Spatial variability in temporal trends of precipitation and its impact on the agricultural scenario of Mizoram

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Long-term monthly rainfall observations (1986–2014) were analysed for 12 rain-gauge stations installed at variable altitudes of Mizoram. Our objective was to assess the temporal change in the standardized precipitation index (SPI) values at different timescales using Mann–Kendall trend tests. Significant reductions in post-monsoon and winter rainfall were recorded for most of the sites. Increasing dryness during the winter months may intensify the acute water shortage in Mizoram. Our results emphasize the altitudinal insensitivity of mean monthly rainfall trend and prove the urgent need for adopting suitable water management practices to cope with the water scarcity problem to increase the resiliency of *rabi* agriculture in Mizoram in near future.

Keywords: Agriculture, rainfall pattern, standardized Precipitation Index, spatial variability.

MIZORAM is one of the vast geologically and climatologically diverse sister-lands among the seven sister states of North East India. Agriculture has been traditionally a subsistence profession and majority of the cultivable area is under rainfed condition. A major portion of the state receives heavy rainfall (>250 cm annually) with low intra-annual variability. The dependency on the seasonal rainfall for agriculture is high. Substantial amount of annual rainfall (~36%) received during pre-monsoon season (March–May) has reduced the sole dependency on monsoonal rainfall during June–September (~58%). Thus, it provides a good scope of prolonged crop-growing season to majority of farmers practising shifting cultivation in Mizoram. But the spatial distribution of rainfall is highly variable. The dependency of agricultural production on monsoonal rainfall is high with increasing proneness of Mizo agriculture towards the consequences of rainfall variability.

Das *et al.*[1] addressed the role of significant erratic annual rainfall received for imposing serious threats of agricultural drought in the different states of NE India. Modelling studies under A1B baseline scenario revealed the possibility of increase in agricultural vulnerability that poses a serious threat for water availability in the entire state of Mizoram[2]. Jhajharia *et al.*[3] observed no significant trends in monsoonal rainfall for the plains of Assam, Arunachal Pradesh and Meghalaya, but increasing trend for Tripura, mostly during winter season. Significant decrease in summer monsoon rainfall over the 'South Assam Meteorological Subdivision' (including Mizoram) was observed @ 11 mm/decade[1]. Jain *et al.*[4] reported significant increase in August rainfall (as well as monsoon rainfall), with no significant trend in annual rainfall for NMMT (Nagaland, Manipur, Mizoram and Tripura ~ 70,495 sq. km) hydro-meteorological subdivision. Saikia *et al.*[5] analysed the 1° × 1° gridded rainfall data and reported a significant reduction in rainy days (9%) and annual rainfall (7.7%) for all districts of Nagaland and Mizoram from the IMD satellite data product without any ground validation.

Fragmented literature is available on the temporal trends in rainfall at larger spatial scale, but with limited number of observations across the different states of NE India. We found that any study of annual rainfall trend reported from this South Assam Meteorological Subdivision often ignored the spatial variability in the weather trends across Mizoram. In the present study, we project the variation in temporal pattern of rainfall using standardized precipitation index (SPI) for different timescales across Mizoram, to assess its possible impact on Mizo agriculture. In the recent past, such validation study was rarely reported for this region aiming to unveil the existing reality of any trend for sudden or creeping change in monthly or seasonal drought proneness towards the agriculture/horticulture-based crop planning for this NE Himalayan state of India.

Monthly rainfall data of selected 12 rain-gauge stations located at variable altitudes across Mizoram were collected from the Directorate of Economics and Statistics, Government of Mizoram for the period 1986–2014. Table 1 presents details about the location of the rain-gauge stations. We analysed the trends in seasonal rainfall recorded by categorizing the yearly available 12 months period in a calendar year into four distinct seasons: January and February (winter), March–May (pre-monsoon), June–September (monsoon) and October–December (post-monsoon). SPI was computed with the available time-series data for different timescales, viz. 1 month (1-SPI), 2 months (2-SPI), 3 months (3-SPI), 4 months (4-SPI), 6 months (6-SPI) and 12 months (12-SPI)[6–8]. Missing values were replaced by the monthly average to maintain the dataset continuity. Nonparametric Mann–Kendall tests were adopted for monotonic trend analysis using DOS executable program downloaded from the United States Geological Survey website (http://pubs.usgs.gov/sir/2005/5275/downloads/), for seasonal rainfall

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Table 1. Detailed location information of the 12 selected rain gauge stations across the Mizoram, with the period of rainfall data unavailability

District	Site	Latitude (N)	Longitude (E)	Altitude (m)	Missing value
Aizawl	Aizawl	23°43′37″	92°43′03″	1231	–
	Neihbawih	23°49′59″	92°44′37″	1123	–
	Sialsuk	23°24′01″	92°44′59″	1488	–
Lunglei	Lunglei	22°54′25″	92°45′30″	1128	2008–2010
	Hnahthial	22°57′51″	92°55′42″	883	–
	Tlabung	22°54′43″	92°29′53″	21	2009–2010
Kolasib	Kolasib	24°12′74″	92°40′63″	622	–
	Bilkhawthlir	24°19′53″	92°42′38″	594	–
Saiha	Saiha	22°29′24″	92°58′50″	1226	–
Lawngtlai	Lawngtlai	22°31′56″	92°53′50″	847	2010–2011
Serchhip	Serchhip	23°18′29″	92°51′24″	1281	–
Champhai	Champhai	23°28′40″	93°19′44″	1678	–

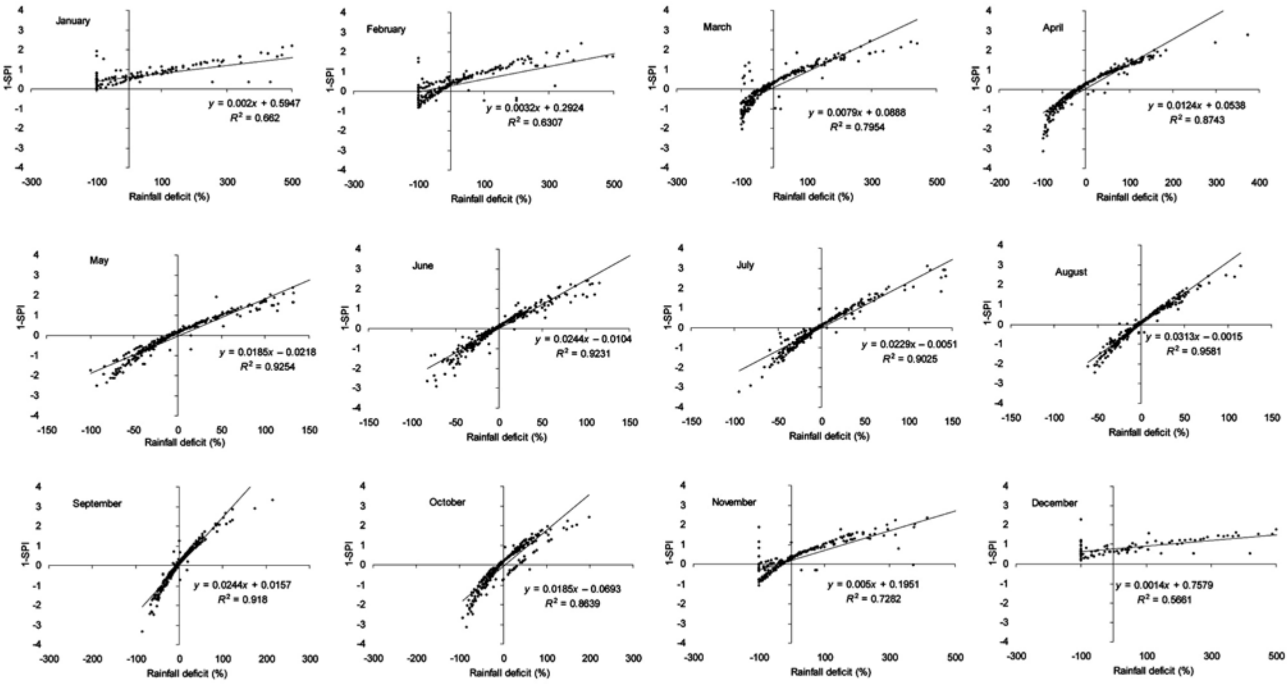

Figure 1. Scatter plot between 1-SPI and monthly rainfall deficit (%) for Mizoram.

and the specified time-series datasets of corresponding SPI values, with 29-year time series[9]. The seasonal trends in SPI were represented by the trends in 3-SPI during May (pre-monsoon), 4-SPI during September (monsoon), 3-SPI during December (post-monsoon) and 2-SPI during February (winter). For the months with erratic and very low rainfall normal (<100 mm and CV > 0.40; November–April), the calculated values of 1-SPI were discarded for further statistical trend analysis[6]. Additionally, the magnitude of local changes in 12-SPI/annual precipitation patterns in hydrometeorological series (Sen's estimator) was estimated. Spatial distributions of trends in seasonal and annual SPI were mapped under GIS environment (Arc GIS 9.3).

We observed a significant spatial variability for the monthly rainfall trend among the specified rain-gauge stations of Mizoram. 1-SPI was considered to be the representative of short-term variation in the normalized monthly precipitation for any rain-gauge station[6]. To eliminate the error in interpretation for the low-rainfall months (<100 mm) with high coefficient of variation (>40%), all the rain-gauge station data (monthly) were pooled into the scatter plots separately (Figure 1). Unlike the all-India scenarios, the regressed value ($R^2 > 0.90$; $P < 0.05$) with linear best fit confirmed the period from May to September as the major rainfall receiving months in Mizoram (Figure 2). Therefore, the seasonal rainfall deficit from May to September will be more useful to

Table 2. Trend in monthly rainfall (Z values for 1-SPI) during the jhum season at Mizoram

Site	May	June	July	August	September
Aizawl	–0.30	–0.37	–0.45	+0.10	+1.51
Neihbawih	+3.25***	+3.30***	+1.50	+2.17**	+1.90*
Sialsuk	+1.28	+1.84*	+0.79	+2.47**	+0.08
Lunglei	+1.69*	+2.57***	+2.48**	+2.30**	+0.15
Hnahthial	+0.56	+0.89	–2.11**	+0.55	+0.47
Tlabung	+0.42	+0.42	–0.05	–2.17**	–1.85*
Kolasib	+0.83	–1.15	–0.95	+1.80*	+0.57
Bilkhawthlir	+1.35	–0.06	0.24	+0.95	–0.61
Saiha	+1.67*	+0.51	–1.27	+1.51	–1.03
Lawngtlai	+0.87	+0.05	–0.65	–1.10	–0.26
Serchhip	+0.17	–0.08	–1.58	–1.80*	–0.79
Champhai	+0.81	–0.65	–0.85	–0.55	–0.83
Mizoram State	+1.35	–0.38	–1.46	+1.47	+0.14

*Significant at $P \leq 0.1$; **Significant at $P \leq 0.05$; ***Significant at $P \leq 0.01$.

Table 3. Theil–Sen's estimator value for estimating the magnitude of changes (1986–2014) in August rainfall at different rain-gauge stations of Mizoram

Site	Theil–Sen's estimator (mm/decade)
Aizawl	–2.30
Neihbawih	+11.25**
Sialsuk	+8.90**
Lunglei	+16.12**
Hnahthial	+3.54
Tlabung	–5.59**
Kolasib	+5.05
Bilkhawthlir	+4.28
Saiha	+7.07*
Lawngtlai	–1.55
Serchhip	–3.68*
Champhai	–1.19

*Significant at $P \leq 0.1$; **Significant at $P \leq 0.05$.

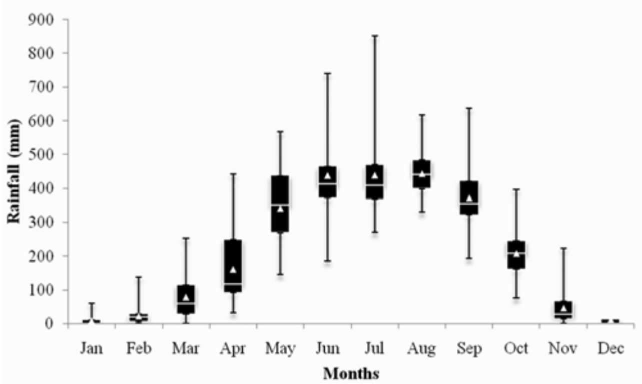

Figure 2. Box and whisker plot of areal average mean monthly rainfall (1986–2014) in Mizoram. Triangle denotes the mean value, solid line is the median, and height of the box is the difference between the third and first quartiles (IQR). Any data observation which lies 1.5 IQR lower than the first quartile or 1.5 IQR higher than the third quartile can considered an outlier in the statistical sense.

determine the advent of any drought event during the major crop cultivation period in Mizoram, rather than existing one, viz. June–July–August–September (JJAS) rainfall only.

Month-wise monotonic trend analysis of the site-specific 1-SPI values from May to September show significant variability in mean monthly rainfall trend across Mizoram (Table 2). For Neihbawih station, a significant increase ($P < 0.01$) in monthly rainfall was observed for May and June. Similar increasing trend was significant at Lunglei for May ($P < 0.1$), June ($P < 0.01$) and July ($P < 0.05$) and June rainfall ($P < 0.01$) at Sialsuk. In contrast, Hnahthial experienced significant reduction in the July rainfall ($P < 0.05$). Being the month of major monsoonal activity, August rainfall showed an increasing trend for different rain-gauges sites. No significant trend was observed during the rest of the major rainfall-receiving months (May–September). Thus, based on the analysis of these ground rain-gauge station data we disagree with the prediction of increasing drought occurrence during the monsoon months in Mizoram in near future[2]. The increasing trend in August rainfall was significant for some of the high-altitude regions, receiving >450 mm August rainfall[4], viz. Neihbawih ($P < 0.05$), Lunglei, ($P < 0.05$), Sialsuk ($P < 0.05$) and Saiha ($P < 0.1$) (Table 3). August–September is the major harvesting season for tribal farmers practising the traditional shifting jhum cultivation. Excess moisture availability during this period has the potentiality to hinder the jhum harvesting. This may hamper crop harvesting from the distant jhum fields and increase the possibility of crop damage. In contrast, significant decreasing trend in August and September rainfall at Serchhip ($P < 0.1$) and Tlabung ($P < 0.05$) may reduce the length of crop growing period in the rainfed jhum fields, with increasing risk of crop failure.

Figure 3 shows the spatial distribution pattern of the seasonal SPI trends. In contrast to the finding of decreasing annual rainfall trend obtained from IMD gridded data product[5], we observed no significant change in average annual rainfall received across Mizoram[4]. We accounted for the high spatial variability with simultaneous existence of both positive and negative location-specific

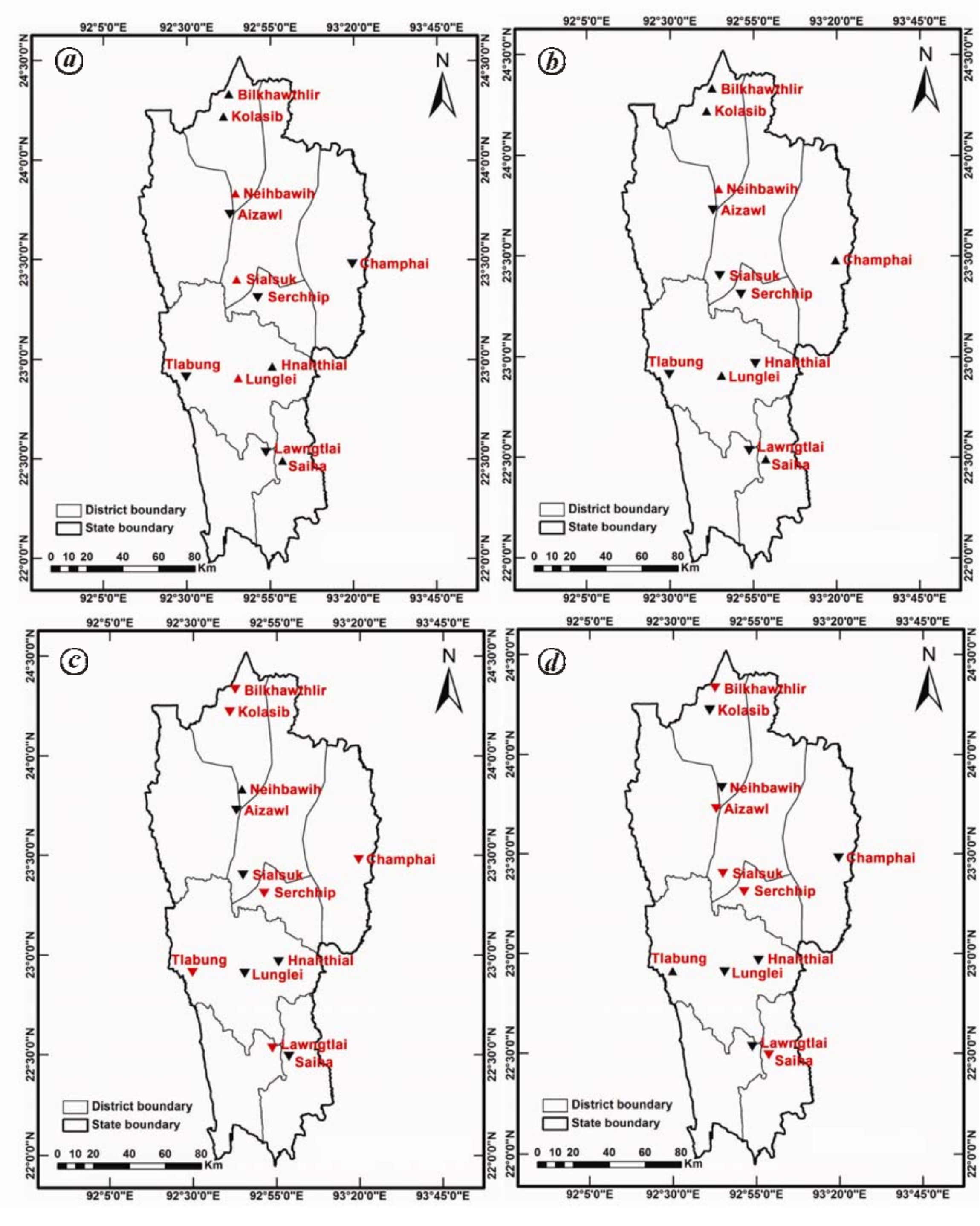

Figure 3. Spatial distribution of seasonal SPI trends: ***a***, March–May (pre-monsoon); ***b***, June–September (monsoon); ***c***, October–December (post-monsoon); ***d***, January–February (winter). Red upright triangle and inverted triangle indicate significant positive (wet) and negative (drying) trends respectively; black upright triangle and inverted triangle indicate non-significant positive (wet) and negative (drying) trends respectively.

weather trends in seasonal and annual SPI distribution pattern at the different rain-gauge stations independent of the altitudinal variations across Mizoram. The changing pattern in the annual rainfall received was confirmed with the increasing trend in the annual wetness at Neihbawih ($P < 0.01$), Lunglei ($P < 0.05$) and Sialsuk ($P < 0.1$) due to increasing trend in rainfall received during the pre-monsoon and monsoon season (Figure 3 *a* and *b*). Most of the places show a significant sharp declining trend of seasonal SPI values (towards increasing dryness) in either post-monsoon ($P < 0.1$) or winter rainfall ($P < 0.05$) received during the past 29 years across different districts

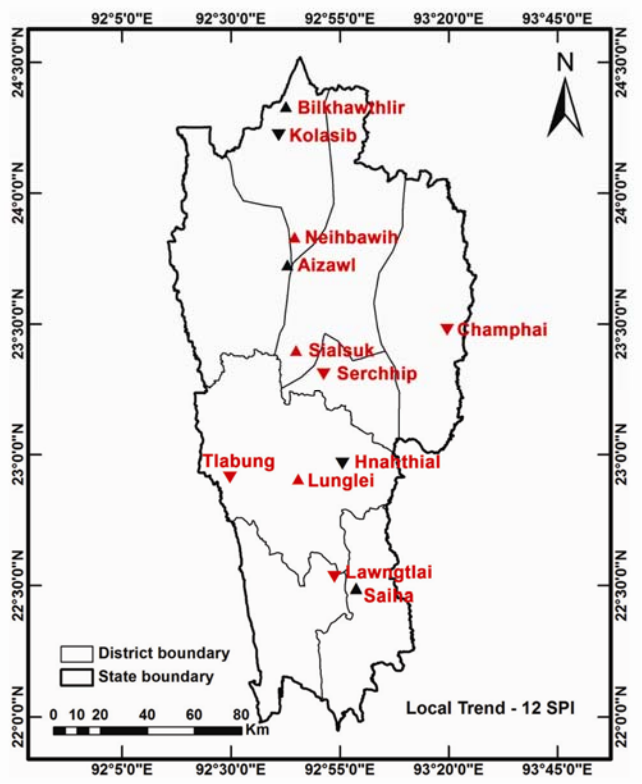

Figure 4. Local trends in annual SPI (12 SPI). Red and black triangles, same as in Figure 3.

of Mizoram (Figure 3 *c* and *d*). Significant decrease in winter rain reduced the 2-SPI values at Sialsuk ($P < 0.05$), Serchhip ($P < 0.01$), Aizawl ($P < 0.01$), Bilkhawthlir ($P < 0.05$), Kolasib ($P < 0.1$), Saiha ($P < 0.1$) and Neihbawih ($P < 0.1$). This may intensify the risk of loss due to uncontrolled forest fire from the jhum burning during January and February. At the state level, the significant decrease in post-monsoon ($P < 0.1$) and winter rainfall ($P < 0.05$) poses a serious threat of increasing agricultural drought occurrence during *rabi* cultivation period[1].

In contrast to the predicted scenarios for Mizoram by Ravindranath *et al.*[2], the local annual SPI (12-SPI) trend map confirmed a pattern of negative trend over southern Mizoram, which indicates an increasing trend in dry conditions with time (Figure 4). Lunglei ($P < 0.05$) was the only place in southern Mizoram, where the annual SPI showed significant increasing trend for the 29 years time-period. The decreasing trend of annual SPI was significant at Champhai ($P < 0.05$), Serchhip ($P < 0.01$), Lawngtlai ($P < 0.05$) and Tlabung ($P < 0.05$), which may result in acute water shortage problem due to increasing dryness in near future. The increasing annual wetness over northern Mizoram, viz. Sialsuk ($P < 0.05$), Lunglei ($P < 0.05$) and Aizawl ($P < 0.05$), indicates the trend of more water availability for the rainfed cultivation practices in the state.

We accounted for the considerable variability in seasonal and monthly rainfall received over the Mizoram for the last 29 years. The rainfall received during May–September, will be more useful to sustain the agricultural production scenario in Mizoram, rather than simply citing the monsoonal rainfall (JJAS) only. Decreasing rainfall trends in the post-monsoon season with increasing dryness poses a serious threat to the effort for increasing cropping intensity by adopting the *rabi* vegetable cultivation in Mizoram. Rainwater harvesting during the peak monsoon months will gain increasing importance to maintain the resiliency of *rabi* agriculture in the foreseeable future.

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