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RESEARCH ARTICLE

Validation of PERSIANN Precipitation Product Using TAWN Rain Gauge Network Over Different Agro-climatic Zones in Tamil Nadu

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ABSTRACT

Currently, several satellite-precipitation products were developed using multiple algorithms to estimate rainfall. This study carried out using Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) product over seven agro-climatic zones of Tamil Nadu during the northeast monsoon (NEM) season of October to December for 2015-2017 (three years) against 118 rain-gauges data of Tamil Nadu Agricultural Weather Network (TAWN). The performance compares aggregated seasonal scale of rainfall using continuous (CC, RMSE, and NRMSE) statistical approaches. It was observed that PERSIANN is accurate in the high-altitude hilly zone and the Cauvery delta zone. For 2015, 2016, and 2017, the correlation values were 0.77, 0.52, and 0.71, respectively. The highest RMSE value was measured for northeast zone (NEZ) during 2015 (222.17 mm), and the lowest was determined for 22.63 in the High-altitude hilly zone (HAHZ) during 2016 and NRMSE had less errors during all three seasons. The study concluded that the PERSIANN data set could be useful substitute for rain-gauge precipitation data.

Keywords: *Validation; PERSIANN; Rain-gauge; Agro-Climatic zones; Tamil Nadu.*

INTRODUCTION

In agriculture, remote sensing technology is an opportunity for continuous and repetitive measurement of water, climate and environmental monitoring studies for a better water resource management and decision-making of regional and global values of rainfall with higher spatial and temporal coverage (Larson and Peck 1974; Duan *et al*., 2013; Prajesh *et al*., 2019). Precipitation data can be obtained from direct measurements such as rain-gauge, radar and disdrometers for accurate amounts at local scale; But their cost, spatial coverage, and irregular gauge network is a major problem (Franchito *et al*., 2009; AghaKouchak *et al*., 2012). To overcome the limitations of ground techniques (Pan *et al*., 2014), several satellite-based precipitation products have been developed using IR, microwave, and combined observations. These rainfall products include Global Precipitation Climatology Project (GPCP; Huffman *et al*., 2001), Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks (PERSIANN; Sorooshian *et al*., 2000), Tropical Rainfall Measuring Mission (TRMM; Huffman *et al*., 2007), Global Satellite Mapping of Precipitation (GSMaP) (Ushio *et al*., 2009), and Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG) (Huffman *et al*., 2018), and the recent global datasets, Multi-Source Weighted-Ensemble Precipitation (MSWEP) (Beck *et al*., 2018), and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk *et al*., 2015) products developed. Satellite rainfall products should be validated in order to use in other applications (Meng *et al*., 2014; Xue *et al*., 2013).

In India, many research have been examined for the validation and estimating of PERSIANN and other rainfall products using observed rain-gauge data at various scales (daily, monthly, seasonally, and annual). Prakash *et al*., (2014) compared the four different satellite-based rainfall products (CMORPH, PERSIANN, TRMM, and The Naval Research Laboratory (NRL)-blended) with IMD data from 2004 to 2009 on daily scale for the summer monsoon season (June to September) in India. Similarly, Sunilkumar *et al*. (2015) used CMORPH, PERSIAN, TRMM, CPC, and Global Precipitation Climatology Project (GPCP) for comparison with IMD data during 2000–2010 at 1° × 1° grid size.

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Mondal *et al.*, (2018) compared Multi-satellite High-Resolution Precipitation Products (HRPPs) with IMD gridded data for 25 river basins of India. Their results revealed that, PERSIANN precipitation data shown better agreement with IMD data. Hence, it is important to compare PERSIANN product with rain-gauge observations for the hydrological applications in Tamil Nadu.

The objective of this study is to assess the PERSIANN product for different agro-climatic zones across Tamil Nadu against rain-gauge-based observations using statistical indices at seasonal scale for the northeast monsoon season of 2015-2017 (three years). The season was selected because of the high rainfall receives over Tamil Nadu during the NEM.

MATERIAL AND METHODS

Study Area

The state of Tamil Nadu is located between the latitude of 08°05′ to 13°35′ N and 76°15′ to 80° 20′ E longitude in the southern part of the Indian peninsular region and total geographical area is 130.33 lakh hectare. The state has tropical climate regions and entirely dependent on monsoon rainfall for agriculture and recharging water resources with average annual rainfall is around 921 mm and North-East Monsoon contributes over 48% (October - December) (Department of Land resources, Govt. of Tamil Nadu). The state is divided into seven agro-climate zones, namely, North Eastern Zone (NEZ), North-Western zone (NWZ), Western zone (WZ), Cauvery delta zone (CDZ), Southern zone (SZ), High rainfall zone (HRZ) and Hill and high-altitude zone (HHAZ).

Datasets Used

The data and methodology used to validate the PERSIANN precipitation product and rain-gauge networks are described in this section. Finally, the PERSIANN accuracy was assessed against rain-gauge measurements using statistical analysis.

Satellite rainfall data - PERSIANN

PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) provide daily quasi-global precipitation product at each 0.25° x 0.25° pixel for the latitude band 60°N-60°S and data available in multi-time scale from 2000 to present. The PERSIANN algorithm uses a neural network approach (Sorooshian *et al.* 2000) to estimate rainfall from geostationary IR measurements. The product is developed using the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine (UCI). The data were collected for three seasons (October, November, and December) from 2015 to 2017.

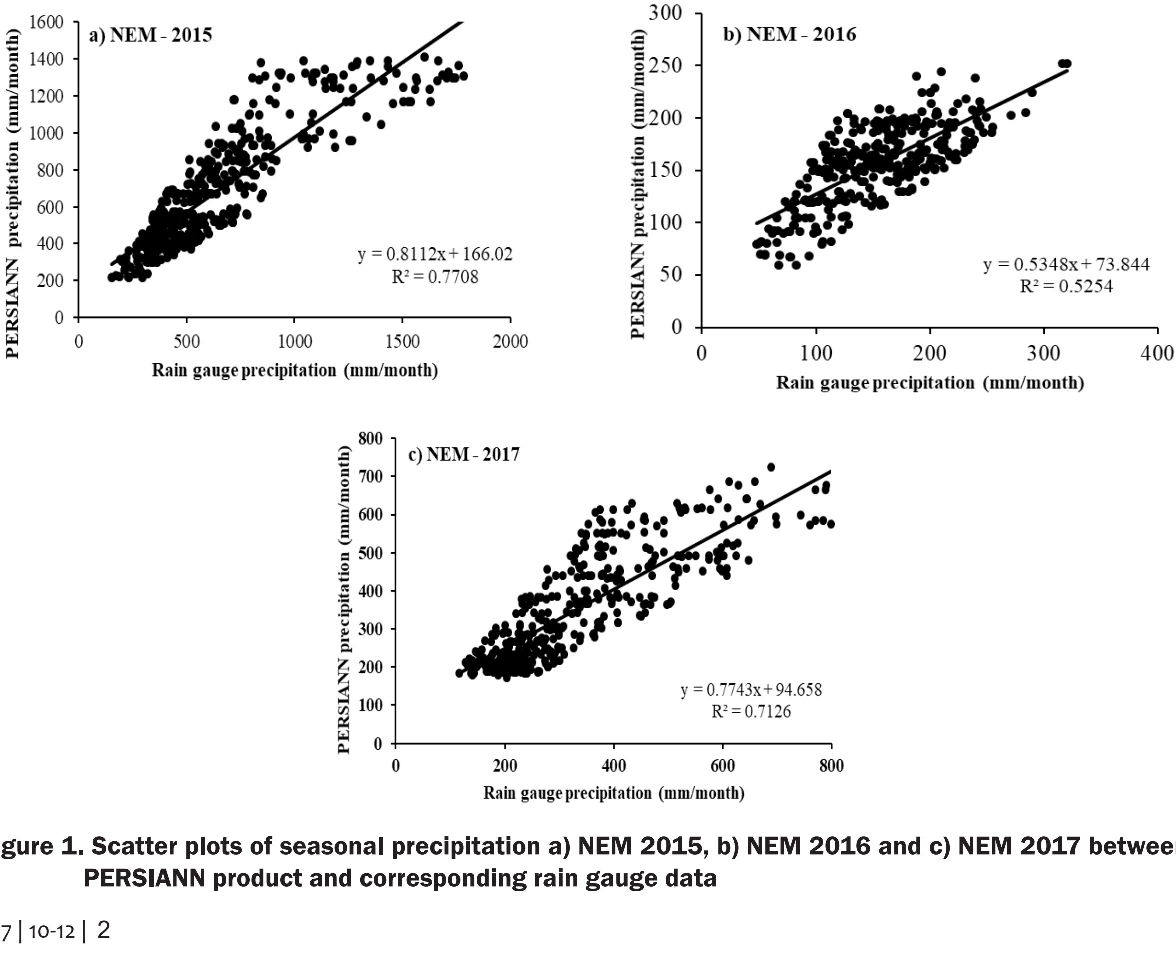

Figure 1. Scatter plots of seasonal precipitation a) NEM 2015, b) NEM 2016 and c) NEM 2017 between PERSIANN product and corresponding rain gauge data

Observed Rain-gauge data - Tamil Nadu Agricultural Weather Network (TAWN)

Tipping bucket based rain gauge measurements of 118 rain gauge stations data were used for the same periods of three NEM (2015–17) from the automatic weather network of Tamil Nadu Agricultural Weather Network (TAWN) is jointly maintained by the Agro Climate Research Centre (ACRC), Tamil Nadu Agricultural University and Department of Agriculture, Tamil Nadu (http://tawn.tnau.ac.in/General/HomePublicUI.aspx) after the quality checking of rainfall data.

Performance evaluation methods

A point-to-pixel analysis were applied for comparison of PERSIANN and rain-gauge data and the collected daily data were aggregated to seasonal scales. The correlation coefficient (CC), root mean square error (RMSE), and Normalized Root mean square error (NRMSE) were selected to validate among seven agro-climatic zones for the study period. CC is used to represent the degree of agreement between the satellite product and the observation of gauges. RMSE is used to represent the average difference between satellite estimates and gauge measures and NRMSE computed as the RMSE divided by the mean precipitation of rain gauge data.

RESULTS AND DISCUSSION

The focus of this validation work is to assess the performance of the PERSIANN product with the TAWN network over seven agro-climatic zones during three NEM seasons across Tamil Nadu. This section presents validation results at different temporal scales.

Table 1. Correlation coefficient of PERSIANN in different agro-climatic zones at seasonal scale for the northeast monsoon season over 2015 – 2017

Agro-Climatic Zones / Seasons	NEM 2015	NEM 2016	NEM 2017
Cauvery delta zone (CDZ)	0.69	0.25	0.71
High-altitude and Hilly zone (HAHZ)	0.79	0.56	0.70
High rainfall zone (HRZ)	0.10	0.45	0.59
North Eastern Zone (NEZ)	0.52	0.53	0.47
North Western zone (NWZ)	0.44	0.48	0.4
Southern zone (SZ)	0.35	0.26	0.71
Western zone (WZ)	0.56	0.71	0.30

Seasonal validation for northeast monsoons

It is to examine the accuracy of seasonal comparison of NEM for respective years (2015, 2016, and 2017) of rainfall estimates derived from PERSIANN against rain-gauge observations were analyzed using scatter-plots of point-based variations presented in Figure 1a, b, and c. A strong linear relationship between PERSIANN and rain gauge was observed for all the stations. Overall, a significant improvement has been observed in all study periods for each season. The correlation between the precipitation datasets for 2015, 2016, and 2017 was 0.77, 0.52, and 0.71, respectively, which indicates PERSIANN data had a high agreement with rain gauge observations at accumulated seasonal scale. The selected study period receives higher rainfall during the monsoon months (October, November, and December) associated with the effect of cyclones and trough patterns.

Statistical analysis of PERSIANN product for different agro-climatic zones

During the study period, categorical statistical indices (CC, RMSE, and NRMSE) indicate the detection accuracy, the PERSIANN product performed irregularly during the respective seasons. It estimates a comparable correlation over the seven agro-climatic zones with maximum value observed of 0.77 in HAHZ during the 2015 season and 2016 shows less than 0.5 except in WZ with 0.71. Besides, 2017 had a good correlation with rain gauge data observed from > 0.4 values in all climatic zones.

Table 2. RMSE of PERSIANN in different agro-climatic zones at seasonal scale for the northeast monsoon season over 2015 - 2017

Agro-Climatic Zones / Seasons	NEM 2015	NEM 2016	NEM 2017
Cauvery delta zone (CDZ)	93.33	33.38	85.04
High-altitude and Hilly zone (HAHZ)	75.60	22.63	55.52
High rainfall zone (HRZ)	139.17	38.62	124.01
North Eastern Zone (NEZ)	222.17	31.18	104.69
North Western zone (NWZ)	109.3	23.41	50.55
Southern zone (SZ)	106.34	33.07	51.90
Western zone (WZ)	41.74	25.26	32.22

Correlation Coefficient (CC)

Table 1 compares the CC for the PERSIANN product based on discrete variations between agro-climatic zones and rain-gauge measurements. During NEM 2015, low CC (0.10) in the HRZ and the HAHZ had the highest CC (0.79), as well as NEM 2016, CDZ had low CC (0.25) and WZ shows highest CC of 0.71 and finally, for NEM 2017, WZ had the lowest correlation (0.30) and CDZ and SZ both had 0.71 CC value observed, respectively. CC has increased in 2015 and 2017, but 2016 observed less significant in Fig 2a. In addition to the seasonal scale HRZ, NWZ, and SZ in 2015, CDZ, HRZ, NWZ, and SZ in 2016 and finally, NEZ, NWZ, and WZ in 2017 observed low correlations (< 0.5) among the agro-climatic zones across Tamil Nadu. HAHZ (0.79), WZ (0.71), and CDZ (0.71) only show higher correlations over all the zones for the respective year of 2015, 2016, and 2017. As a results, the consistency of PERSIANN precipitation data was better with data of observation stations.

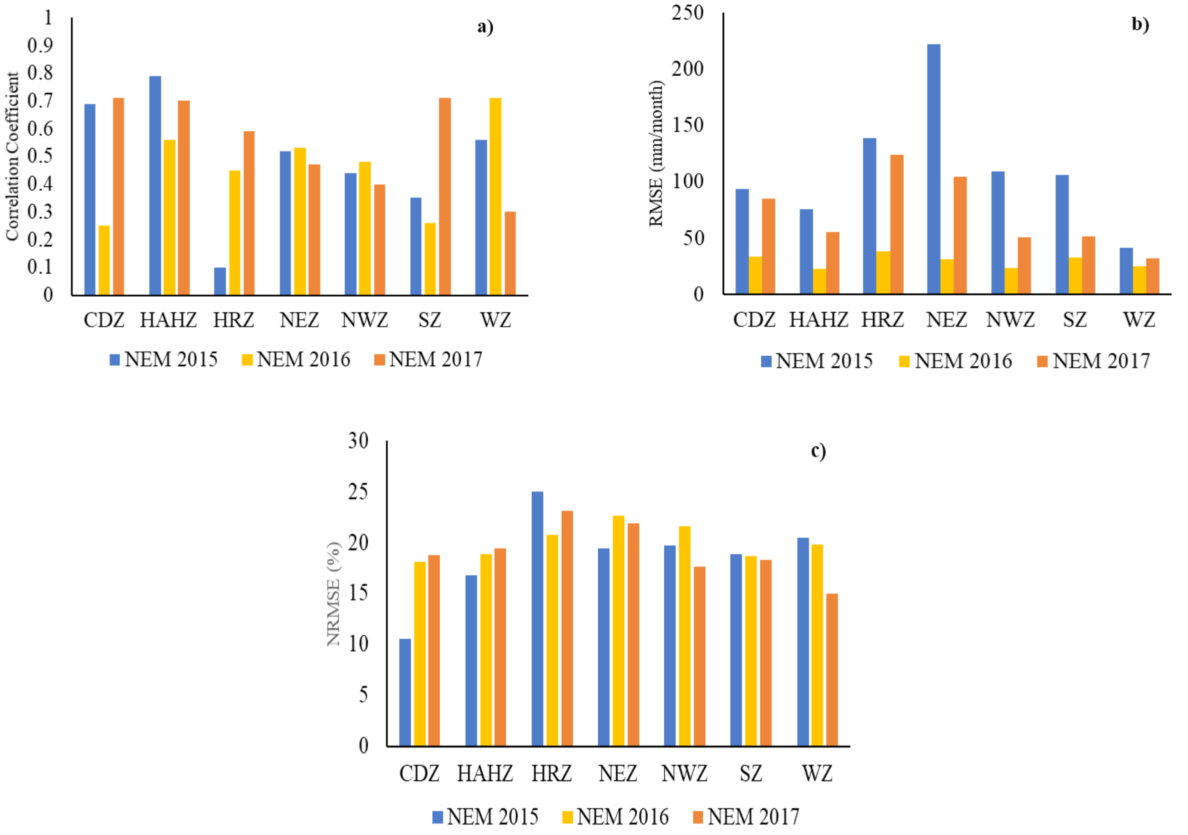

Figure 2. Variations of a) correlation coefficient, b) RMSE and c) NRMSE of the northeast monsoon rainfall for the period of 2015 –2017.

Root Mean Square Error (RMSE)

The relative amount of rainfall in each climate zones calculated for each season (Table 2). The RMSE in respective zones of rainfall is used to assess the difference between PERSIANN and gauge patterns in Fig 2b. In general, during the rainy seasons in India, PERSIANN captured good agreement against rain gauge by Brown (2006). RMSE value range of 22.63–222.17 for all three seasons (Fig 2b). The highest RMSE value was measured for NEZ during 2015 (222.17 mm), and the lowest was 22.63 in HAHZ during 2016. The RMSE values showed that WZ had a relatively small error in NEM of 2015; in 2016, most of the climatic zones had the lowest error with < 38.62, and HRZ had high RMSE score registered during NEM 2017. Furthermore, during all seasons, the PERSIANN more precisely captures rainfall against rain-gauge measurements.

Table 3. NRMSE of PERSIANN in different agro-climatic zones at seasonal scale for the northeast monsoon season over 2015 - 2017

Agro-Climatic Zones / Seasons	NEM 2015	NEM 2016	NEM 2017
Cauvery delta zone (CDZ)	10.57	18.15	18.8
High-altitude and Hilly zone (HAHZ)	16.79	18.82	19.40
High rainfall zone (HRZ)	24.99	20.80	23.15
North Eastern Zone (NEZ)	19.45	22.63	21.87
North Western zone (NWZ)	19.73	21.57	17.64
Southern zone (SZ)	18.90	18.69	18.3
Western zone (WZ)	20.45	19.85	14.98

Normalized Root Mean Square Error (NRMSE)

The lower NRMSE value, the smaller error. NRMSE values lower than 100 % indicating good accuracy for three seasons. Therefore, the smallest error and highest accuracy vice-versa show during 2015. In all climatic zones, a higher NRMSE value was observed. For NRMSE, HRZ topped the group, with NEZ second and NWZ third among the zones (Table 3). Furthermore, from 2015 to 2017, the NRMSE decreased on a time scale. During NEM 2015, PERSIANN showed smaller errors in CDZ (10.57), and higher in HRZ (24.99). As can be found in Fig 2c, for the agro-climatic zones PERSIANN data, the NRMSE of the NEM of 2015, 2016, and 2017 was showed to be the smallest in CDZ (10.57), followed by the WZ (14.98) and HAHZ (16.79). Finally, NRSME values show closer to rain-gauges measurement over seven agro-climatic zones from 2015 to 2017.

CONCLUSION

The accuracy of the PERSIANN satellite-based precipitation product was statistically evaluated (CC, RMSE, and NRMSE) by comparing TAWN rain-gauge network data at seasonal scale for seven agro-climatic zones in Tamil Nadu. A PERSIANN rainfall product has good agreement with the observed dataset showing a high correlation. In particular, the values > 0.5 between 2015 and 2017. Especially HAHZ recorded better performance of correlation with 0.79 during the 2015 NEM season. The highest RMSE value was measured at the NEZ during 2015 (222.17 mm), and the lowest was determined 22.63 in HAHZ during 2016 and NRMSE less errors during all three seasons. Over a regional scale, the evaluated PERSIANN product is needed to use for further spatial and temporal study of hydrological applications flood and drought monitoring.

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Consent for publication

All the authors agreed to publish the content.

Competing interests

There was no conflict of interest in the publication of this content

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