An Integrated Approach to the Preparedness and Mitigation of Cyclone *Tauktae*: The Case of Kerala

1. Introduction

The term 'tropical cyclone' refers to warm-core, non-frontal synoptic systems of low pressure that develop over tropical or subtropical oceans (Hobgood 2005). The winds can spread hundreds of kilometres from the eye of the storm (IMD 2021). They create a whirl in the atmosphere with very strong winds circulating around them. The air circulates at high speeds around the low-pressure area, in the northern hemisphere direction in an anticlockwise direction, and in the southern hemisphere direction in a clockwise direction (Spiridonov and Špuric 2021). Generally, they develop in the North Indian Ocean (Arabian Sea and Bay of Bengal) during the pre-monsoon (March-May) and post-monsoon season (October-December).

About 76% of India's coastline is prone to cyclones (NDMA 2008). Although the Bay of Bengal and Arabian Sea generate only about 7% of the world's cyclones, the impact is comparatively high and devastating (Gupta et al. 2019). Kerala's 589.5 km long coastline has been witnessing several cyclones in the recent past. According to the 2011 census, the state has a coastal population of nearly 42.29 lakh people and a coastal urban density of 4228 people per square kilometre. This further exacerbates the disaster risk of the coast.

1.1. Increasing occurrence of cyclones in the Arabian Sea

Earlier, tropical cyclones in the Arabian Sea were restricted to Gujarat and Maharashtra. Now even Kerala and Karnataka have become more vulnerable to cyclones. Recently, cyclones *Ockhi* and *Tautkae* have adversely affected the western coast, including Kerala.

The Intergovernmental Panel on Climate Change (IPCC) Special Report on 'Oceans and Cryosphere in a Changing Climate' (2019) states that even though the cyclones did not make landfall, they produced heavy rainfall on western Indian coasts. With a rapidly warming Indian Ocean, such severe cyclones are projected to increase in number and the possibility of them making landfall over the west coast of India cannot be overlooked.

A recent study (Deshpande et al. 2021) from the Indian Institute of Tropical Meteorology (IITM), under the Ministry of Earth Sciences, reveals that very severe cyclones in the

Arabian Sea have increased by 150% and their duration has risen by 260% in the past four decades. Climatologically, the Bay of Bengal is more frequented by tropical cyclones (TCs) than the Arabian Sea. However, recent years exhibit a greater number of TCs forming in the Arabian Sea than in the Bay of Bengal during the study period (1982–2019). The frequency of cyclonic storms in the Arabian Sea increased by 52% between 2001 and 2019 compared to the 19-year period between 1982 and 2002.

Not just the frequency, the intensity and duration of cyclones is also changing over the Arabian Sea. There was an 80% increase in the total duration of cyclones in the Arabian Sea in the most recent epoch (2001-2019). The intensity of cyclones has also increased in the Arabian Sea, by about 20% (post-monsoon) to 40% (pre-monsoon). Due to the increase in frequency, intensity, and duration of tropical cyclones, Accumulated Cyclone Energy (ACE), which is the measure of the total wind energy during a cyclone's lifetime, has also increased over the Arabian Sea.

Increased TC duration in the Arabian Sea is due to an increase in the relative mid-level relative humidity and averaged moist static energy columns which is significantly associated with the increase in temperature of the sea surface and the tropical cyclone heat potential in the basin. Tropical cyclone genesis in the lower latitudes (8°N) has been reported in recent times, which is another factor that contributes to extended TC duration. This increases the likelihood of TC intensification with the support of other favourable environmental conditions.

Tauktae is the fourth cyclone in consecutive years to develop in the Arabian Sea. Cyclone *Mekunu* hit Oman in 2018, *Vayu* in Gujarat (2019), and *Nisarga* in Maharashtra (2020). All these cyclones have been categorized as either severe cyclones or above. Cyclone *Tauktae* took only 2 days to become VSCS, while cyclones *Mekunu* and *Nisarga* developed more slowly, taking 4 and 5 days, respectively.

1.2. History of cyclones in Kerala

Kerala has been hit mainly by 5 cyclones in the history of the last 127 years. Recently, there were two cyclones, *Gaja* (16 November, 2018) and *Ockhi* (28 November- 7 December, 2017), earlier in 1912 (19-22 November 1912, 17-19 December 1912) and one cyclone in 1925 (06-10 November) (see Fig. 1, 2 and 3). All three cyclones affected the southern districts of Kerala and Tamil Nadu. The cyclone, which occurred in 1925 (November 06-10),

passed through north Kerala on November 10. The cyclone that occurred in November 1912 passed through the southern coasts of Kerala and Tamil Nadu. *Ockhi* was the fourth cyclone to form in the Comorin Sea (South of Kerala and Tamil Nadu, and west of Sri Lanka). It was after 92 long years that a cyclone passed through the Kerala coast. But *Ockhi* (2017) did not cross the Kerala-Tamil Nadu coast.

On November 8, 2018, low pressure formed between Thailand's sea and the Malay Peninsula, entered the Andaman coast in the Bay of Bengal and became the *Gaja* cyclone. *Gaja* travelled along the longest track in recent times, crossed the Indian Peninsula for the first time and entered the Arabian Sea at extreme low pressure over Kerala in the afternoon on November 16. Since 1990, after the India Meteorological Department (IMD) started monitoring cyclones accurately, this was the first cyclone that formed in the Bay of Bengal and reached the Arabian Sea through Kerala.

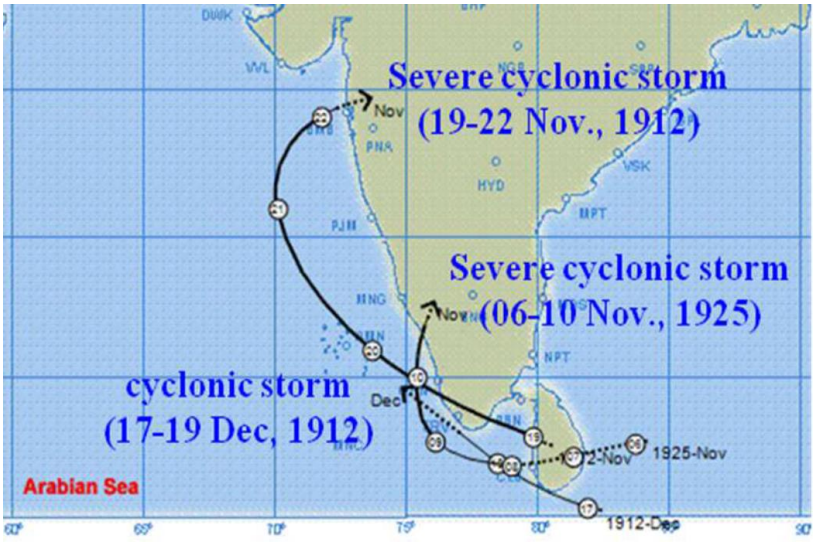


Figure 1. Climatological tracks of cyclones affecting Kerala during 1891-2016 (**Source:** India Meteorological Department)

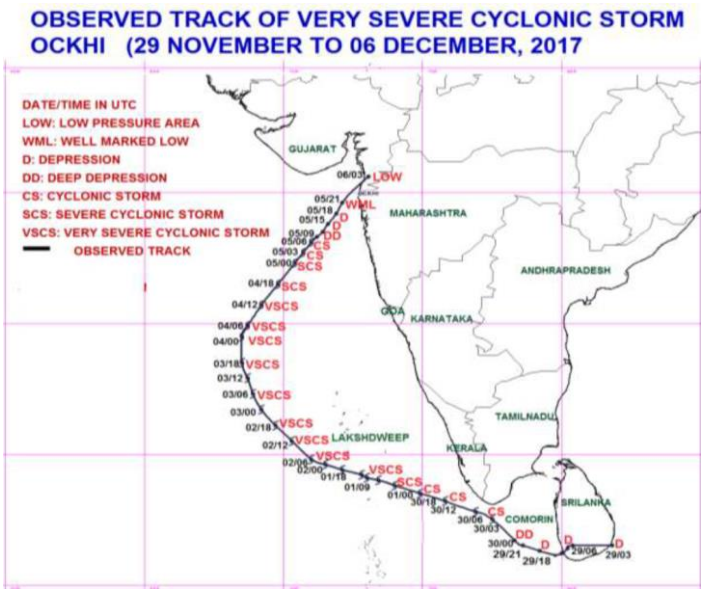


Figure 2. Observed track of Very Severe Cyclonic Storm *Ockhi* (29 Nov- 06 Dec 2017) (**Source:** India Meteorological Department)

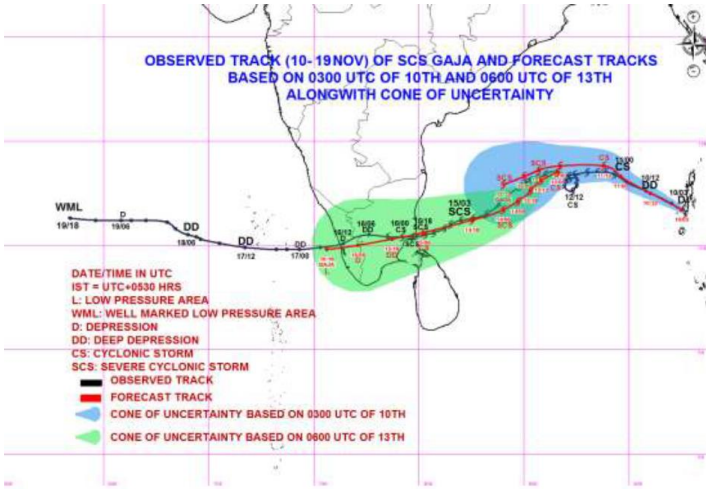


Figure 3. Observed track of Very Severe Cyclonic Storm *Gaja* (10-19 Nov 2018) (**Source:** India Meteorological Department)

2. Extremely Severe Cyclonic Storm Tauktae over the Arabian Sea (14th - 19th May, 2021)

2.1. Cyclogenesis and Track

As per the bulletins issued by India Meteorological Department (IMD) the details of cyclogenesis and track of the cyclone *Tauktae* are as follows

- A low-pressure area formed over the southeast Arabian Sea & adjoining Lakshadweep area in the morning (0830 hrs IST of May 13th,2021). It lay as a well-marked low-pressure area over the Lakshadweep area and the adjoining southeast Arabian Sea in the same evening (1730 hours IST on May 13th).

- Under favourable environmental conditions, it concentrated into a ***depression*** over the Lakshadweep area in the morning (0830 hrs IST) of May 14th, 2021.
- It intensified into a deep depression over the Lakshadweep area and the adjoining southeast & east central Arabian Sea in the same afternoon (1430 hrs IST of May 14th) and into a ***cyclonic storm "TAUKTAE"*** at midnight (2330 hrs IST) over the same region.
- It moved nearly northwards and intensified into ***a severe cyclonic storm*** in the evening (1730 hrs IST) of May 15th over the east central Arabian Sea.
- Continuing to move nearly northwards, it intensified into a ***very severe cyclonic storm*** over the east central Arabian Sea in the early hours of May 16th (0230 hrs IST) over the east central Arabian Sea.
- It gradually started moving north-northwestwards from noon (1130 hours IST) on May 16th and intensified rapidly into an ***extremely severe cyclonic storm*** in the early hours (0530 hrs IST) of May 17th.
- Thereafter, it entered a marginally unfavourable environment, weakened gradually, and crossed the Saurashtra coast near latitude 20.8°N and longitude 71.1°E, close to northeast of Diu (about 20 km northeast of Diu) during 2000-2300 hours IST on May 17th, 2021, with a maximum sustained wind speed of 160-170 kmph gusting to 185 kmph.
- During the landfall, the system moved slowly nearly northward, as it started recurvature in the track. After landfall, it weakened into a very severe cyclonic storm over Saurashtra at midnight (2330 hrs IST) on May 17th.
- Thereafter, it started moving north-northeastwards and weakened into a severe cyclonic storm in the forenoon (0830 hours IST) over Saurashtra and further into a cyclonic storm at noon (1130 hours IST) on May 18th, 2021 over Saurashtra and the adjoining Gujarat region.
- Continuing to move north-northeastwards, it weakened into a deep depression over the Gujarat region in the evening (1730 hrs IST) and into a depression over the Gujarat region and adjoining South Rajasthan at midnight (2330 hrs IST) of the 18th. The observed track of the system is presented in Fig. 4.

As the cyclone moved parallel to the west coast, it caused heavy to extremely heavy rainfall, strong winds, and tidal waves that affected Lakshadweep on 13-14th, Kerala on 14-15th, Karnataka on 15th, Goa and south coastal Maharashtra on 15-16th, north Maharashtra on 16-

17th, and Gujarat, Daman & Diu, Dadra & Nagar Haveli on 17th and 18th. Its remnant also impacted northwest India with heavy to very heavy rainfall activity at isolated places over Rajasthan, Haryana, Chandigarh, Delhi, Uttar Pradesh, and Uttarakhand on 19th May 2021.

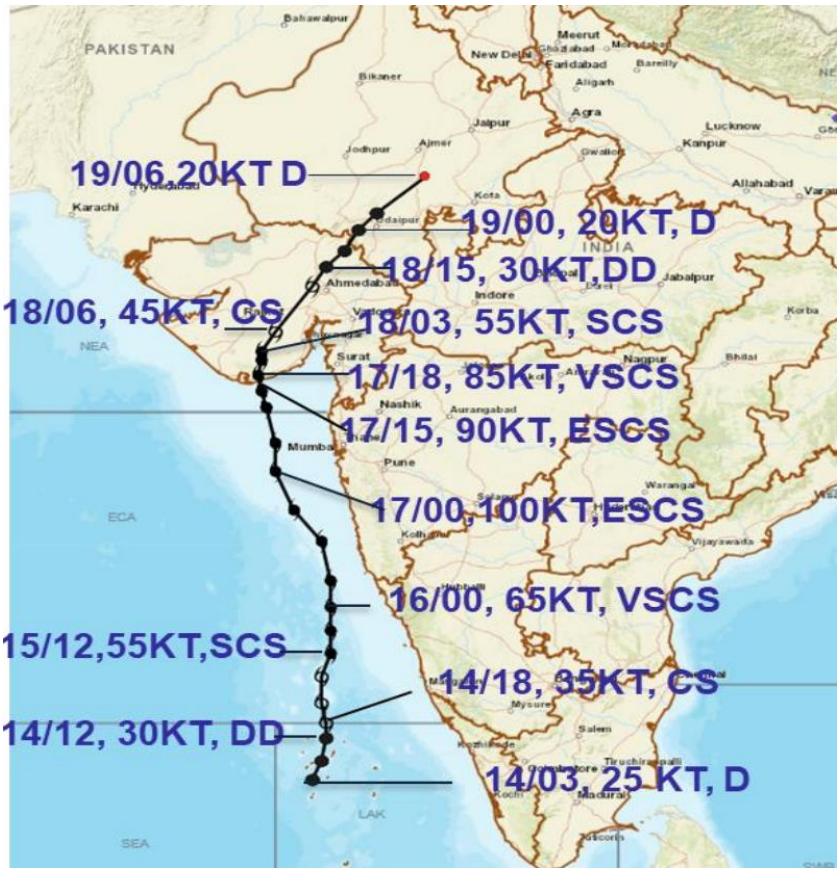
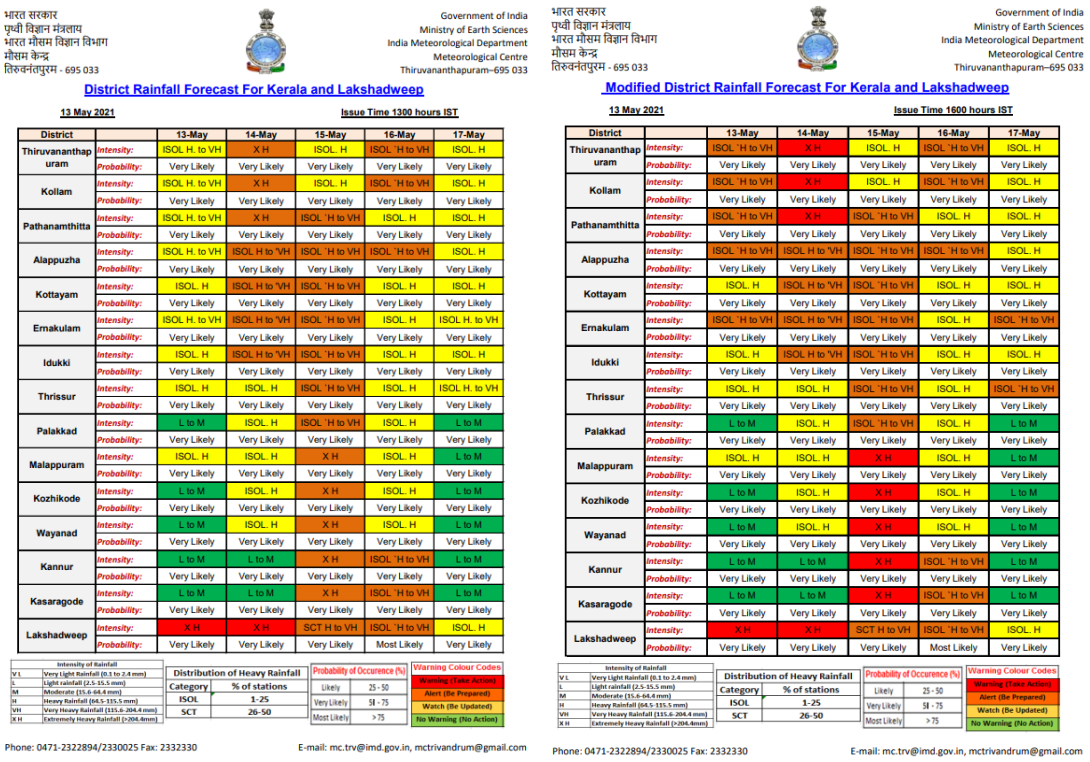


Figure 4. Observed track of Extremely Severe Cyclonic Storm *Tauktae* (14- 19 May 2021) (**Source:** India Meteorological Department)

2.2. Alerts issued for various districts in Kerala

The IMD issued a total of 41 national bulletins, 39 WMO/ESCAP Panel Member Countries RSMC bulletins, nine press releases, 15 hourly bulletins (on the day of landfall), 18 bulletins for 3 international civil aviation, 83 lakh SMS for fishermen, farmers, and coastal populations. IMD, Thiruvananthapuram also issued district-wise alerts during these periods. Although Kerala was not in the cyclone's path, IMD projected significant rainfall.



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District Rainfall Forecast For Kerala and Lakshadweep

13 May 2021 — **Issue Time 1300 hours IST**

District		13-May	14-May	15-May	16-May	17-May
Thiruvananthapuram	Intensity:	ISOL H. to VH	X H	ISOL. H	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	ISOL H. to VH	X H	ISOL. H	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	ISOL H. to VH	X H	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	ISOL H. to VH	ISOL H to 'VH	ISOL `H to VH	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	ISOL. H	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	ISOL H. to VH	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL H. to VH
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	ISOL. H	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL. H	ISOL. H	ISOL `H to VH	ISOL. H	ISOL H. to VH
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	L to M	ISOL. H	ISOL `H to VH	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL. H	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	L to M	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	L to M	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	L to M	L to M	X H	ISOL `H to VH	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	L to M	L to M	X H	ISOL `H to VH	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	X H	X H	SCT H to VH	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Most Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
Watch (Be Updated)
No Warning (No Action)

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Modified District Rainfall Forecast For Kerala and Lakshadweep

13 May 2021 — **Issue Time 1600 hours IST**

District		13-May	14-May	15-May	16-May	17-May
Thiruvananthapuram	Intensity:	ISOL `H to VH	X H	ISOL. H	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	ISOL `H to VH	X H	ISOL. H	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	ISOL `H to VH	X H	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	ISOL `H to VH	ISOL H to 'VH	ISOL `H to VH	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	ISOL. H	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	ISOL `H to VH	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL `H to VH
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	ISOL. H	ISOL H to 'VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL. H	ISOL. H	ISOL `H to VH	ISOL. H	ISOL `H to VH
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	L to M	ISOL. H	ISOL `H to VH	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL. H	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	L to M	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	L to M	ISOL. H	X H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	L to M	L to M	X H	ISOL `H to VH	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	L to M	L to M	X H	ISOL `H to VH	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	X H	X H	SCT H to VH	ISOL `H to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Most Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
Watch (Be Updated)
No Warning (No Action)

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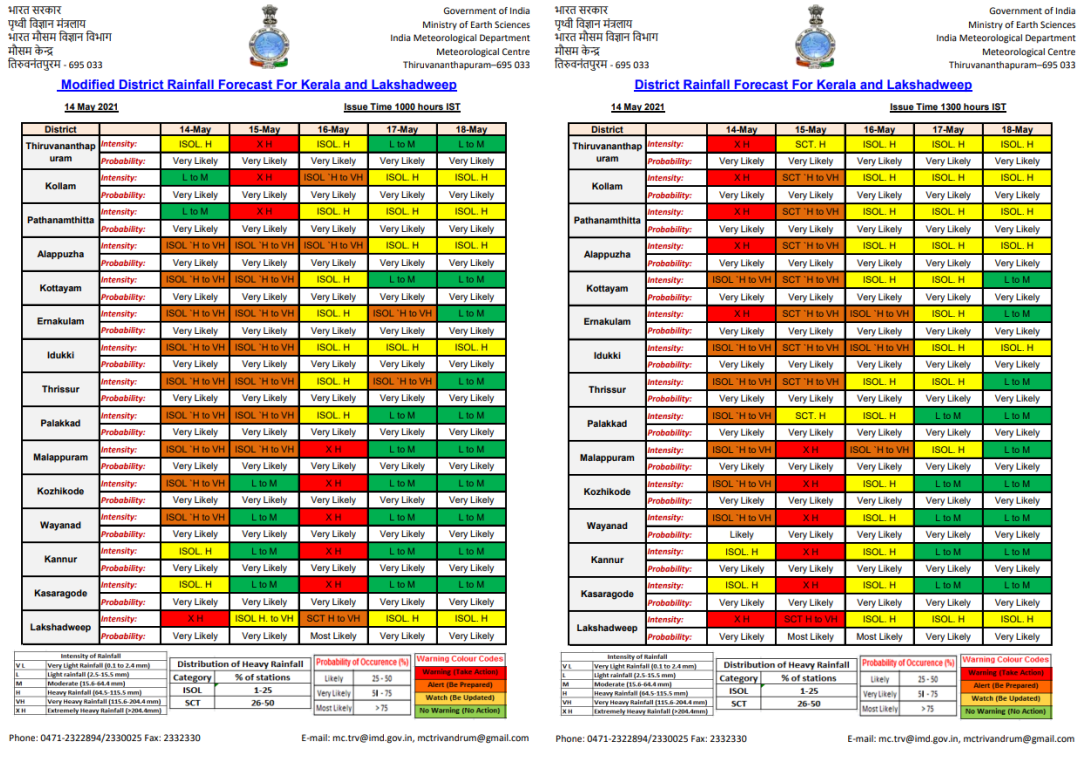
Figure 5. 5 Days district-wise rainfall forecast alerts issued on 13 May 1300 IST and 1600 IST (**Source:** India Meteorological Department)



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Modified District Rainfall Forecast For Kerala and Lakshadweep

14 May 2021 — **Issue Time 1000 hours IST**

District		14-May	15-May	16-May	17-May	18-May
Thiruvananthapuram	Intensity:	ISOL. H	X H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	L to M	X H	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	L to M	X H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL. H	ISOL `H to VH	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL. H	ISOL `H to VH	L to M
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Palakkad	Intensity:	ISOL `H to VH	ISOL `H to VH	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL `H to VH	ISOL `H to VH	X H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	ISOL `H to VH	L to M	X H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	ISOL `H to VH	L to M	X H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	ISOL. H	L to M	X H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	ISOL. H	L to M	X H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	X H	ISOL H. to VH	SCT H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Most Likely	Very Likely	Very Likely

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District Rainfall Forecast For Kerala and Lakshadweep

14 May 2021 — **Issue Time 1300 hours IST**

District		14-May	15-May	16-May	17-May	18-May
Thiruvananthapuram	Intensity:	X H	SCT. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	X H	SCT `H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	X H	SCT `H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	X H	SCT `H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	ISOL `H to VH	SCT `H to VH	ISOL. H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	X H	SCT `H to VH	ISOL `H to VH	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	ISOL `H to VH	SCT `H to VH	ISOL `H to VH	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL `H to VH	SCT `H to VH	ISOL. H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	ISOL `H to VH	SCT. H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL `H to VH	X H	ISOL `H to VH	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	ISOL `H to VH	X H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	ISOL `H to VH	X H	ISOL. H	L to M	L to M
	Probability:	Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	ISOL. H	X H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	ISOL. H	X H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	X H	SCT H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Most Likely	Very Likely	Very Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
Watch (Be Updated)
No Warning (No Action)

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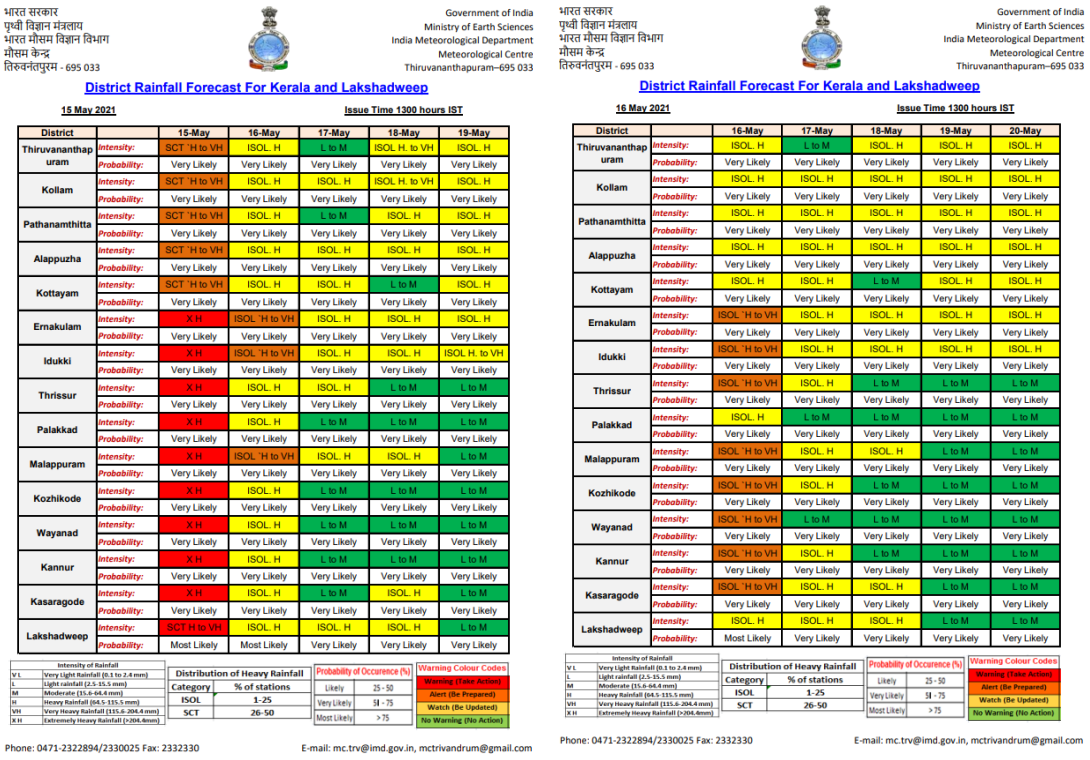
Figure 6. 5 Days district-wise rainfall forecast alerts issued on 14 May 1000 IST and 1300 IST (**Source:** India Meteorological Department)



भारत सरकार
पृथ्वी विज्ञान मंत्रालय
भारत मौसम विज्ञान विभाग
मौसम केन्द्र
तिरुवनंतपुरम - 695 033

Government of India
Ministry of Earth Sciences
India Meteorological Department
Meteorological Centre
Thiruvananthapuram–695 033

District Rainfall Forecast For Kerala and Lakshadweep

15 May 2021 — Issue Time 1300 hours IST

District		15-May	16-May	17-May	18-May	19-May
Thiruvananthapuram	Intensity:	SCT `H to VH	ISOL. H	L to M	ISOL H. to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	SCT `H to VH	ISOL. H	ISOL. H	ISOL H. to VH	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	SCT `H to VH	ISOL. H	L to M	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	SCT `H to VH	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	SCT `H to VH	ISOL. H	ISOL. H	L to M	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	X H	ISOL `H to VH	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	X H	ISOL `H to VH	ISOL. H	ISOL. H	ISOL H. to VH
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	X H	ISOL. H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	X H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	X H	ISOL `H to VH	ISOL. H	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	X H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	X H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	X H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	X H	ISOL. H	L to M	ISOL. H	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	SCT H to VH	ISOL. H	ISOL. H	ISOL. H	L to M
	Probability:	Most Likely	Most Likely	Very Likely	Very Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
Watch (Be Updated)
No Warning (No Action)

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16 May 2021 — Issue Time 1300 hours IST

District		16-May	17-May	18-May	19-May	20-May
Thiruvananthapuram	Intensity:	ISOL. H	L to M	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	ISOL. H	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	ISOL. H	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	ISOL. H	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	ISOL. H	ISOL. H	L to M	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	ISOL `H to VH	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	ISOL `H to VH	ISOL. H	ISOL. H	ISOL. H	ISOL. H
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL `H to VH	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	ISOL. H	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL `H to VH	ISOL. H	ISOL. H	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	ISOL `H to VH	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	ISOL `H to VH	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	ISOL `H to VH	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	ISOL `H to VH	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	ISOL. H	ISOL. H	ISOL. H	L to M	L to M
	Probability:	Most Likely	Very Likely	Very Likely	Very Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
Watch (Be Updated)
No Warning (No Action)

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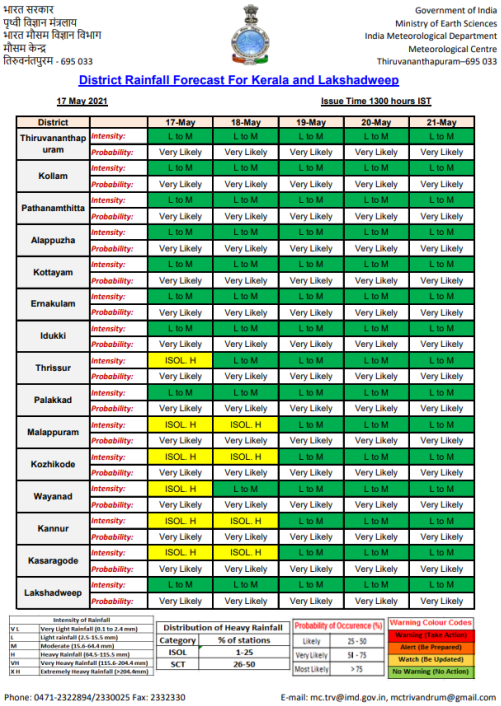
Figure 7. 5 Days district-wise rainfall forecast alerts issued on 15 May 1300 IST and 16 May 1300 IST (**Source:** India Meteorological Department)



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तिरुवनंतपुरम - 695 033

Government of India
Ministry of Earth Sciences
India Meteorological Department
Meteorological Centre
Thiruvananthapuram–695 033

District Rainfall Forecast For Kerala and Lakshadweep

17 May 2021 — Issue Time 1300 hours IST

District		17-May	18-May	19-May	20-May	21-May
Thiruvananthapuram	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kollam	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Pathanamthitta	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Alappuzha	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kottayam	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Ernakulam	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Idukki	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Thrissur	Intensity:	ISOL. H	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Palakkad	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Malappuram	Intensity:	ISOL. H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kozhikode	Intensity:	ISOL. H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Wayanad	Intensity:	ISOL. H	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kannur	Intensity:	ISOL. H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Kasaragode	Intensity:	ISOL. H	ISOL. H	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely
Lakshadweep	Intensity:	L to M	L to M	L to M	L to M	L to M
	Probability:	Very Likely	Very Likely	Very Likely	Very Likely	Very Likely

Intensity of Rainfall	
V L	Very Light Rainfall (0.1 to 2.4 mm)
L	Light rainfall (2.5-15.5 mm)
M	Moderate (15.6-64.4 mm)
H	Heavy Rainfall (64.5-115.5 mm)
VH	Very Heavy Rainfall (115.6-204.4 mm)
X H	Extremely Heavy Rainfall (>204.4mm)

Distribution of Heavy Rainfall	
Category	% of stations
ISOL	1-25
SCT	26-50

Probability of Occurence (%)	
Likely	25 - 50
Very Likely	51 - 75
Most Likely	> 75

Warning Colour Codes
Warning (Take Action)
Alert (Be Prepared)
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No Warning (No Action)

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Figure 8. 5 Days district-wise rainfall forecast alerts issued on 17 May 1300 IST (**Source:** India Meteorological Department)

2.3. Rainfall received in different districts

As the cyclone moved parallel to the west coast, it caused heavy to extremely heavy rainfall activity, strong winds, and tidal waves to affect Kerala on 14th -15th May 2021 (as recorded on 15th -16th May 2021) (see Table 1).

Table 1. Rainfall received in different districts during 13-19 May 2021 (**Source:** India Meteorological Department)

Sl. No.	Districts/ State	Rainfall in mm						
		May 13	**May 14**	**May 15**	**May 16**	**May 17**	**May 18**	**May 19**
1	Thiruvananthapuram	27.8	85.1	75.4	78.5	14.7	5.3	15.1
2	Kollam	1.9	49.1	103.6	45.2	21.7	4.3	19.9
3	Pathanamthitta	0.1	124.2	114.7	58	34.4	1.5	0.7
4	Alappuzha	20.7	102.9	126	46.8	41.6	19.4	2.1
5	Kottayam	30.7	86.3	123.6	70.1	42.7	3.8	6.3
6	Idukki	0	32.4	95	86.6	29.3	3.8	10.2
7	Ernakulum	21.1	62.9	134.1	126.8	31	9.7	6.4
8	Thrissur	27.7	53	151.1	74.9	45.3	11.1	3.5
9	Palakkad	0.1	18.5	68.5	57.9	33.2	5.4	4
10	Malappuram	9.5	18.2	94.8	78.6	47.5	6.4	12.4
11	Kozhikode	3.1	30.7	111.2	155.2	65.9	15.3	12.5
12	Wayanad	1.6	6.9	43.2	116.3	30.8	7.4	2.2
13	Kannur	23.6	6.3	104.4	147.1	36.6	11.6	20
14	Kasargod	31.4	8.2	79.1	79.2	20.4	12.6	14.1
Kerala		**12.5**	**44.6**	**100.9**	**87.2**	**35.4**	**7.7**	**8.8**

Figure 9. High tide at Cheriyazheekkal, Kollam **(Source:** District Emergency Operations Centre, Kollam**)**

Figure 10. Flooded roads in Ernakulam **(Source:** District Emergency Operations Centre, Ernakulam)

2.4. Damages caused

A total of 11 people (see Table 2) lost their lives due to the impact of Cyclone *Tauktae*. The causes of the deaths of people were falling trees and electric posts, lightning, drowning, and electric shocks that occurred during the cyclone. In addition, 22 people were seriously injured and hospitalised.

Table 2. Human fatalities during Cyclone *Tauktae* (**Source:** District Emergency Operations Centres)

Sl. No.	District	No. of Human Fatalities (11.05.2021 to 20.05.2012)
1	Thiruvananthapuram	2
2	Kollam	1
3	Pathanamthitta	0
4	Alappuzha	1
5	Kottayam	1
6	Idukki	2
7	Ernakulam	1
8	Thrissur	0
9	Palakkad	0
10	Malappuram	0
11	Kozhikode	3
12	Wayanad	0
13	Kannur	0
14	Kasaragod	0
Total		**11**

The number of Local Self Government Institutions (LSGIs) affected during the cyclone is as given in Table 3. The district with the highest number of LSGIs affected was Thiruvananthapuram.

Table 3. Number of LSGIs affected by Cyclone *Tauktae* (**Source:** District Emergency Operations Centres)

Sl. No.	District	No. of LSGIs affected
1	Thiruvananthapuram	64
2	Kollam	11
3	Pathanamthitta	8
4	Alappuzha	5 Taluks
5	Kottayam	10
6	Idukki	28
7	Ernakulam	13
8	Thrissur	38
9	Palakkad	4
10	Malappuram	12
11	Kozhikode	16
12	Wayanad	0
13	Kannur	27
14	Kasaragod	25

The damages occurred in the housing sector have been given in Table 4. The number of fully damaged houses as well as the number of partially damaged houses was highest in Thiruvananthapuram district.

Table 4. House damage due to Cyclone *Tauktae* (**Source:** District Emergency Operations Centres)

Sl. No.	District	No. of Fully Damaged Houses	No. of Partially Damaged Houses
1	Thiruvananthapuram	66	984
2	Kollam	20	643
3	Pathanamthitta	2	70
4	Alappuzha	30	650
5	Kottayam	5	342
6	Idukki	6	372
7	Ernakulam	35	420
8	Thrissur	25	81
9	Palakkad	3	55
10	Malappuram	1	20
11	Kozhikode	8	258
12	Wayanad	3	40
13	Kannur	5	120
14	Kasaragod	11	144
Total		**220**	**4199**

Figure 11. House damaged in Palakkad district (**Source:** District Emergency Operations Centre, Palakkad)

Figure 12. House damaged in Malappuram district (**Source:** District Emergency Operations Centre, Malappuram)

As per the database of KSDMA,

- Heavy rains, strong winds and flooding caused considerable damage in the agriculture sector. Crop damage occurred mainly in perennial crops like rubber, banana, coconut etc. About 24433 hectares of perennial crop loss is estimated to have occurred due to cyclone *Tauktae*.

Figure 13. Damage to crops in Thrissur district (**Source:** District Emergency Operations Centre, Thrissur)

- In the fisheries sector, the cyclone caused damage to boats, nets, and fish farms. The total loss assessed in the sector amounts to 1,40,88,874 INR.
- Considering the damage that occurred to electric poles, transformers, and conductors, the loss in the power sector is estimated to be 21.44 crore INR.
- Furthermore, 5 *anganwadis* and 80 schools were affected by the cyclone. As for health infrastructure, only 1 Primary Health Centre was affected in the state.

3. Mitigation and preparedness measures taken

Disaster risk reduction requires an integrative approach not only to mitigate damage but also to ensure seamless transition between the different phases of the disaster management cycle. The institutional mechanism of disaster management at the national, state, district, and taluk levels works in a top-down manner, whereas community-based disaster risk reduction emphasizes a bottom-up approach. A combination of these two approaches is usually seen at work during disasters.

In Kerala, the key measures taken to prepare for and to mitigate the impact of Cyclone *Tauktae* include the following

- Local Self Government Disaster Management Plans (LSG DMP)
- Multi-Purpose Cyclone Shelters (MPCS) under the National Cyclone Risk Mitigation Project (NCRMP)

- Activation of Standard Operating Procedure (SOP) as per the Orange Book of Disaster Management 2: Monsson Preparedness and Response Guidelines 2021 (Edition 2)[1]
- Promulgation of multilingual warnings and IEC materials

These measures are described in detail in the following sections.

3.1. Local Self Government Disaster Management Plans (LSG DMP)

Following the 2018 floods and landslides which hit Kerala, a Post Disaster Needs Assessment[2] (PDNA) was carried out by the Government of Kerala (GoK) which put forth the idea of *Nava Keralam* (meaning new Kerala). Subsequently, Rebuild Kerala Initiative (RKI) was formed as a Special Purpose Vehicle to develop, coordinate, facilitate and monitor the Rebuild Kerala Development Programme (RKDP) through a participatory and inclusive process. The RKDP document[3] constitutes the State's strategic road-map for a green and resilient Kerala. Both the PDNA and RKDP documents recommend the preparation of local level disaster management plans. Kerala also witnessed tremendous participation of people in the 2018 and 2019 flood response activities. The community members donned multiple hats when they acted as first responders, volunteers and resource mobilizers for relief and rehabilitation. Acknowledging the PDNA-RKDP recommendation as well as the role played by the community in disaster management, GoK decided to prepare Local Self Government Disaster Management Plans (LSG DMP) through Local Self Government Institutions (LSGIs). This was done through a campaign called "*Nammal Namukkayi*" which was aimed at utilizing the knowledge, experience and ideas of the entire people of the state in a participatory manner for rebuilding Kerala.

Kerala, in its 14 districts, has 941 Gram Panchayats, 87 Municipalities, and 6 Municipal Corporations, adding up to a total of 1034 LSGIs. It was directed by the government vide G.O. (MS) No.14/2020/LSGD; dated 14.01.2020, that disaster management plans be formulated for all these local bodies in the state. This was a pioneering move, as no other state in the country has undertaken such a pan-state effort.

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[1] Available at https://sdma.kerala.gov.in/wp-content/uploads/2019/12/Orange-Book-of-Disaster-Management-2-2020.pdf

[2] Available at https://sdma.kerala.gov.in/wp-content/uploads/2019/03/PDNA-report-FINAL-FEB-2019_compressed.pdf

[3] Available at https://rebuild.kerala.gov.in/reports/RKDP_Master%2021May2019.pdf

The Local Self-Government Department, Kerala State Disaster Management Authority (KSDMA) and Kerala Institute of Local Administration (KILA) jointly engaged in a resource-intensive, time-bound, pan-Kerala grassroot-level consultation to develop the DM plans at local level. The template of the plan was prepared by KSDMA and KILA. The LSG DMP has 2 parts:

- A template comprising Situation Analysis, Resource Mapping and Intervention Reports. Data, as per the template, can be collected from institutions and available secondary sources.
- The projects proposed to be taken up in the annual plan are based on the above template. Data, as per the template, can be collected by conducting transect walks, focus group discussions, and one-on-one issues that need to be addressed.

KSDMA also prepared a set of 31 maps each for every LSGI. Subsequently, a team of local resource persons were given training by KSDMA on how to prepare LSG DMPs.

This exercise of preparation of disaster management plans at the LSGI level has proved to be very crucial in tackling subsequent disasters, especially cyclone *Tauktae*. LSG DMPs helped in analyzing the present situation, understanding probable hazards, assessing current capacities, ideating preparedness and mitigation measures and proposing appropriate projects.

- The plan documents general information about the LSGI, records past disasters, analyses risks and vulnerabilities, as well as assesses the strength, weaknesses, opportunities, and threats of the LSGI.
- The plan lists down buildings that are identified to be used as relief camps and documents their existing conditions along with the requirements for improving these facilities.
- As part of the DM plan preparation, the following Emergency Response Teams (ERTs) have been formed in every LSG:
    - Early Warning Dissemination Team;
    - Search, Rescue and Evacuation Team;
    - Shelter Management Team; and
    - First Aid/ Basic Life Support Team.

In short, LSG DMPs helped the different stakeholders, such as community members, officials, and elected representatives, understand their LSGI from the perspective of hazard susceptibility and make informed decisions during the cyclone. The document also acted as a resource inventory (material resources as well as human resources) and streamlined response and relief activities.

3.2. Multi-purpose Cyclone Shelters (MPCS) under the National Cyclone Risk Mitigation Project (NCRMP)

The Government of India aims to undertake suitable structural and non-structural measures to mitigate the effects of cyclones in the coastal states and Union Territories through the National Cyclone Risk Mitigation Project. The project is being implemented through the National Disaster Management Authority (NDMA) in coordination with respective state governments and the National Institute of Disaster Management (NIDM). Based on the frequency of occurrence of cyclones, size of the population and the existing institutional mechanism for disaster management, the coastal states and union territories are divided into two categories, namely, 'Category I: Higher Vulnerability States' and 'Category II: Lower Vulnerability States.' Kerala belongs to Category II along with Maharashtra, Karnataka, Goa, Pondicherry, Lakshadweep, Daman and Diu, Andaman and Nicobar Islands. One of the project objectives of NCRMP is '*improved access to emergency shelter, evacuation, and protection against wind storms, flooding and storm surge in high areas.'* Hence, a vital component of the structural measures under this project is the construction of Multi-purpose Cyclone Shelters (MPCS).

The current practice of sheltering vulnerable people in schools and community halls is not feasible, especially for prolonged periods of time, as the facilities in these shelters are inadequate to satisfy the basic needs of the population. MPCS provides permanent infrastructure to facilitate the immediate camping needs of the vulnerable coastal population. Shelters constructed primarily on school premises can be used for classroom purposes and other social activities during normal times. Shelters on revenue land during normal times will also be put to use as training centres, auditoriums, social gatherings, etc. by collecting suitable user-fees. These funds can supplement the efforts to better mainten these shelters.

Table 5. List of MPCS as on 23rd September 2021 (**Source:** NCRMP Kerala)

Sl. No.	LSGI where MPCS is located	District	Adjoining Coastal LSGIs Served by the MPCS
1	Thiruvananthapuram Corporation (Muttathara)	Thiruvananthapuram	Kadinamkulam, Vilappil
2	Thazhava	Kollam	Alappad, Kulashekharapuram, Karuvatta, Karunagapally Municipality, Thodiyoor, Sooranad South, Sooranaadu North, Ochira, Klappana
3	Mararikulam North	Alappuzha	Cherthala South, Mararikulam South
4	Cheruthana	Alappuzha	Thrikunnappuzha, Karthikapally,

			Harippad, Veeyapuram
5	Kumarapuram	Alappuzha	Kumarapuram
6	Vadakekkara (Thuruthipuram)	Ernakulam	Pallippuram, Eriyad (Kozhikode), Chittattukara, Chendamangalam
7	Pallippuram	Ernakulam	Kuzhuppily, Eriyad, edavanakkade, Chittattukara, Ezhikara
8	Kadappuram	Thrissur	Chavakkad Municipality, Orumanayor, Engandiyur
9	Eriyad (Azhikode)	Thrissur	Edavilangu, Pallippuram, Kodungallur Municipality
10	Perumbadappu (Palappetty)	Malappuram	Veliyamcode, Punnayurkulam
11	Vettam (Paravanna)	Malappuram	Niramaruthur, Mangalam
12	Kozhikode Corporation (Kasaba)	Kozhikode	Elathur, Beypore
13	Kannur Corporation (Chalad)	Kannur	Muzhappilangad, Azhikode
14	Kathirur	Kannur	Thalassery Municipality
15	Kumbla	Kasaragod	Mangalpady, Mogral-Puthur
16	Madhur (Kudlu)	Kasaragod	Mogral -Puthur, Kasargod Municipality
17	Pullur Periya	Kasaragod	Pallikkare, Ajanoor

In the wake of the cyclone, all completed MPCSs were kept ready to accommodate people relocated from their houses.

3.3. Activation of Standard Operating Procedure (SOP) as per the Orange Book of Disaster Management 2: Monsoon Preparedness and Response Guidelines 2021 (Edition 2)

Drafted as per Section 22 (2) (f) of the Disaster Management Act, 2005, The Orange Book published by KSDMA spells out the roles and responsibilities of individual departments. Edition 2[4] of the Orange Book contains the Incident Response System structure to be followed at the State, District, and Taluk level. It also provides details of Emergency Operations Centres at the State and District Level and the Standard Operating Procedures to be followed during various hazards. In addition, the handbook also contains the emergency support functions plan, indicating the Suo-moto responsibilities of various departments in the event of emergencies.

[4] The latest edition of the Orange Book is "Orange Book of Disaster Management 2: Monsoon Preparedness and Response Guidelines 2021 (Edition 3)" published on 25 May 2021. This is available at https://sdma.kerala.gov.in/wp-content/uploads/2021/05/orangebook_2021.pdf. However, Edition 2 was in use during Cyclone *Tauktae*.

The Orange Book takes cognizance of the LSG DMPs, especially with regard to the identification of camps in LSGIs and the prioritisation of vulnerable people during warning dissemination and relocation.

The following actions were taken by the government in wake of the cyclone warning:

- 11th May 2021
    - The State Executive Committee of KSDMA was held on May 11th 2021 to assess the threat to the State due to the Low-Pressure System.
    - A total ban on fishing from Kerala from 12th May night (13th, 00:00 hrs) onwards was already issued as per SOP. Heavy rainfall - orange alert; appropriate instructions were issued to Districts.
    - The Coast Guard and Navy were instructed to announce the ban and direct fishermen to return to a safe coast by May 12th midnight.
- 12th May 2021
    - A Monsoon Preparedness review meeting was conducted with IMD, the Central Armed Forces, and State Departments.
    - The State Executive Committee of KSDMA was held to ensure provisions for redundant power supply to oxygen generation units, plants, filling units, distribution units, and COVID-19 treatment centres and hospitals.
    - District Disaster Management Authorities were directed to facilitate COVID-19 Safe Camps as given in the Annexure 3 of the Orange Book. 4 types of camps were to be identified, i.e., 1) Normal camps, 2) Camps for the elderly and those with comorbidities, 3) Camps for those with COVID-19 symptoms, 4) Camps for those under quarantine. Over 2500 camps identified and kept ready
- 13th May 2021
    - 9 teams of NDRF were requisitioned for pre-positioning.
    - Two helicopters of the IAF were kept on standby.
    - Two teams of the Indian Army and two teams of the Defence Service Corps (DSC) were readied and one ETF was kept on standby in Bangalore.
    - The Coast Guard and Navy conducted air sorties and made announcements through the VHF network and microphone announcements in traditional fishing areas in the sea up to the Lakshadweep area.

- Warnings were issued to 100 long-distance fishing boats through satellite phones and to 1.5 lakhs fishermen through SMS from INCOIS.
- The Hon'ble Chief Minister reviewed the preparedness and issued specific instructions.

- 14th May 2021
  - 44 camps were opened due to rampant coastal erosion.
  - All 9 NDRF teams were pre-positioned: Kollam, Alappuzha, Pathanamthitta, Idukki, Ernakulam, Thrissur, Malappuram, Kozhikode, and Wayanad.
  - One team of DSC was pre-positioned in Kasargode.
  - One team of DSC was pre-positioned in Kannur.
  - The Hon'ble Chief Minister reviewed the preparedness and the coastal erosion situation.
- 15th May 2021
  - Coastal erosion, windfall, urban flooding, and coastal flooding were reported from all the coastal districts of Kerala.
  - There were no major power outages at any of the major COVID-19 care facilities.
  - 106 relief camps were opened.
  - The Hon'ble Chief Minister reviewed the situation.
- 16th- 20th May 2021
  - 180 camps were opened.

Table 6. District wise number of camps opened and the number of inmates. (**Source:** District Emergency Operations Centres)

Sl. No.	District	No. of relief camps	No. of families	No. of persons
1	Thiruvananthapuram	17	Not available	1461
2	Kollam	16	Not available	1588
3	Pathanamthitta	11	66	277
4	Alappuzha	26	143	399
5	Kottayam	34	171	575
6	Idukki	3	7	11
7	Ernakulam	36	424	1604
8	Thrissur	17	174	480
9	Palakkad	0	0	0
10	Malappuram	4	68	172
11	Kozhikode	13	58	298
12	Wayanad	0	0	0
13	Kannur	3	45	176

14	Kasaragod	0	0	0
Total		**180**	**1156**	**7041**

3.4. Promulgation of Multilingual Warnings and IEC materials

Taking into account the considerable migrant labour population in the state, KSDMA issued warnings in languages other than Malayalam.

Figure 14. Hindi poster with cyclone preparedness measures (**Source:** KSDMA)

As part of its disability inclusive disaster risk reduction programme, KSDMA issued warnings in sign language with the support of the National Institute of Speech and Hearing. In addition, KSDMA also prepared a video on cyclone safety of buildings giving instructions to house owners on how to ensure the safety of their houses during heavy winds and rain associated with cyclones. All of these warnings and videos were promulgated through the website of KSDMA, official WhatsApp groups, Facebook page and Twitter handle.

Figure 15. Screenshot of the list of KSDMA's WhatsApp groups (**Source:** KSDMA)

4. Conclusion

The activation of SOP based on the Orange Book, which deals with preparedness, and the LSG level Disaster Management plans (Kerala being the only state in India to have DM plans for all LSGs) helped the state in implementing the preparedness and mitigation measures effectively. These preparedness mitigation measures helped the state to reduce casualties. In a nutshell, while the Orange Book helps in managing disasters at the state level by assigning roles and responsibilities to lower levels, the LSG DM Plans bring more attention to the idea of community-based disaster risk reduction. To conclude, a combination of top-down and bottom-up approaches helped in tackling the cyclone in the state.

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