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Short communication

Rainfall analysis across the north east Indian state of Tripura

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The warm and humid tropical climate of Tripura (Hyperthermic) in the Purvachal range manifests a high degree of seasonal variability in rainfall (length of growing period >300 days), which is the main support to rainfed shifting cultivation and horticultural plantations in the hill slopes and extensive rice cultivation along with vegetable integration in the plain areas. The spatiotemporal variability in meteorological parameters like rainfall, temperature and wind speed were evident over the NE region including Tripura, with increasing irregularities in the seasonal rainfall distribution and extremes over NE Indian region (Saha *et al*., 2016; Chakraborty *et al*., 2017). Despite present concerns about the potential consequences of global climate change on the spatiotemporal variability of regional wetness trend evaluation; such time series datasets are rarely available for different northeast Indian states (Saha *et al*., 2016). Therefore, our present study focused on characterization of the spatiotemporal variability of intrastate location-specific wetness trend rather than rainfall pattern at different time scales in Tripura.

The rainfall dataset from twelve rain gauge stations were available across Tripura from 1970 to 2016 (Fig. 1). The variability in average annual rainfall ranged between 2153 mm (Agartala) to 2725 mm (Sabroom). The available rainfall datasets were unimodal and free from any first-order autocorrelation. Trend in seasonal and annual rainfall pattern (mean values) for four distinct seasons namely, winter (January–February), pre-monsoon (March-May), monsoon (June–September) and post-monsoon (October–December) months. Standardised Precipitation Index (SPI) follow the normal distribution but rainfall series rarely. SPI based wetness analysis gained major importance in recent years as the potential indicator of drought occurrence and its intensity, permitting comparisons over variable space and time (Saha et al., 2015). The SPI was calculated for different timescales *viz.* 1 month (1-SPI), 2 months (2-SPI), 3 months (3-SPI), 4 months (4-SPI), 6 months (6-SPI), 12 months (12-SPI) and 24 months (24-SPI). We tested null hypothesis (H_0) for having no trend in the time series against alternative hypothesis (H_1) for identifying significant increasing or decreasing trend in the respective time series using rank-based non-parametric Man Kendall test. Finally, the spatial distribution of identified seasonal and annual SPI trend was mapped under GIS environment (Arc GIS 9.3).

Long-term trend in monthly, seasonal and annual rainfall unveiled a high degree of spatial variability (Table 1). However, the decreasing trend in monthly and seasonal rainfall was prominent for all the selected rain gauge stations. Pre-monsoonal rainfall significantly reduced at AD Nagar ($P< 0.01$) and Belonia ($P< 0.05$) station; monsoon ($P< 0.01$) and post-monsoon ($P< 0.05$) rainfall at Amarpur. Sonamura and Udaipur experienced a reduction in pre-monsoon rainfall over the entire period, including April rainfall in particular ($P<0.1$). The decline in pre-monsoon shower will adversely affect the net water availability for growing *rainfed* crops in

Table 1: Observed trend in periodic rainfall pattern at different raingauge stations across the Tripura State

Period	Agartala	Kailashar	AD Nagar	Amarpur	Dharmanagar	Belonia	Kamalpur	Khowai	Sabroom	Sonamura	Udaipur
January	-1.75^	-2.68**	0.54	0.72	0.31	0.44	0.08	1.92^	0.00	0.86	0.18
February	-0.59	-0.82	-0.56	-1.07	-0.40	-0.76	0.20	0.77	-0.82	0.35	-0.64
March	-1.03	-1.47	-0.37	-0.30	-0.78	0.30	0.70	0.23	0.30	0.44	0.32
April	-0.14	-0.64	-2.52**	-2.25**	-1.87^	-2.50**	-0.89	-1.60	-0.52	-1.68^	-1.86^
May	1.34	1.34	-1.63	-0.32	0.43	-0.99	0.82	-0.73	1.03	-1.22	-0.80
June	-0.98	-1.58	-1.16	-1.01	0.46	0.11	0.06	0.12	-0.59	0.16	-0.67
July	-1.17	-1.48	-1.69^	-2.65**	0.48	-2.17*	0.46	0.26	-0.71	-1.04	-1.28
August	-1.09	-0.50	-0.96	-1.68^	-0.86	-0.50	0.36	-1.51	-0.90	-1.09	-0.31
September	0.27	1.24	-0.78	0.89	0.92	0.20	-0.68	0.33	0.63	0.03	-0.54
October	0.26	-0.78	0.14	-0.62	0.38	0.76	1.54	2.39**	0.82	0.12	1.00
November	-1.25	-1.78^	-2.04*	-2.36**	-1.61	-2.61**	-1.56	-1.52	-1.98^	-1.61	-1.54
December	-0.80	-0.18	-0.83	-1.09	-0.97	-1.30	-0.99	-0.49	-0.43	-1.11	-1.59
Annual	-0.62	-0.86	-2.46**	-2.49**	0.11	-2.40**	-0.01	-1.49	-0.65	-1.65	-1.49
Winter	-1.16	-1.72^	-0.39	-0.80	0.25	-0.36	0.41	1.38	-0.52	0.55	-0.39
Pre monsoon	1.01	0.25	-2.54**	-1.40	-0.50	-2.22*	-0.03	-1.05	0.86	-1.72^	-1.44
Monsoon	-1.20	-1.01	-1.67	-2.49**	0.98	-1.22	-0.01	-1.42	-0.84	-1.18	-1.38
Post Monsoon	-0.53	-1.04	-0.66	-1.28	0.00	-0.50	0.59	1.11	-0.21	-0.69	0.15

(Note: '^'signifies p< 0.1; '*'signifies p< 0.05; '**'signifies p< 0.01)

Tripura (Chakraborty *et al*., 2017). The annual rainfall also indicated a significant declining trend at AD Nagar (P< 0.01), Amarpur (P< 0.01) and Belonia (P< 0.05). Under limited availability of water harvesting structures (*jalkunds*), supportive irrigation facilities, mulching and water conservation facilities, reduction in annual rainfall may take toll on *rabi* cultivation with limited soil moisture availability (Saha *et al*., 2015). Rapid clustered urbanization in the nearby areas of rain gauge stations replaced the natural vegetation with agricultural croplands, such localized human-induced land-use changes may be resulted in such anomalies for the selected locations in Tripura. The changes in rainfall dynamics may remould the present pattern of stream flows and agricultural water availability from runoff, antecedent soil moisture and groundwater reserves (Jain and Kumar, 2012).The scatter plot between 1- SPI and monthly rainfall deficit (%) for all the selected raingauge stations are presented in Fig. 2. The monthly linear slope values (m) of the fitted curve varied between 0.221-2.145 with statistically significant R^2 values (p<0.01).We observed that the steepness of slope served as an effective and promising indicator for characterization of the major rainfall receiving months in Tripura region. the linear fitted curves, it was evident that major rainfall receiving months bear the linear slope values > 1. The slope values of major rainfall receiving months varied from 1.34 (April) to its peak at august (m = 2.145) and then declined to 1.27 during October. From November to March the values of the slopes were <1.0. Indian monsoon monitoring systems. However, the pattern differed for the NE Indian states of Mizoram, so as for Tripura also between April to October (Saha *et al*., 2016). Therefore, it was clear that the slope of linear plot between 1- SPI and rainfall deficit (%) would be simple effective criteria for characterization of major rain-bearing months in any location. The identified criteria still require extensive supportive validation studies for getting wide acceptablity from different very low to moderate rainfall receiving regions of India (Saha *et al*., 2015).

Site-specific SPI based time series over different timescales were more robust and efficient to detect the periodic progress pattern in seasonal wetness, than the cumulative rainfall time series in Tripura. The significant reduction in average winter wetness (2 SPI) may intensify the water scarcity for *rabi* cultivation at Kailshar in near future (Fig.3a). For the other nine stations, there

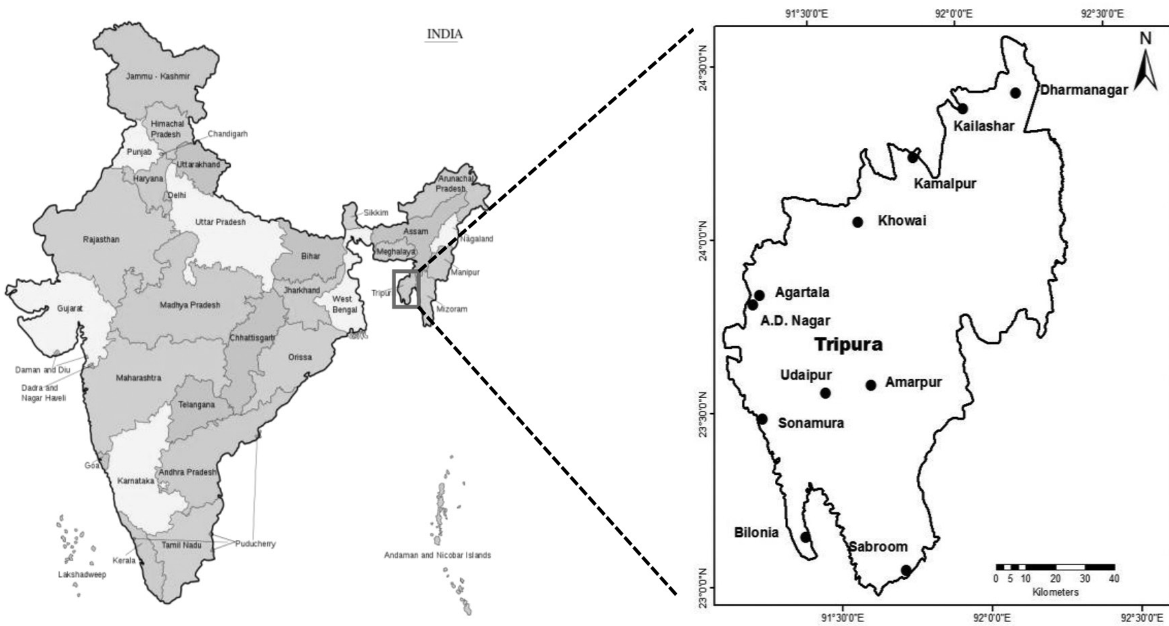

Fig 1: Location details for the selected raingauge stations across the Tripura state

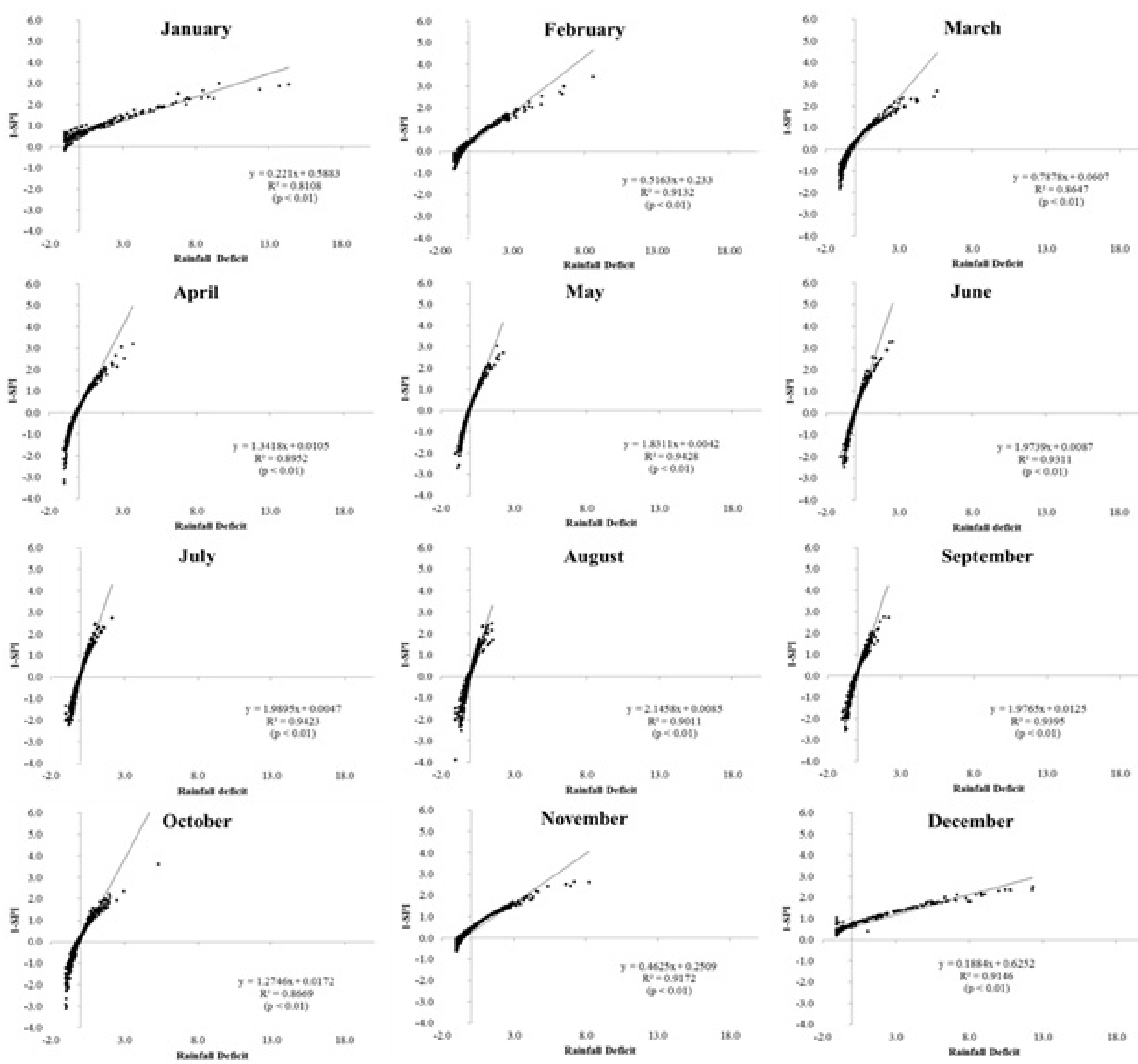

Fig. 2: Scatter plot between 1-SPI and monthly rainfall deficit (%) in Tripura

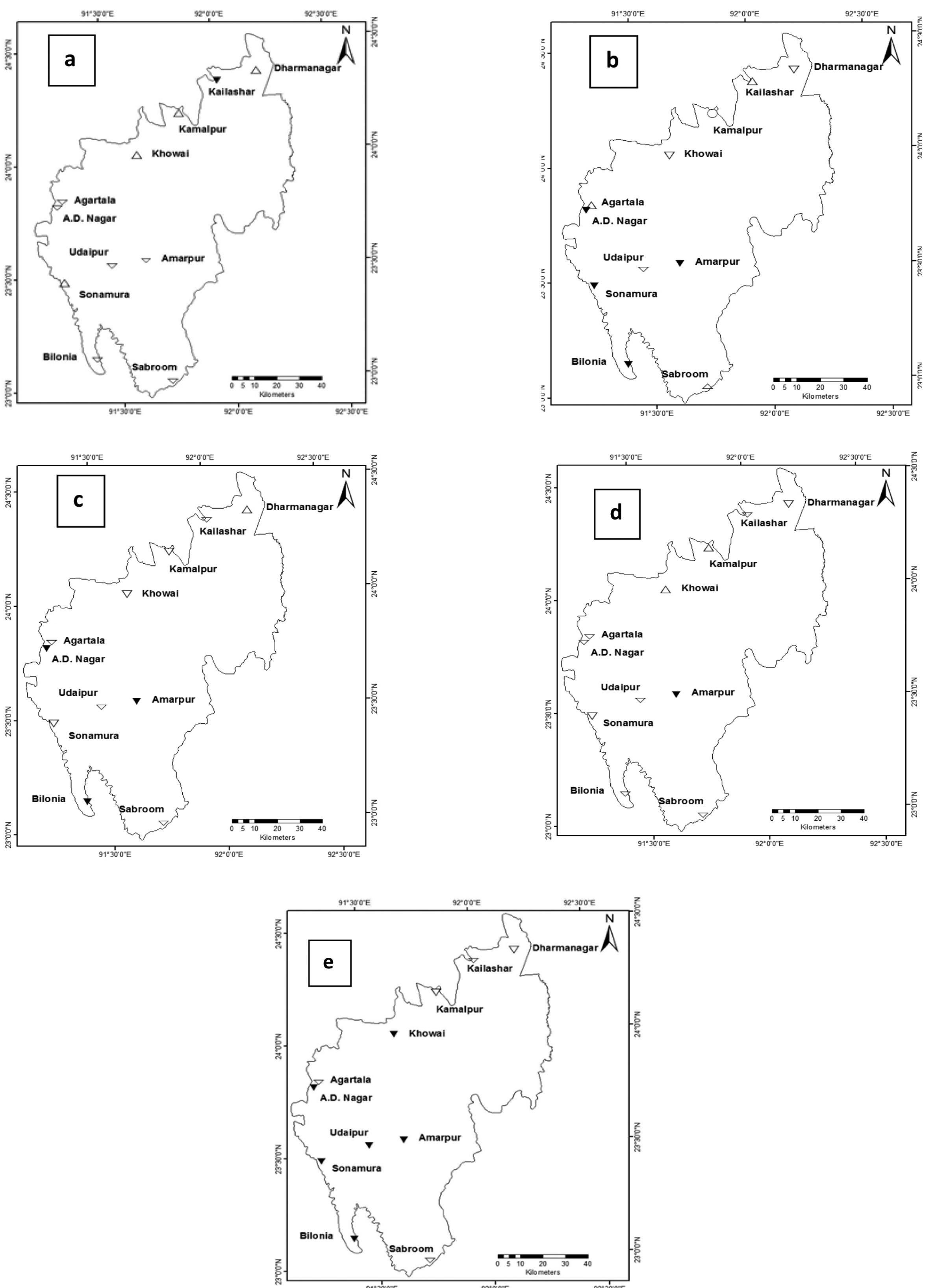

Fig. 3: Spatial distribution of seasonal SPI trends: a. winter b. pre-monsoon c, monsoon d, post-monsoon e. Annual and Bi-annual. Upright and inverted filled (black) triangle indicate significant positive (wet) and negative (drying) trends respectively; white filled upright triangle and inverted triangle indicate non-significant positive (wet) and negative (drying) trends

was no significant change in winter wetness during the study period. Pre-monsoon wetness (3-SPI) significantly decreased at AD Nagar, Amarpur, Sonamura, and Belonia (Fig.3b). For Amarpur station, a non-significant reducing trend in pre-monsoon rainfall resulted in a significant reduction in SPI based pre-monsoon wetness time series. In contrast to the significant reduction in monsoon rainfall at Amarpur, we observed a significant reduction in 4-SPI based monsoon wetness at AD Nagar, Amarpur and Belonia station (Fig.3c). Crop management practices facilitating diversification and shifting cropping pattern i.e. from high requiring (rice) to low water requiring (pulses) crops or cultivation of abiotic stress tolerant cultivars may reduce the risk of crop failure during monsoon months. At Amarpur, the significant reduction in post-monsoon shower was in synchrony to the significant reduction in 3-SPI based post monsoon wetness that may hamper the progress of *rabi* agriculture without widespread adaptation of suitable soil water conservation measures in near future (Table 1 and Fig.3d). Rest all other stations, remained un-affected from localized seasonal wetness variability over the present study period in Tripura. Though the initial annual rainfall trend analysis confirmed the significant reduction in annual rainfall at AD Nagar, Amarpur and Belonia station only (Table 1); but a significant reduction in annual wetness (12 SPI) was evident at Khowai, Amarpur, AD Nagar, Udaipur, Sonamura and Belonia (Fig.3e). This gradual significant decline in seasonal and annual wetness over past four decades poses a potential threat for agricultural water availability and annual regional watershed hydrology in Tripura (particularly at Amarpur, Belonia and AD Nagar; Chakraborty *et al*., 2017). Widespread adaptation of water-saving irrigation techniques, cover crop cultivation, mulching, and selection of suitable crops or appropriate water stress tolerant cultivars will encounter the adverse impact of periodic water scarcity across identified locations prone to periodic water scarcity in Tripura.

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