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Satellite Based Estimation and Validation of Rainfall Distribution in Monsoon over Washim (Maharashtra), India

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ABSTRACT

Worldwide agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. The variations in the meteorological parameters have overriding influence on the agricultural systems. It is widely believed that developing countries such as India will be impacted more severely than developed countries, where, about 56% of the net cultivated area is rain-fed that largely depends on monsoon rainfall. Thus accurate estimation of rainfall is crucial for crop yield assessment, water resource management and flood and drought monitoring for the area. But, traditional precipitation records are thought to be rarely complete, to analyze these limitations a comparison between rain gauge observations and satellite-based estimates such as the Tropical Rainfall Measuring Mission (TRMM) is carried out in this paper. Different statistical tools like coefficient of determination, Mean Bias Error, Root Mean Square Error and NRMSE are used to have validation of TRMM data with rain gauge data. TRMM data found overestimated to the rain gauge data with 58.17 % of error, capturing 60.6 % of variability in spatial distribution with traditional rain gauges. It is concluded from the analysis that there is some dissimilarity in the spatial distribution between the two which may due to lack of ground rain gauge stations at some remote areas or diversified topography of the district area. Hence, it may be useful in estimating rainfall particularly in regions where no gauge observations available and therefore such measurements are useful for many water related applications.

Introduction

Worldwide agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in rainfall. It is widely believed that developing countries like India will be impacted more severely than developed countries. Where, about 56% of the net cultivated area of the country is rain-fed that largely depends on monsoon rainfall, accounting for 44% of food production contributing 17-18 percent to the country's GDP. Large parts of the country are severely affected due to deficit monsoon rainfall where Government of India spends large amount of money on providing relief in affected areas. Thus accurate estimation of rainfall is crucial for crop yield assessment, water resource management and flood and drought monitoring for the area. But our knowledge of rain in the Tropics is limited due to poor conventional observations. Rain gauges can deliver accurate point observations but have poor ability to describe the spatial structure of rainfall especially due to high rainfall variability because they are punctual instruments that cover an area of about 10^{-1} m^2 (Nerini *et al.,* 2015). In many areas, precipitation estimates are also subject to considerable uncertainty due to the small number of rain gauges or non-representative observation sites. Ultimately, recording devices, human operators, and data transmission are susceptible to errors and outages for various reasons. Hence, traditional precipitation records are rarely available with good spatial and temporal coverage (Hongfen *et al.,* 2017). To overcome these limitations of rain gauge measurements, remote sensing techniques using space borne sensors provide an excellent complement to continuous monitoring of rain event both spatially and temporally. It is one of the most useful missions for calculating rainfall over the earth. The TRMM satellite was developed by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC), on November 28, 1997. It is a joint space mission between the NASA and the Japan Aerospace Exploration Agency (JAXA). In this research work TRMM 3B43 V7 is especially used for determination of the rainfall variations. It produces three hourly rainfall data at 0.25°×0.25° spatial resolutions estimating rainfall and energy exchange on tropical and subtropical regions of the world based on the characteristics of cloud cover, cloud tops and temperature (Shukla, *et al.,* 2014; Huffman *et al.,* 2007). It is the first mission dedicated for measuring tropical and subtropical rainfall (Simpson, *et al.,* 1988 and Kummerow, *et al.,* 2000) aimed to measure tropical and subtropical rainfall through microwave and visible infrared sensors with continuous representation of the distribution of rainfall data (Santos, 2014). In recent years, satellite rainfall estimates based on microwave data have demonstrated more promises for studies of the tropical convective systems, including the monsoon. But according to Shukla *et al.,* (2012) TRMM satellite data is underestimated with low accuracy, though TRMM data and rain gauge data had positive correlation. A good agreement and relationship was observed on comparing the monthly TRMM satellite rainfall data with gauge rainfall data. Similar findings of Knies, *et al.,* (2014) and Mitra *et al.,* (2008) stated that the satellite-based precipitation estimates suffer from deficiencies in the registration of intense rainfall events. At the same time, the remote-sensing data frequently overestimate rainfall amounts observed at the ground. Hence, it was thought imperative to conduct a validation study on recorded rain gauge data with the TRMM satellite derived rainfall estimates.

Materials and Methods

Present study was carried out in the Washim district of Maharashtra, India which comprises six sub divisions namely Washim (77.191287°E 20.087518°N), Karanja (77.513479°E 20.550669°N), Mangrulpir (77.346789°E 20.310143°N), Malegaon (77.015647°E 20.278819°N), Manora (77.545922°E 20.207221°N) and Risod (76.789665°E 20.029344°N). The district is basically agriculture oriented with varied topographical and climatological features, categorized under two agro climatic zone type viz. Assured rainfall zone (ACZ-7) and Moderate Rainfall Zone (ACZ-8). Monthly rainfall data of above mentioned six rain gauge stations of Washim district (Table 1) from 2007-2017 were taken from the Indian meteorological department (IMD), Pune, India. Further seasonal rainfall data for monsoon season was calculated as more than 80 % of annual rainfall is received during the monsoon season Jun-Sept and the analysis of this study compares the seasonal rainfall estimates of the TRMM data with rain gauge rainfall. The considered data sets known as 3B43 that routinely produced by the tropical rainfall measuring mission (TRMM) from passive microwave and infrared recordings.

The data are made available at no charge by the TRMM mission. This product is an optimal combination of various high quality microwave estimates to adjust infrared estimates from high-frequency geostationary observations (http://trmm.gsfc.nasa.gov/). The TRMM rainfall data is valuable in finding the rain location and intensity of rainfall. The comparison of observed rainfall and TRMM rainfall was not done station by station data but monthly and average seasonal rainfall over the entire district region on sub-divisional scale. It was found that the inverse squared distance method in GIS software gave better results compared to the other interpolation methods. In this method, the weighted rainfall is calculated from the rain gauge data by its distances from the interpolating point. This helps in improving the accuracy of the spatial interpolation in regions having low density of rain gauge networks. To validate the satellite rainfall estimates with the rain gauge rainfall observations following statistical measures were used:

Coefficient of determination (R_2): It is the degree of linear association between the observed rainfall and satellite estimated rainfall. The goodness of fit of the relation is evaluated by R_2 (Eq.1)

$$R^2 = \frac{n\sum(Obs_i Sat_i) - (\sum Obs_i)(\sum Sat_i)^2}{\sqrt{n(\sum Obs_i)^2 - (\sum Obs_i)^2 * n((\sum Sat_i)^2 - (\sum Sat_i)^2}} \quad \text{…. Eq. (1)}$$

Where R^2 is the coefficient of determination, where, Obs_i the observed rainfall measurements, Sat_i stands for satellite rainfall estimates, and n the number of data pairs.

Mean Bias Error (MBE): It is the simple ratio of average satellite rainfall estimation to average observed rainfall estimation values (Eq.2). A bias of 1.1 means the satellite rainfall is 10% higher than the average

$$MSB(\%) = \frac{\sum_{i=1}^{n}(Obs_i - Sat_i)}{\sum_{i=1}^{n} Obs_i} * 100 \quad \text{…. Eq. (2)}$$

Root Mean Square Error (RMSE): measures are used to assess the difference between the distributions of the rain gauge observed rainfall with satellite rainfall estimation. It calculates a weighted average error, with reference to the square of the error. RMSE is useful when large errors are undesirable. The lower the RMSE score, the closer the satellite rainfall estimation represents the observed ground rainfall measurement (Eq.3).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Obs_i - Sat_i)^2}{n}} \quad \text{…. Eq. (3)}$$

Where RMSE is the root mean square error, Obs_i the observed rainfall measurements, Sat_i the satellite rainfall estimates, and n the number of data pairs. RMSE is an inappropriate measure for calculating mean error and can be easily misinterpreted (Willmott *et al.*, 2005) in this study, NRMSE (Eq.4) is also used to evaluate the accuracy of TRMM precipitation.

$$NRMSE(\%) = RMSE / \left[\frac{\sum_{i=1}^{n} Obs_i}{n} \right] * 100$$ …. Eq. (4)

The NRMSE, is considered to be excellent if it is < 10%, good if 10-20%, fair if 20-30%, and poor > 30% (Jamieson, *et al.,* 1991 and Signoretto, *et al.,* 2011). Pearson product moment correlation (Sample Correlation Coefficient):

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2}\sqrt{\sum(y-\bar{y})^2}}$$ …. Eq. (5)

The correlation should be between +1 to -1 showing perfect increasing or decreasing linear relationship and the values in between shows the degree of linear relationship between estimated and observed values. If r is 0 that means there is no linear relationship between the variables.

Results and Discussion

India's most of the rainfall (more than 80%) is received during the monsoon season (Jun-Sept), so, the analysis compares the seasonal rainfall estimates of the TRMM data products with that of rain gauge rainfall data over the Washim district region during 2007-2017.

Seasonal performance over the district

The statistics of average monthly rainfall during monsoon season (Jun-Sept) recorded at TRMM 3B43 and rain gauge for the six stations of Washim district region are given in (Table 1, Table 2) along with the annual rainfall for comparison. It is found that monthly average seasonal rainfall data of rain gauge at Washim station have overestimated by TRMM 3B43 with low difference for the year 2009, 2013, 2014 and 2017 as well as at Malegaon for 2013 and 2017 and Mangrulpir, Manora and Karanja during 2017, 2013 and 2017 respectively. Whereas only for the year 2013 Mangrulpir station rain gauge data have underestimated by TRMM 3B43 with low difference. In Figure 2 the TRMM values are found to the higher side for most of the monsoon months (Jun-Sept) of year 2007, 2008, 2009, 2010, 2011, 2012, 2014, 2015 and 2016 except for the year 2013 and 2017 where have hardly any difference between the two. It is cleared from Table 1, 2 and Figure 2 that observed average monthly rainfall readings for monsoon season in rain gauge and TRMM 3B43 are low comparable.

Table 3 summarizes the bias, MSB %, MAE, RMSE and NRMSE between the monthly rain gauge observations and TRMM data sets for monsoon season (2007-2017). The 11-year monthly averages of monsoon season in the rain gauge and TRMM dataset are 183.17 and 289.71 respectively. The big difference between rain gauge and TRMM is observed. The estimates of TRMM (3B43) algorithm tend to be higher than rain gauge observations, the biases are also much high with error of 58.17 %. On the other hand the maximum average monthly rainfall in monsoon season in case of observed rainfall is 306.5 mm in the year 2013 and in TRMM rainfall is 371.2 mm in the year 2010. The level of confidence at 95% was 36.60 in Rain gauge and 38.08 in TRMM (Table 3). The TRMM 3B43 data (-0.41) is found to be moderately skewed with lack of outliers whereas rain gauge observation (1.28) data as highly skewed with heavy tails or outliers.

Table.1 Seasonal rainfall observed in Rain gauge and TRMM data sets of Washim District (2007-2017)

Station	Long.	Lat.	Annual	2007		2008		2009		2010		2011		2012	
				R/G	TRMM	R/G	TRMM	R/G	TRMM	R/G	TRMM	R/G	TRMM	R/G	TRMM
Washim	77.191287	20.087518	871.40	212.50	359.96	169.73	331.23	153.05	203.18	265.13	377.09	178.43	288.21	178.43	313.23
Risod	76.789665	20.029344	769.61	215.25	373.73	181.75	306.33	131.00	229.56	240.08	367.81	151.95	298.34	151.95	315.34
Malegaon	77.015647	20.278819	783.18	191.75	331.19	158.75	264.95	131.50	245.40	264.83	368.06	150.00	284.60	150.00	272.89
Mangrulpir	77.346789	20.310143	820.04	206.10	335.32	127.33	258.30	122.95	204.59	249.80	385.10	187.63	288.87	187.63	300.36
Manora	77.545922	20.207221	737.05	181.05	336.05	116.40	298.17	87.40	229.51	266.60	347.09	203.20	373.13	203.20	362.84
Karanja	77.513479	20.550669	742.18	237.40	360.40	101.68	303.92	150.00	211.26	182.68	381.97	190.23	319.12	190.23	311.80

R/G: Rain Gauge Station, TRMM: Tropical Rainfall Measurement Mission

Table.2 Seasonal rainfall observed in Rain gauge and TRMM data sets of Washim District (2007-2017)

Station	Long.	Lat.	Annual	2013		2014		2015		2016		2017	
				R/G	TRMM	R/G	TRMM	R/G	TRMM	R/G	TRMM	R/G	TRMM
Washim	77.191287	20.087518	871.40	339.00	367.24	209.20	239.68	162.23	248.07	245.80	313.30	148.33	184.71
Risod	76.789665	20.029344	769.61	271.38	340.29	149.13	252.69	159.78	257.90	181.60	292.21	157.40	232.40
Malegaon	77.015647	20.278819	783.18	299.38	327.59	149.10	222.86	137.53	220.58	186.83	289.35	156.95	184.50
Mangrulpir	77.346789	20.310143	820.04	380.10	333.44	108.27	214.56	150.80	237.87	207.43	300.09	130.10	173.99
Manora	77.545922	20.207221	737.05	320.63	342.74	118.93	267.39	122.47	270.56	192.68	321.44	99.23	181.07
Karanja	77.513479	20.550669	742.18	228.40	320.97	109.05	268.52	144.10	286.34	203.58	315.10	116.43	174.84

R/G: Rain Gauge Station, TRMM: Tropical Rainfall Measurement Mission

Table.3 Statistical analysis of average monthly rainfall recorded at Rain gauge and TRMM data set for monsoon season (Jun-Sept) during 2007-2017.

TRMM		***Rain gauge***	
Mean	289.7145	Mean	183.1694
Standard Error	17.09138	Standard Error	16.42797
Median	305.2468	Median	176.9042
Standard Deviation	56.6857	Standard Deviation	54.48541
Sample Variance	3213.269	Sample Variance	2968.659
Kurtosis	-0.67904	Kurtosis	1.380175
Skewness	-0.41021	Skewness	1.278854
Range	182.6002	Range	177.1625
Minimum	188.5857	Minimum	129.3167
Maximum	371.1859	Maximum	306.4792
Sum	3186.86	Sum	2014.863
Count	11	Count	11
Confidence Level (95.0%)	38.08197	Confidence Level (95.0%)	36.60379
MAE	106.55		
RMSE	112.25		
NRMSE	0.61		
MAPE	0.63		
MSB%	58.17		

Fig.1 Study area location map Washim District (Maharashtra)

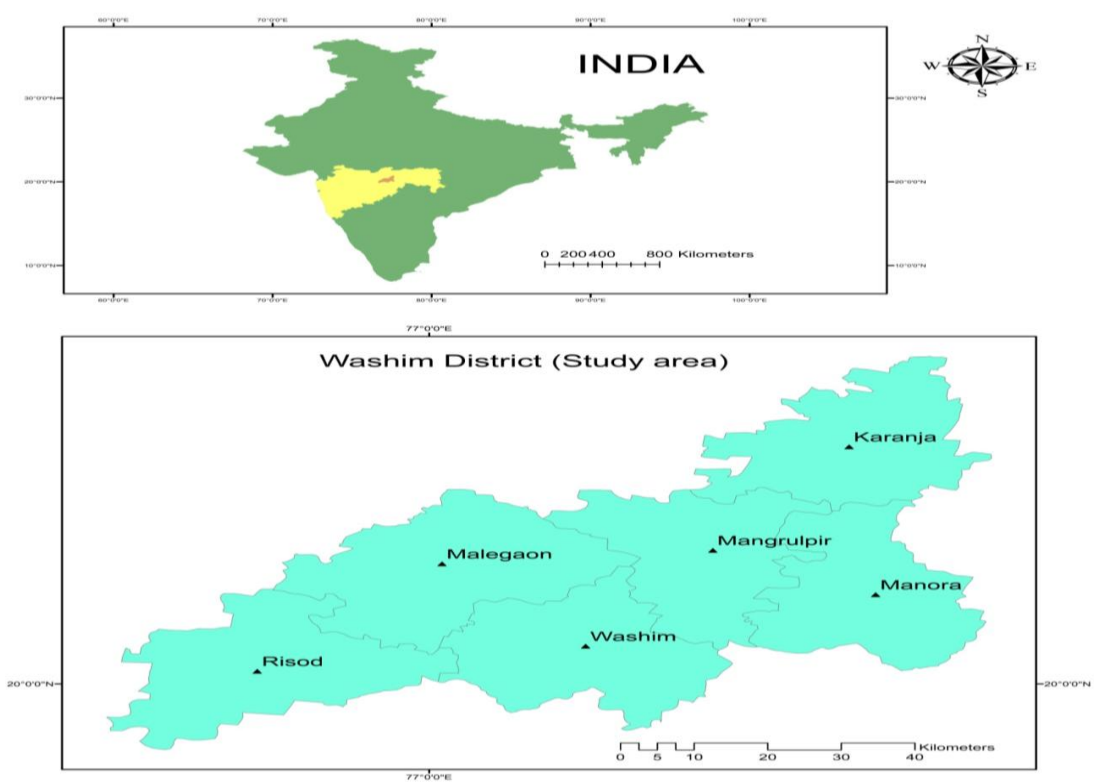


Fig.2 Time series of average monthly rain rate in Monsoon season over entire Washim District for Rain gauge and TRMM 3B43 DATA SETS

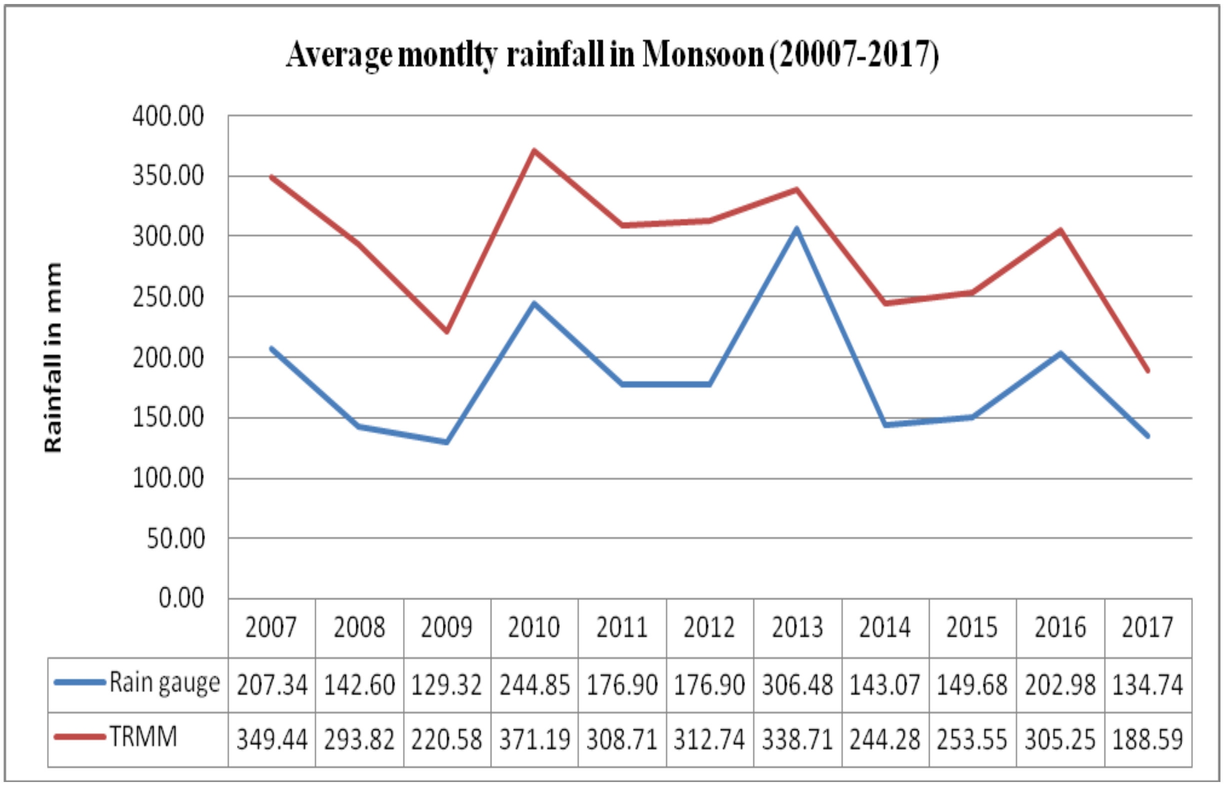
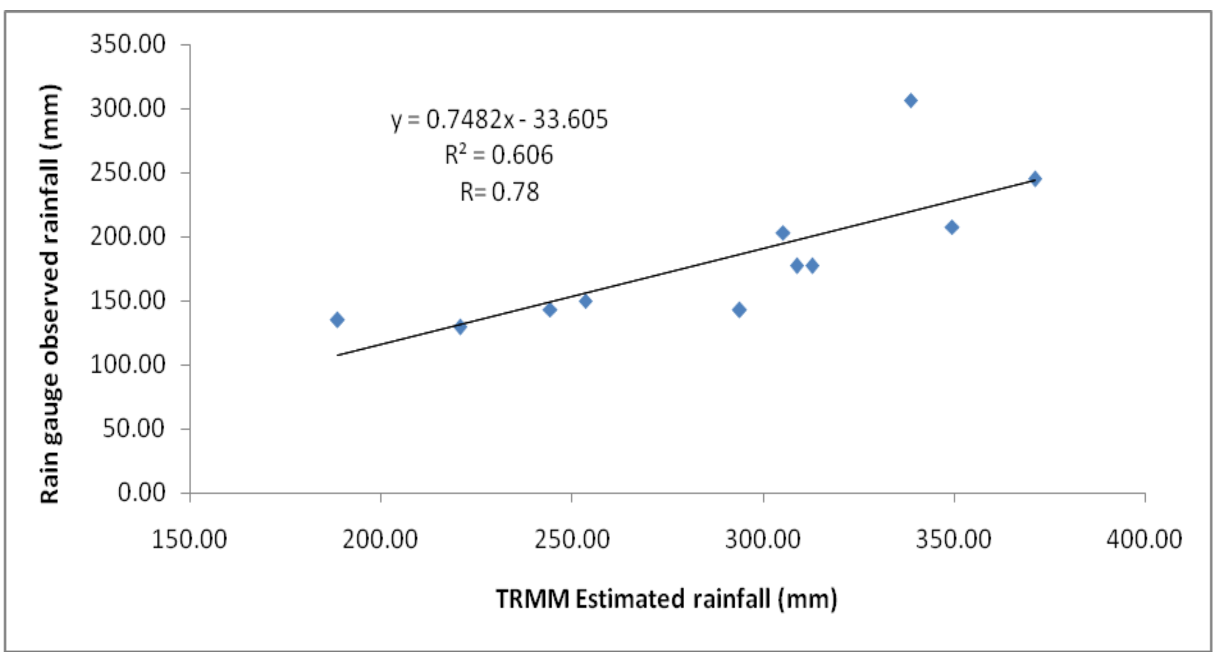


Fig.3 Scatter plot of average monthly rainfall for monsoon season (2007-2017) observed in rain gauge station and TRMM rainfall data (mm)



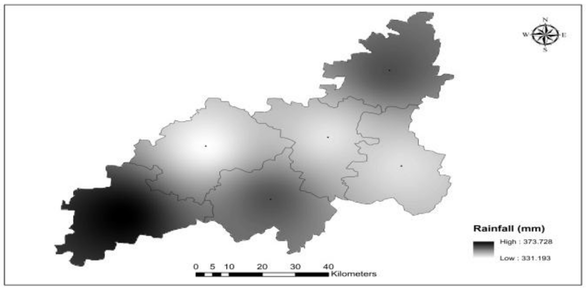


Fig.4 TRMM (2007)

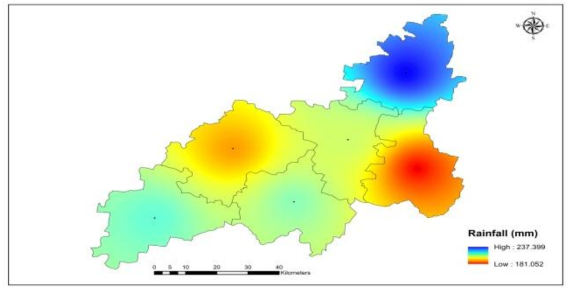


Fig.5 RGS (2007)

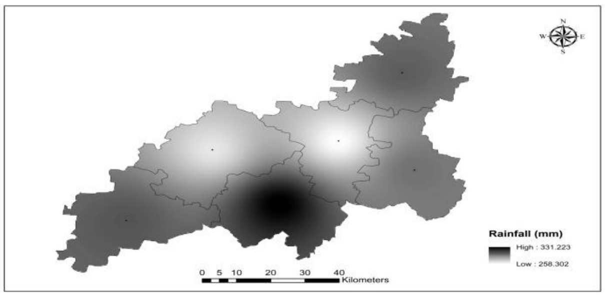


Fig.6 TRMM (2008)

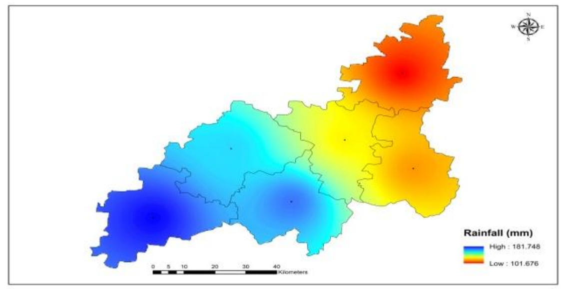


Fig.7 RGS (2008)

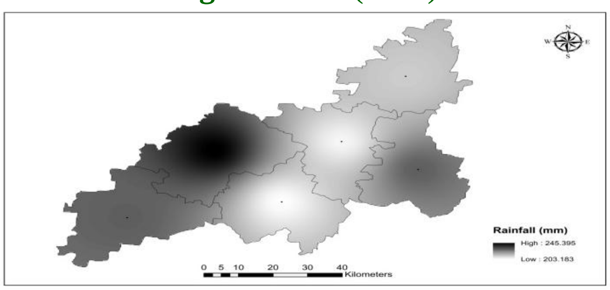


Fig.8 TRMM (2009)

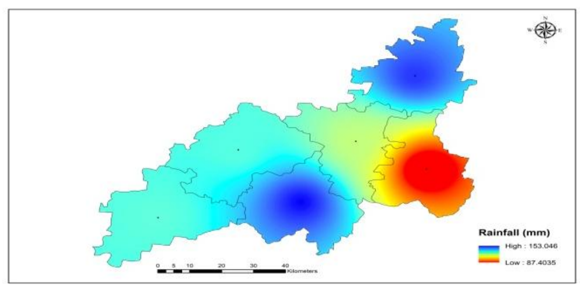


Fig.9 RGS (2009)

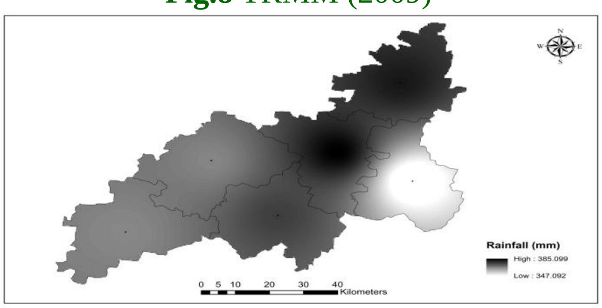


Fig.10 TRMM (2010)

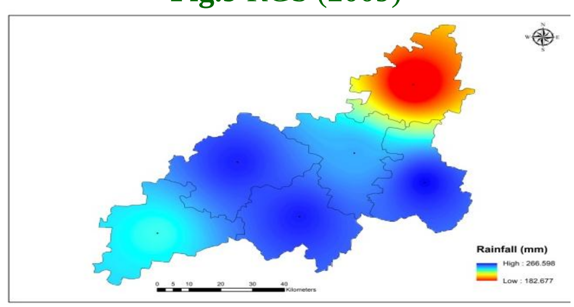


Fig.11 RGS (2010)

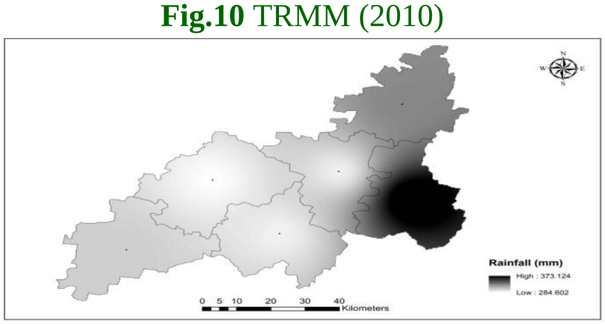


Fig.12 TRMM (2011)

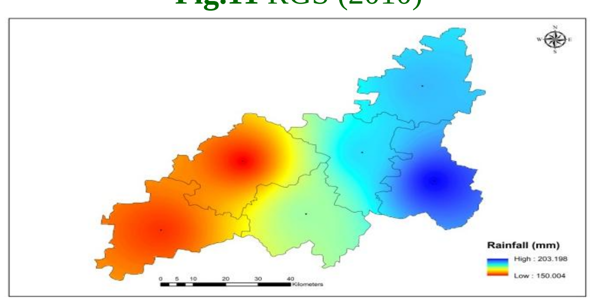


Fig.13 RGS (2011)

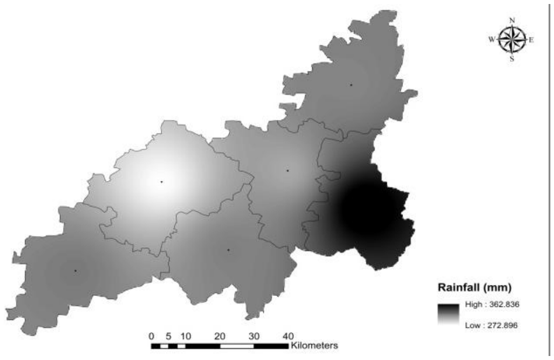


Fig.14 TRMM (2012)

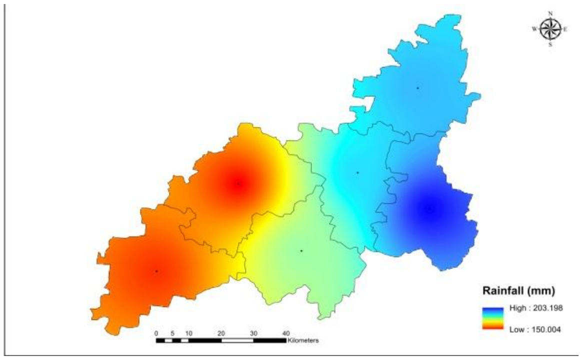


Fig.15 RGS (2012)

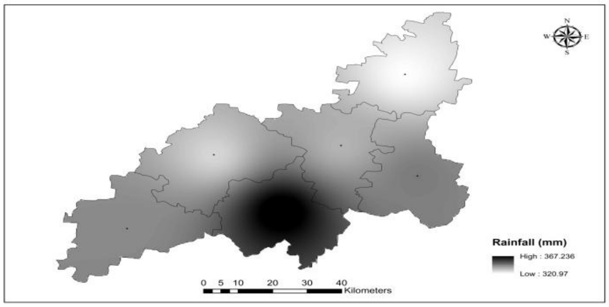


Fig.16 TRMM (2013)

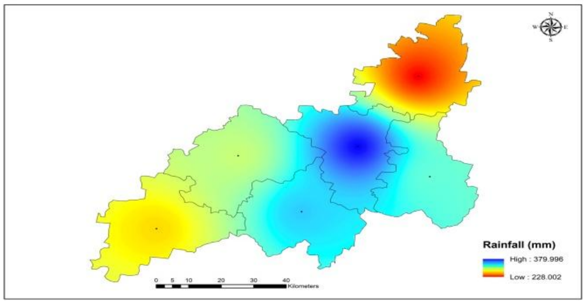


Fig.17 RGS (2013)

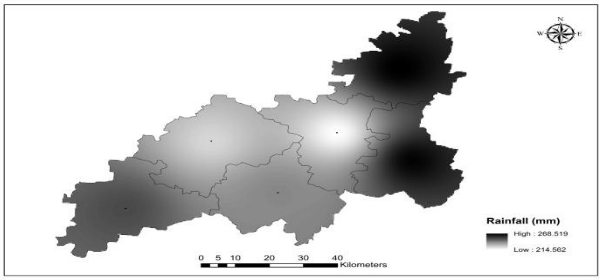


Fig.18 TRMM (2014)

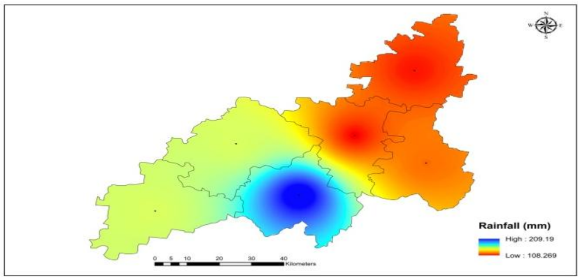


Fig.19 RGS (2014)

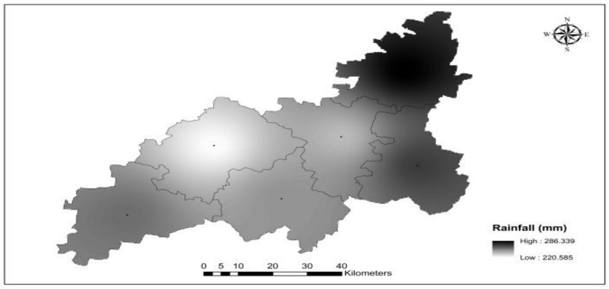


Fig.20 TRMM (2015)

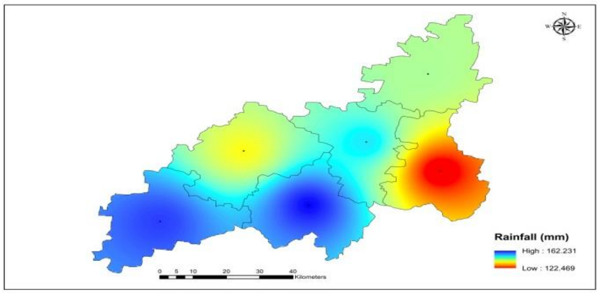


Fig.21 RGS (2015)

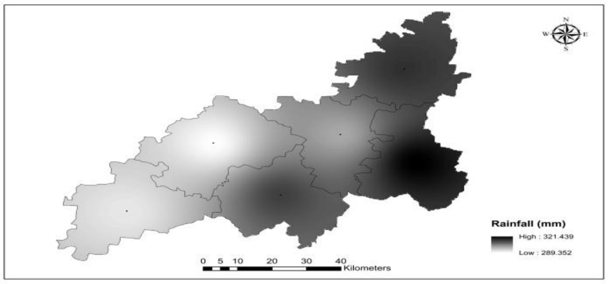


Fig.22 TRMM (2016)

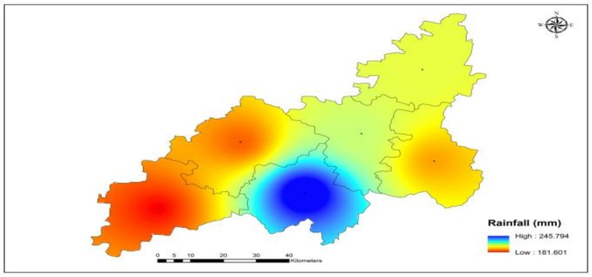


Fig.23 RGS (2016)

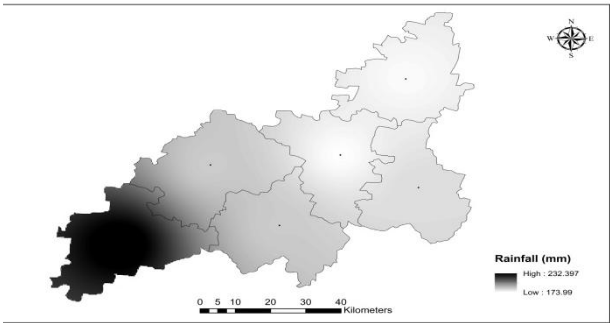


Fig.24 TRMM (2017)

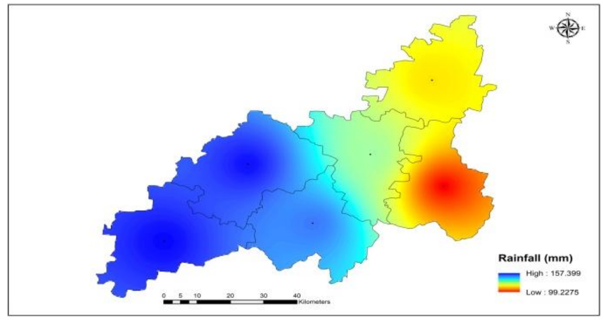


Fig.25 RGS (2017)

RGS: Rain Gauge Station, TRMM: Tropical Rainfall Measurement Mission

Therefore, it is evident from Table 3 that during rainy season very low agreement exists between TRMM based satellite data and gauge rainfall data.

To further evaluate the relationships between the two data sets, the scatter plots of seasonal TRMM rainfall against rain gauges rainfall data is shown in Fig. 3. The results indicate moderate strong positive linear relationship between the two rainfall datasets, which is supported by the correlation coefficient (r = 0.78) with the regression line slope 0.81. Where, the value of r^2= 0.61says that61 % of the variation in traditional rain gauges can capture by the TRMM 3B43 satellite. It reveals that there is some dissimilarity in the spatial distribution between the rain gauge stations and TRMM rainfall data of Washim district which may due to lack of ground rain gauge stations at some remote areas or diversified topography of the district area. For that reason, to recognize the accurateness of spatial distribution of the TRMM rainfall data, the spatial distribution of seasonal rainfall for all the years have been compared (Fig. 4-25). The validity of TRMM data in the Washim region was compared with average monthly rainfall variations in monsoon season and almost similar variations were observed in both the data sets at all the sub-districts. But, still there are many difficulties in quantifying the precision of spatial rainfall distribution derived from the TRMM 3B43 rainfall data. Although the results (Fig. 4 - 25) show that TRMM rainfall data tend to overestimate rainfall. Sometime underestimated that may because of satellite like TRMM 3B43unable to detect the extreme rainfall in a precise manner. As the TRMM mission has ended in April 2015, in future it is essential to develop new algorithms of satellite based rainfall estimation, on the basis of better space-time resolutions to overcome the deficiencies of single sensor methods (Michaelides *et al.*, 2009). Since satellite based precipitation data is now widely used by hydrologists and engineers in various disciplines, new revolutionary data for more accurate results are essential.

This research is an attempt to evaluate satellite rainfall estimates of Tropical Rain Measurement Mission (TRMM 3B43) over rain gauges (Indian Meteorological Department) observations. Monthly accumulated rainfall collected by the rain gauge was compared with TRMM measurements for selected Washim district with six stations. Results suggest that TRMM rainfall measurements are highly overestimated, showing high baises. It is concluded from the analysis that there is some dissimilarity in the spatial distribution between the rain gauge stations and TRMM rainfall data of Washim district which may due to lack of ground rain gauge stations at some remote areas or diversified topography of the district area. Hence, it may be useful in estimating rainfall particularly in regions where no gauge observations available and therefore such measurements are useful for many water related applications. Results also indicated that rain is highly variable from one rainy season to another.

References

Adler, R. F., Huffman, G. J. and Bolvin, D. T., Curtis, S., & Nelkin E. J (2000). Tropical Rainfall Distributions Determined Using TRMM Combined with Other Satellite and Rain Gauge Information. *Journal of Applied Meteorology (39)*, 2007-2023.

Huffman, G.J., Adler, R.F., Bolvin, D.T., Gu, G., Nelkin, E.J., Bowman, K.P., Hong, Y., Stocker, E.F. & Wolff, D.B., (2007). The TRMM Multisatellite Precipitation Analysis (TMPA): quasi-global, multiyear, combined-sensor precipitation estimates at fine scales. *Journal of Hydrometeorology8* (1), pp. 38–55.

Jamieson P, Porter J, Wilson D. A test of the computer simulation model ARCWHEAT1 on wheat crops grown in New Zealand. Field Crop Res. 1991; 27(4):337-50.

Kummerowa, C., Simpson, J., Thielea, O., Barnesa, W., Changa, A.T.C., & Stockera, E (2000). The Status of the Tropical Rainfall Measuring Mission (TRMM) after Two Years in Orbit. *Journal of Applied Meteorology*, (*39*), 1965-1982.

Mitra, A. K., Bohra, A. K., Rajeevan, M. N., & Krishnamurti, T. N (2008). Tropical Rainfall Distributions Determined Using TRMM Combined with Other Satellite and Rain Gauge Information. *Journal of Meteorological Society of Japan, (87A)*, 265-279.

NASA. National Aeronautics and Space Administration. GPM Mission Concept, 2011. http://pmm.nasa.gov/gpm.

Nerini, D., Zulkafli,Z., Wang, L., Onof, C., Buytaert, W., & Casimiro, W. L., & Guyot, J. L. (2015). A Comparative Analysis of TRMM–Rain Gauge Data Merging Techniques at the Daily Time Scale for Distributed Rainfall–Runoff Modeling Applications. *Journal of Hydrometeorology*, *16*(5), 2153-2168.

Santos, A.S.P. Análise de desempenho dos campos de chuva estimados pelo satélite TRMM na Paraíba, para fins de modelagem hidrológica distribuída. 2014. 128 f. Dissertação (Mestrado em Engenharia Urbana e Ambiental) - Universidade Federal da Paraíba, João Pessoa, 2014.

Shukla, A.K., Ojha, C.S.P. and Garg, R.D. (2014). Satellite based estimation and validation of monthly rainfall distribution over upper Ganga river basin. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, 2014. ISPRS Technical Commission VIII Symposium, December 9-12, 2014, Hyderabad, India, pp. 399-404.

Signoretto M, Van de Plas R, De Moor B, Suykens J. Tensor versus matrix completion: a comparison with application to spectral data. IEEE Signal Process Letter. 2011; 18(7): 403-6.

Simpson J, Adler R, North G. A proposed tropical rainfall measuring mission (TRMM) satellite. Bull Am Meteorol Soc. 1988; 69(3): 278- 95.

Teng H. F., Ma Z., Chappell A., Shi Z., Liang Z and Wu Yu (2017). Improving Rainfall Erosivity Estimates Using Merged TRMM and Gauge Data. *Remote Sensing (9)* 1134, 1-15.

Willmott C, Matsuura K. Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance. Climate Res. 2005; 30(1): 79-82.

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