration with scientists at the USGS Earth Resources Observation and Science (EROS) Center in order to deliver complete, reliable, up-to-date data sets for a number of early warning objectives, like trend analysis and seasonal drought monitoring.

Research Location

This research has been conducted in Harrirod-Morghab River basin which has located in the north-west part of Afghanistan. The river basin has border with Turkmanistan in its north side; with Iran in its west side; Furthermore, the basin has border with Qala-e-naw, Qades, Aab Kamari and Jawand Districts of Badghis province in its north east side; it has border with Saghar, Taiwara, Pasaband and Chighcheran districts of Ghor province of Afghanistan in its east side; Also it has border in the south with Khak-e-Safid, Balablook and Aanar Dara districts of Farah province of Afghanistan.

Harirod-Morghab River Basin has 77604 Km^2 area and 1,722,275 population of Afghanistan live in this basin. This River Basin has four main watersheds that consists of: Bala Murghab, Koshak and Kashaan, Upper Harrirod and Lower Harrirod watersheds.

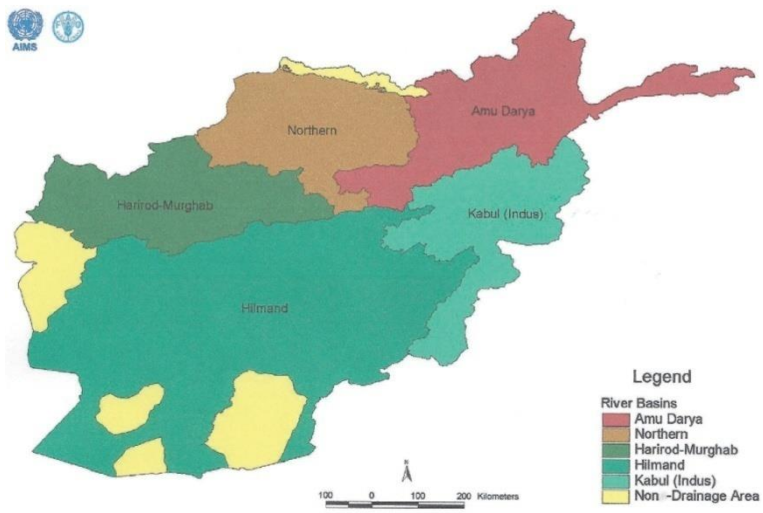

Fig. 1. Afghanistan River Basins Map

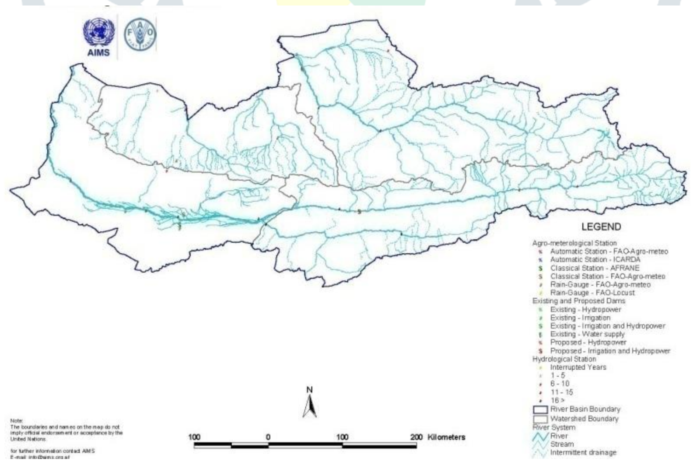

Fig. 2. Harrirod-Morghab River Basin

Research Objectives

- The evaluation of accuracy of rainfall data from satellites and its comparison with rainfall data from hydrological stations in Harrirod-Morghab river basin.
- Precipitation data gap filling the years 1980 to 2008 in all Afghanistan river basins using CHIRPS
- Evaluation of current rain gauge network in Harrirod-Morghab River Basin

Literature Review

Rain gauge is a type of instrument used by meteorologists and hydrologists to measure rainfall rate in a certain period of time. Rain gauges are also known as udometer, pluviometer and ombrometer.

Types of Rain Gauges
1. Non-Recording Type Rain Gauge
Example – Symons Rain Gauge

Non-recording type rain gauge is most common type of rain gauge used by meteorological department. It consists of a cylindrical vessel 127mm in diameter with a base enlarged to 210mm diameter.

At its top section, funnel is provided with circular brass rim which is 127mm exactly so that it can fit into vessel well. This funnel shank is inserted in the neck of a receiving bottle which is 75 to 100mm high from the base section and thinner than the cylinder, placed into it to receive rainfall.

A receiving bottle has capacity of 100mm and during heavy rainfall, amount of rain is frequently exceeded, so the reading should be measured 3 to 4 times in a day. Water contained in this receiving bottle is measured by a graduated measuring glass with accuracy up to 0. 1mm. For uniformity the rainfall is measured every day at 8:30Am IST and is recorded as rainfall of the day.

Proper care, maintenance and inspection of rain gauge especially during dry weather are necessary to keep the instrument free form dust and dirt, so that the readings are accurate.

2. Recording Type Rain Gauges
There are three types of recording rain gauges

a) Weighing bucket type

b) Tipping bucket type

c) Floating or natural siphon type rain gauge

Weighing Bucket Type Rain Gauge
Weighing bucket type rain gauge is most common self-recording rain gauge. It consists of a receiver bucket supported by a spring or lever balance or some other weighing mechanism. The movement of bucket due to its increasing weight is transmitted to a pen which traces record or some marking on a clock driven chart.

Weighing bucket type rain gauge instrument gives a plot of the accumulated (increased) rainfall values against the elapsed time and the curve so formed is called the mass curve.

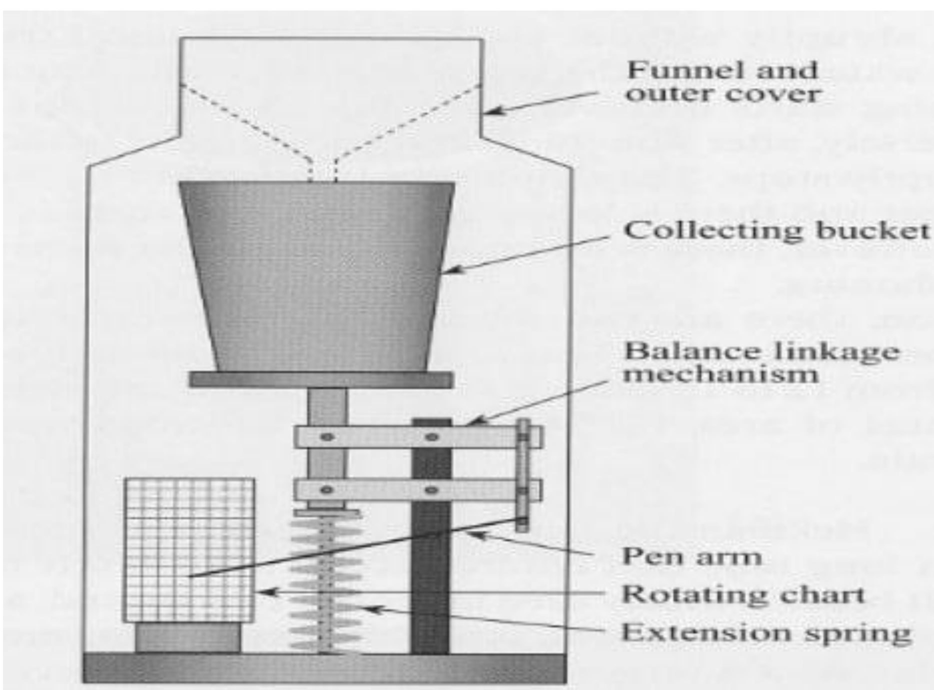

Fig. 3 Weighing Bucket Type Rain Gauge

Tipping Bucket Type Rain Gauge
Tipping bucket type rain gauge is a 30cm sized circular rain gauge adopted for use by US weather bureau. It has 30cm diameter sharp edged receiver and at the end of the receiver is provided a funnel.

Pair of buckets are pivoted under this funnel in such a manner that when one bucket receives 0.25mm of precipitation (rainfall),it tips discharging its rainfall into the container, bringing the other bucket under the funnel.

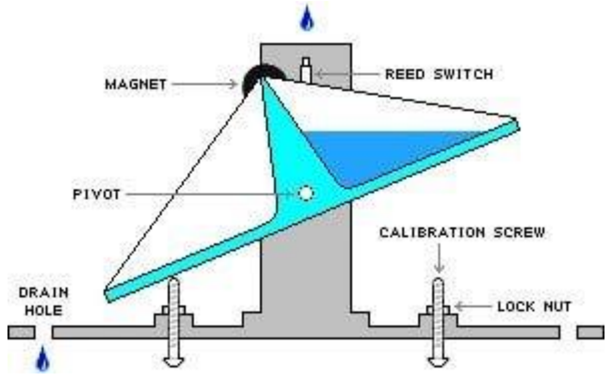

Fig. 4 Tipping Bucket Rain Gauge

Tipping of bucket completes an electric circuit causing the movement of pen to mark on clock driven receiving drum which carries a recorded sheet. These electric pulses generated are recorded at the control room far away from the rain gauge station. This instrument is further suited for digitalizing the output signal[13].

Floating or Natural Siphon Type Rain Gauge

The working of this type of rain gauge is similar to weighing bucket rain gauge. A funnel receives the water which is collected in a rectangular container. A float is provided at the bottom of container, and this float rises as the water level rises in the container; Its movement being recorded by a pen moving on a recording drum actuated by a clock work.

Fig. 5 Natural Siphon or Float Type Rain Gauge

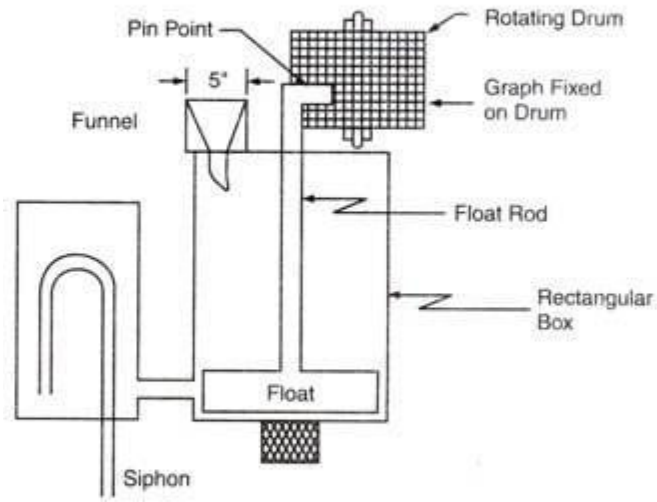

Fig. 6 Natural Siphon or Float Type Rain Gauge Details

When water rises, this float reaches to the top floating in water, and then siphon comes into operation and releases the water outwards through the connecting pipe, thus all water in box is drained out. This rain gauge is adopted as the standard recording rain gauge in India and the curve drawn using this data is known as mass curve of rain fall.

Remote Sensing Estimation:

A. Inactive Techniques

Remote sensing estimation with visible sensors, INFRARED and microwave sensors.

B. Active Techniques

Remote Sensing active Estimation is including spatial and earth methods. TRMM consist of rainfall radar which created in 1977 and it has 13.8GHz accuracy.

There are four methods for remote sensing estimation rainfall data that consist of:

1. Cloud model-based technique
2. Life-historical methods
3. Bispectrality
4. Cloud indexing method

Rainfall measurement using remote sensing method is useful for following activities:

Water availability, climate change analyzes, forecasting, Hydrological disaster, Water management & precision agriculture.

Precipitation data from CHIRIPS model

CHIRIPS created in United State Department of Geology Survey (USGS) and Earth Resources Observation Center (EROS) for prompt warning of some natural disaster like draught.

There is a lot of researches have done in the field of satellite precipitation data and observed precipitation data comparison in around the world; it have showed deferent consequences; for example Moctar Dembélé & Sander J. Zwart has done a research under title of Evaluation and comparison of satellite-based rainfall products in Burkina Faso in West Africa; Hieu Thi Bui1 · Hiroshi Ishidaira2 · Ning Shaowei3 has done research in this field under title of Evaluation of the use of global satellite–gauge and satellite- only precipitation products in stream flow simulation; KORAY K. YILMAZ, TERRI S. HOGUE, KUO-LIN HSU AND SOROOSH SOROOSHIAN, HOSHIN V. GUPTA, THORSTEN WAGENER have done the research in this field under the title of Intercomparison of Rain Gauge, Radar, and Satellite-Based Precipitation Estimates with Emphasis on Hydrologic Forecasting. All of mentioned researches have deferent methodology and results that these methods and results have considered at this research as well.

Research Methodology

The precipitation data have downloaded from CHIRPS website for the period of (2013 to 2014). The data has extracted to the specified location of hydrological station in Harirod-Murghab river basin through Arc GIS. The CHIRPS data is compared with the observed data in each hydrological station and the comparative graphs have prepared for this. The number of mistakes for accuracy assessment of models is including mean bias error (MBE), root mean square error (RMSE) and coefficient of variation (CV). The little amount of MBE, RSME and CV shows the accuracy of satellite data.

$$MBE = \frac{\sum_{t=1}^{T}(P^{Obs} - P^{est})}{\sum_{t=1}^{T} P^{Obs}} x100\ \% \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$RMSE = \sqrt{\frac{\sum_{t=1}^{T}(P^{Obs} - P^{est})^2}{T}} \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

$$CV - RMSE = \frac{RMSE}{\left(\frac{\sum_{t=1}^{T} P^{obs}}{T}\right)} x100 \ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

For better evaluation of accuracy of rainfall data from CHIRPS in this basin; the average monthly rainfall data from thirteen meteorological stations from 2008 up to 2017 have been used:

Table 1 Specification of Hydrological Stations on Harrirod-Morghab River Basin

NO	Station Name	Sub Basin	Province	River	Longitude	Latitude	Elevation
1	Chehel Dukhtaraan	Kashak and Kashaan	Herat	Kashak	62.31555	35.121347	773
2	Torghondy	Kashak and Kaashan	Herat	Kashak	62.282842	35.252925	673
3	Shinia	Upper Harrirod	Ghor	Laal	65.668819	34.508047	2407
4	DahaneZolfeqar	Lower Harrirod	Herat	Harrirod	61.189372	35.291864	615
5	TeerPul	Lower Harrirod	Herat	Harrirod	61.258342	34.605094	746
6	KhoshRabaat	Lower Harrirod	Herat	Sanjaab	62.094522	34.644272	1303
7	Pule Hashimi	Lower Harrirod	Herat	Harrirod	61.936556	34.340703	865
8	Near Herat	Lower Harrirod	Herat	Karokh	62.44585	34.419	1140
9	RabaateAkhond	Lower Harrirod	Herat	Harrirod	62.944228	34.259533	1183
10	TangeeAzoo	Upper Harrirod	Ghor	Kawgaan	64.208531	34.128511	2312
11	TagaabGhaza	Upper Harrirod	Herat	Harrirod	63.756889	34.337303	1519
12	Cheghcheraan	Upper Harrirod	Ghor	Harrirod	65.253572	34.522275	2259
13	Dawlatyaar	Upper Harrirod	Ghor	Harrirod	65.754119	34.547153	2435

The average monthly rainfall data that collected from 13 stations that have located in the Harrirod-Morghab River basin for years of 2013 and 2014 are as following:

Table 2 Average Monthly Rainfall in mm in Hydrological Stations of Harrirod-Morghab River Basin

Station Name	January	February	March	April	May	June	July	August	September	Auctober	November	December
Chehel Dukhtaraan	12.4	42.9	31.3	21.1	6.7	0.2	1.13	1.32	0.64	1.6	33.9	13.7
Torghondy	13.5	38.7	35	24.2	4.7	0.3	0.4	0.8	0.8	2.6	34.2	19.2
Shinia	7.2	21.3	52.8	52.5	28.3	15.1	3.8	1.4	0.7	7.8	32.4	10.1
Dahane Zulfeqar	9.1	16.7	43.2	23.3	5.5	6.5	1.4	1.4	1.5	3.6	22.1	8.2
Teerpul	9.1	16.7	43.2	23.3	5.5	6.5	1.4	1.4	1.5	3.6	22.1	8.2
Khosh Rabaat	20.7	89.5	38.3	22.1	2.2	0.7	0	0.2	0.35	3.9	62.3	12.8
Pule Hashimi	11.5	43	26.5	19.9	5.8	13.7	0	0	0	3.2	27.8	4.1
Near Herat	17.2	54.6	26.8	21.6	0	0	0	0	0	0	28.9	19.7
Rabate Akhond	11.3	47.1	27.6	17.9	8.6	0	1.4	0.5	0.4	0.6	33.6	8.1
Tangee	8.9	50.9	27.6	17.9	23.4	1.9	0	0.6	0.4	1.1	30.9	10.6

Azoo												
Tagaab Ghaza	10.1	49	27.6	17.9	16.8	1.9	1.4	0.5	0.4	1	26.9	6.4
Cheghcheran	5.3	19.5	44.9	42.5	24.4	1.8	0.3	1.31	2.1	6	20.6	7.7
Dawlatyaar	9.5	24.8	44	59.5	23.7	3.8	1.7	1.4	1.4	8.1	25.8	7.8

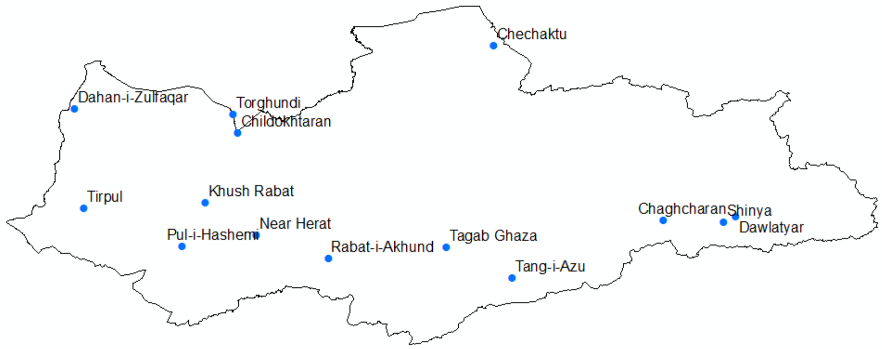

Fig. 7 Location of Hydrological Stations in Harrirod-Morghab River Basin

Table 3 Average Monthly Rainfalls in mm in Hrrirod-Morghab River Basin Estimated by CHIRPS

Station Name	January	February	March	April	May	June	July	August	September	October	November	December
Torghondi	25.8	40.5	84.8	30.5	5.2	0.4	0.0	0.0	0.2	1.2	17.9	18.0
Dahane Zulfeqar	26.5	32.1	62.4	31.5	4.3	0.4	0.0	0.2	1.4	5.8	21.3	17.4
Chehel Dukhtaran	28.4	41.6	88.4	30.9	8.5	0.6	0.0	0.0	0.2	0.9	19.7	19.8
Shinia	25.4	53.0	48.5	64.9	24.3	2.3	2.5	0.8	0.9	13.4	32.7	13.0
Teerpul	24.3	36.4	56.7	21.4	7.2	0.4	0.0	0.1	0.9	2.5	23.8	14.5
Khosh Rabaat	31.4	48.8	63.8	25.2	8.1	0.4	0.0	0.1	0.4	1.9	22.1	16.8
Cheghcheraan	20.9	39.9	43.9	48.5	17.9	1.2	1.7	0.1	0.6	7.4	20.3	14.1
Dawlatyaar	21.7	49.9	45.2	58.4	23.0	1.8	1.6	0.1	0.8	8.9	25.5	12.9
Pule Hashimi	31.0	51.4	61.5	25.2	5.8	0.2	0.0	0.0	0.2	2.6	19.6	14.2
Near Herat	37.0	60.2	68.4	32.3	10.5	0.3	0.0	0.0	0.3	3.1	22.0	22.1
Rabaate Akhond	27.8	42.9	68.3	29.4	29.8	1.1	0.2	0.1	2.0	4.5	31.3	19.0
Tangee Azoo	37.2	47.2	43.7	28.3	10.5	1.1	0.1	0.0	0.5	5.9	55.5	24.8
Tagab Ghaza	32.7	40.6	78.6	41.5	23.4	0.9	0.4	0.0	0.5	6.3	32.6	23.7

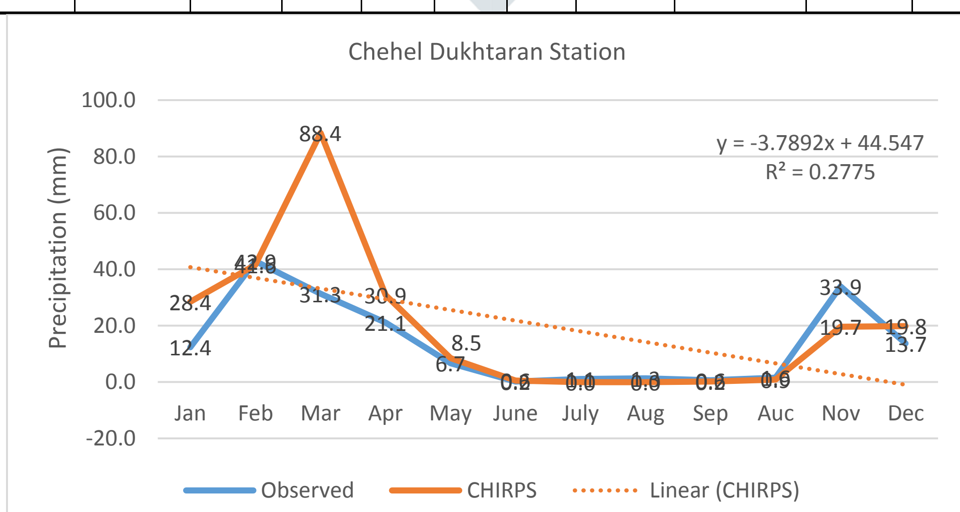

Fig 8 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Chehel Dukhtaran Hydrological Station

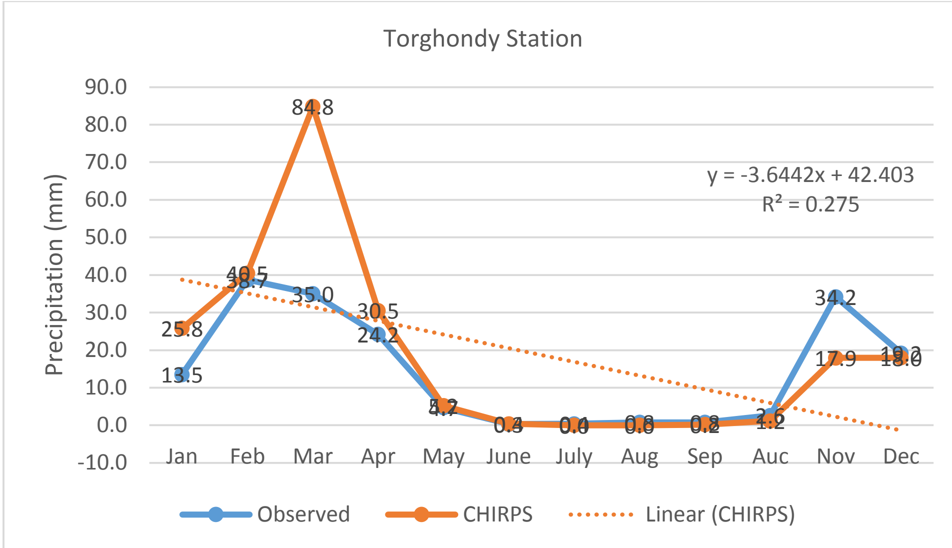

Fig 9 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Torghondy Hydrological Station

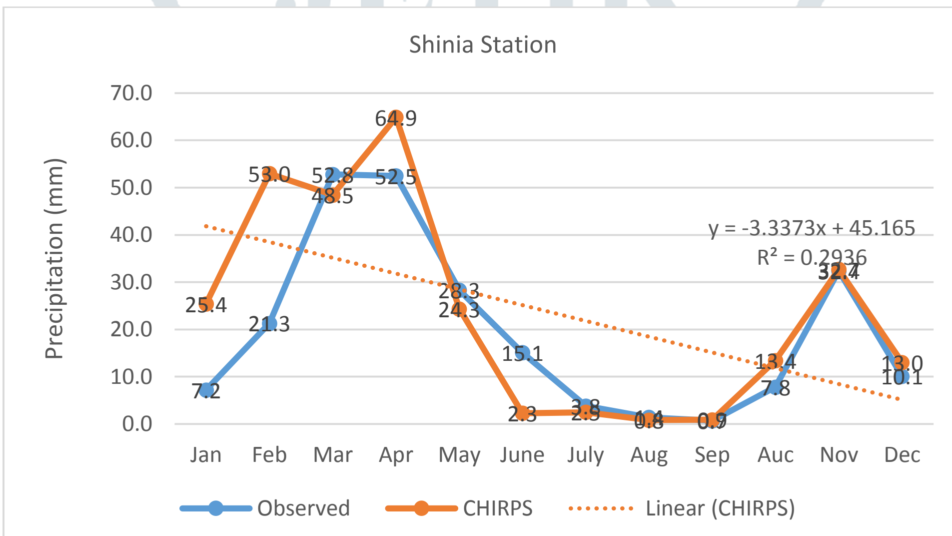

Fig 10 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Shinia Hydrological Station

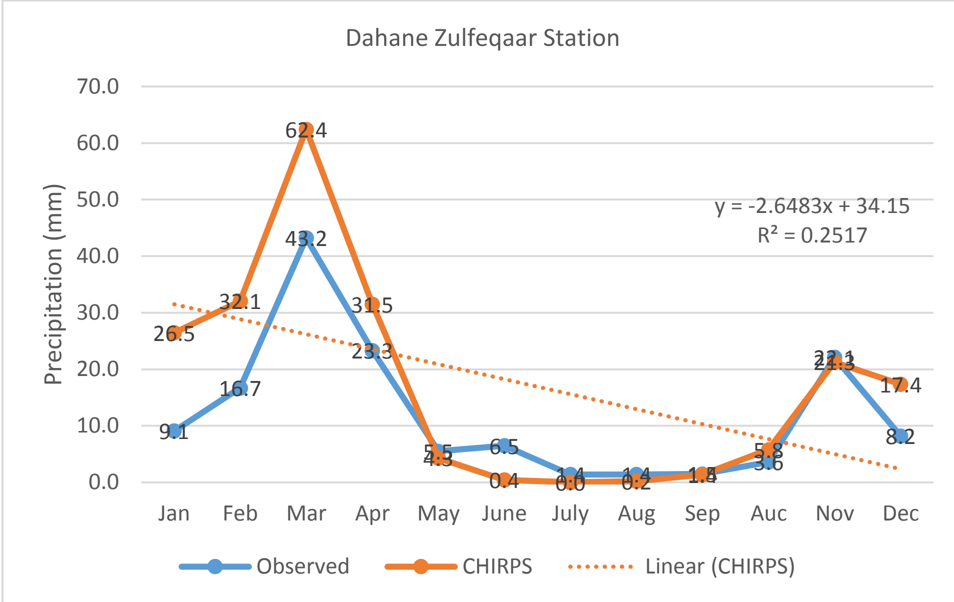

Fig 11 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Dahane Zulfeqaar Hydrological Station

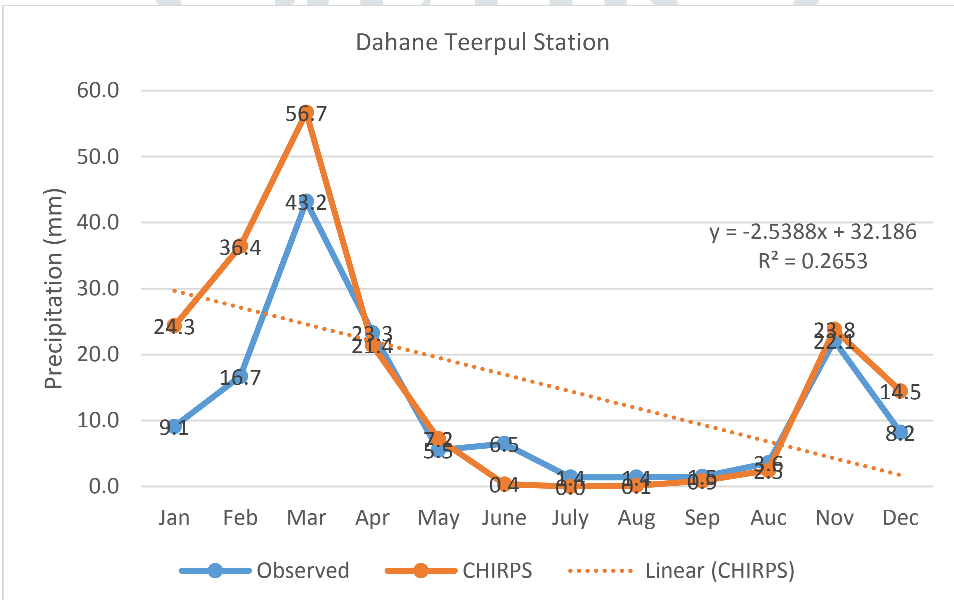

Fig 12 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in DahaneTeerpul Hydrological Station

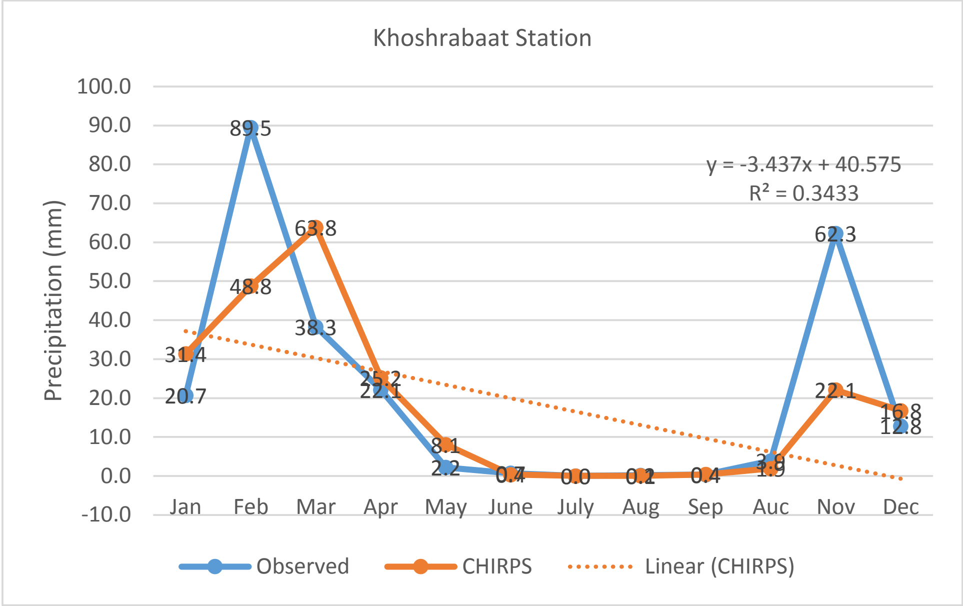

Fig 13 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Khoshrabat Station Hydrological Station

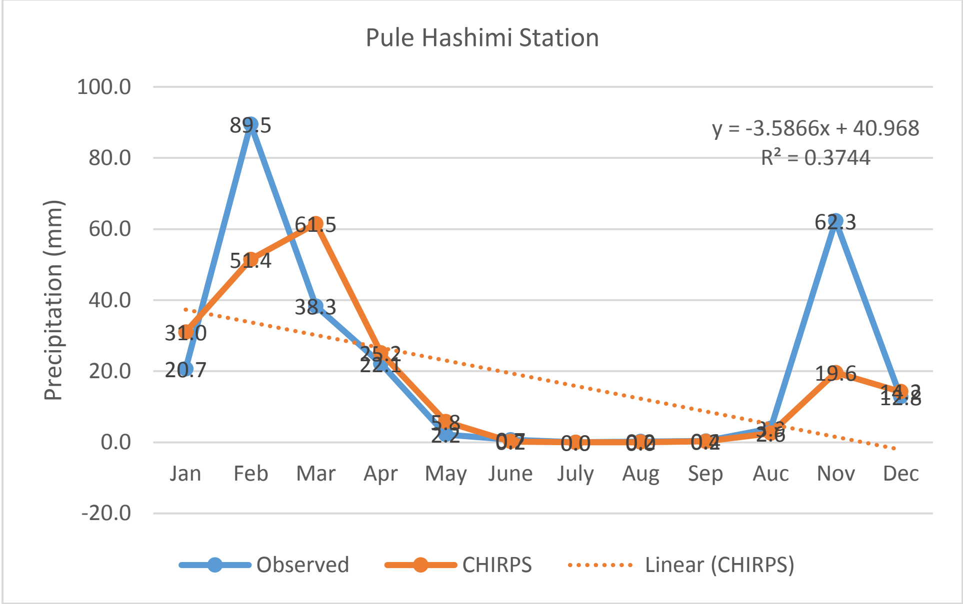

Fig 14 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Pule Hashimi Hydrological Station

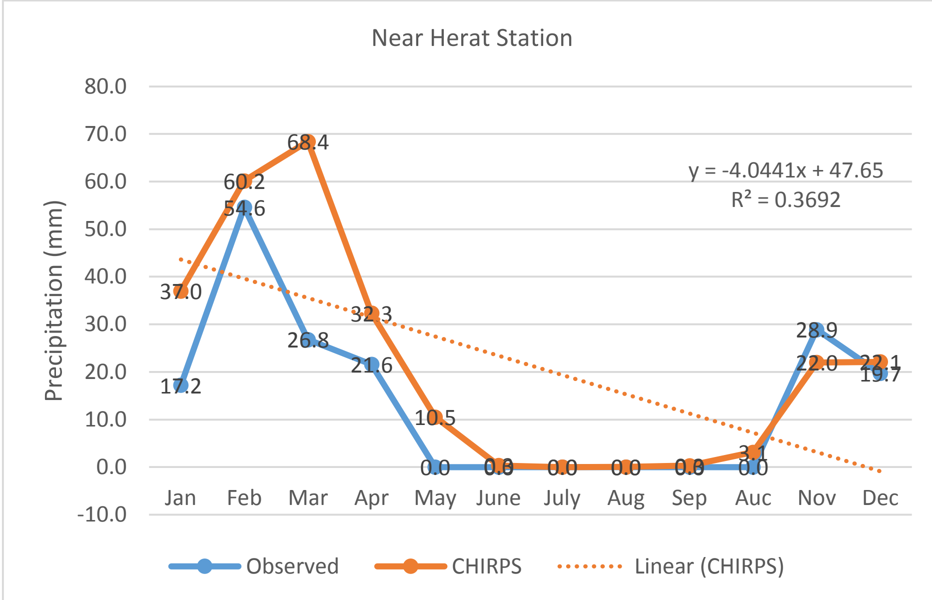

Fig 15 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Near Herat Hydrological Station

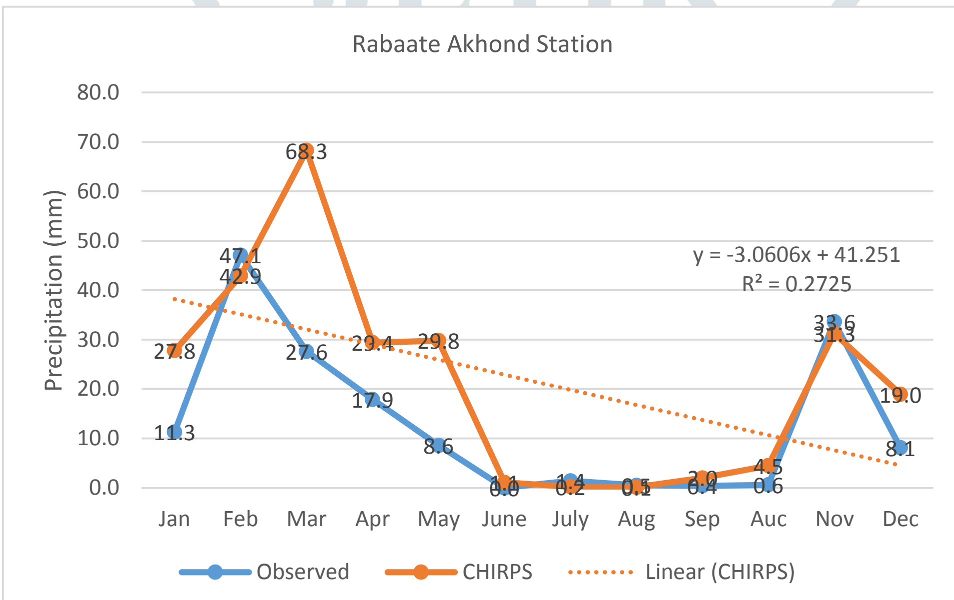

Fig 16 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Robaate Akhond Hydrological Station

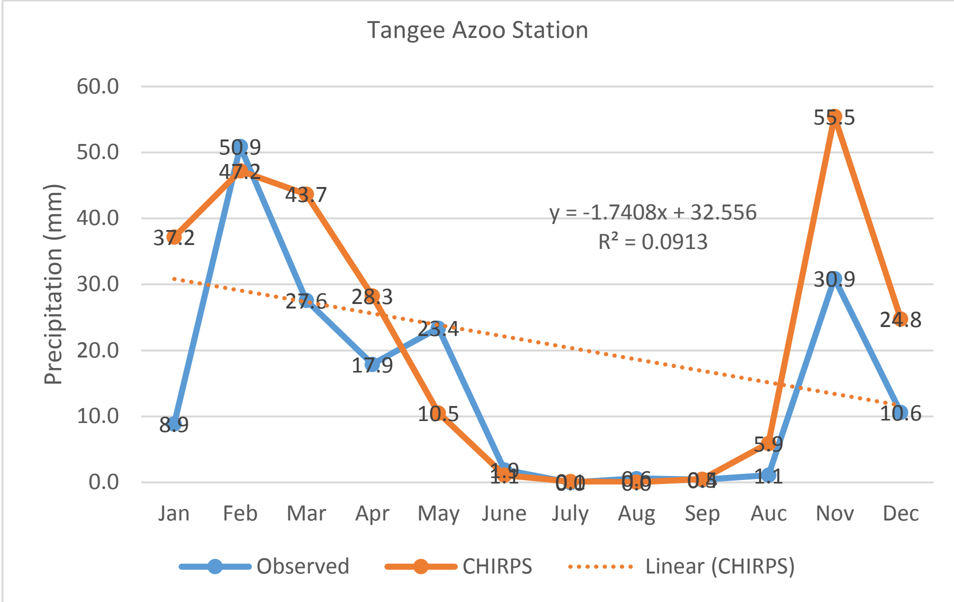

Fig 17 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Tangee Azoo Hydrological Station

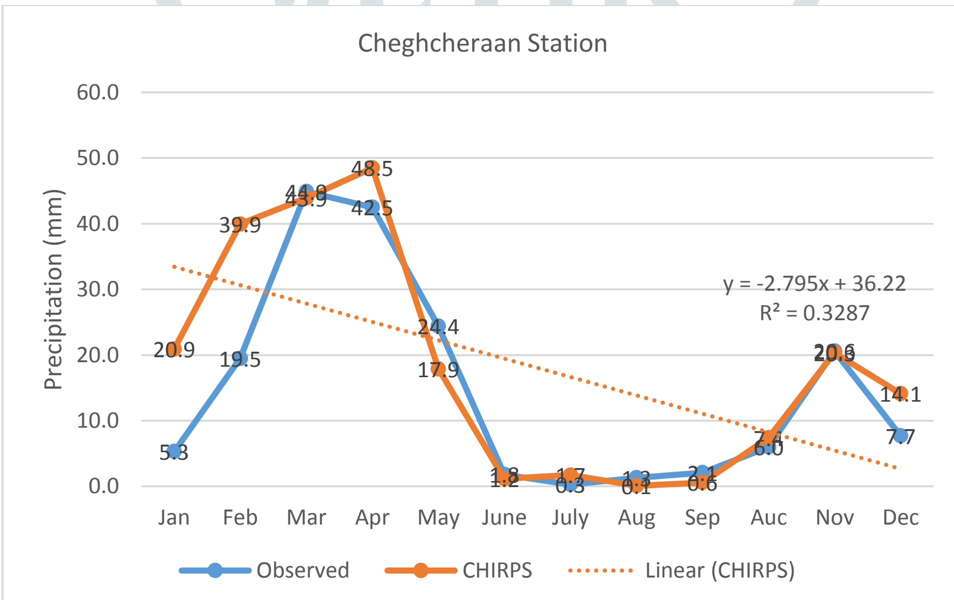

Fig 18 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in CheghcheraanHydrological Station

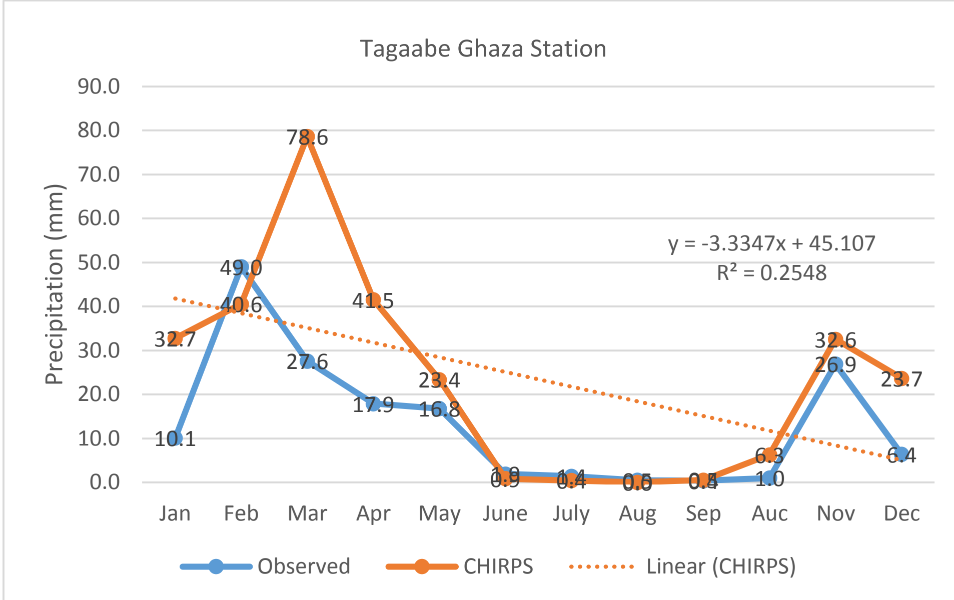

Fig 19 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Tagaab Ghaza Hydrological Station

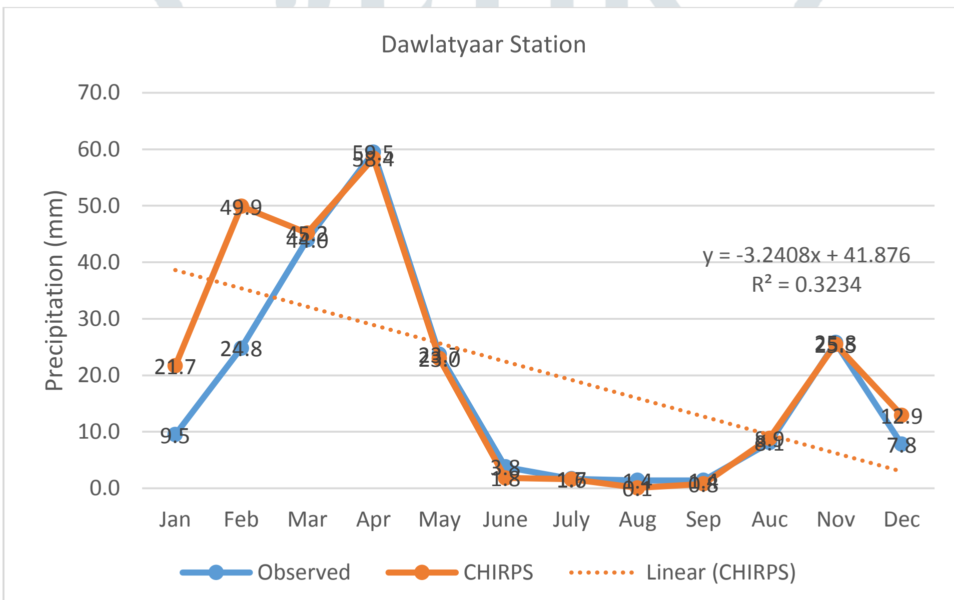

Fig 20 Average Monthly Rainfall in mm Estimated by CHIRPS and Observed in Dawaltyaar Hydrological Station

Conclusion and Results

After the comparison of rainfall data from hydrological station with CHIRPS; it cleared that there is a lot of similarity between these two in the spring and summer seasons and little similarity in the fall and winter seasons. The amount of MBE for all stations else Khosh Rabaat is negative which means the estimation is high. The amount of RMSE is very less the average of this is 18.54mm that shows accuracy of work. The amount of CV-RSME is also little and the average of this is 32 %; this also shows the high estimation.

Rainfall is one the most important element of climate that has variation in time and place as well. For development of Afghanistan and the region, the rainfall information is very important. Estimation of rainfall via satellites is a new method that nowadays information from CHIRIPS data set is using in the researches of meteorology and water engineering. This research showed that there is a good relationship between observed and CHIRIPS rainfall. This research showed that estimation of rainfall data by CHIRIPS is bigger than observed data which have got from hydrological stations. Therefore, the results show that the rain gauge stations should not be replaced by remote sensing data and remote sensing estimation should be calibrated with observed rainfall data. Remote sensing estimation does not show the complication of rain fall and cannot have accuracy like rain gauges.

Recommendations

Remote sensing estimation of rainfall is a new and fast-growing method that needs to be assessed. There are a lot of satellites that estimate the amount of rainfall data such as TRMM, GPM, TAMSAT, MPE and CHIRIPS. A lot of works have been done to improve satellites numerical calculations. Scientists are working hard to enhance the remote sensing method and fill the gaps of rainfall data. It is recommended that the accuracy of remote sensing technology needs to be assessed in the deferent climates and deferent areas as well. As the majority of basins in Afghanistan don't have enough rain gauge stations so estimation of rainfall data through remote sensing method is very useful. The research showed that satellite data is useful but it cannot ignore the meteorological stations data; because the meteorological stations give data in its accuracy so specifically the recommendations are as following:

- As the number of rain gauges in Harrirod-Morghab River Basin is very less, so for accuracy of calculations, their should increase the number of rain gauge in this basin.
- According to standards the required number of rain gauges in the mountainous areas is more than flat areas; therefore for determination of mountainous and flat areas the detailed topographical survey is needed.
- The years 1980 up to 2008 do not have precipitation data, therefore it is a must that this data gap should be filled by international standard methods
- Some rain gauges in this basin are working automatically; but the remaining of these are working manually; therefore it will be better to change it to automatic type as well.
- As the usage of satellites data is increasing day by day; therefore the teaching of satellite and remote sensing is very necessary in the universities.
- There are several satellites that estimate the rainfall data; so this is a must that the accuracy of every satellite data should check in this basin.

Disclosure statement

No potential conflict of interest was reported by the authors.

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