DELINEATING RUBBER PLANTATIONS IN LANDSLIDE PRONE AREAS OF KERALA, INDIA USING REMOTE SENSING AND GIS

Pradeep B*., Jessy M.D and James Jacob
Rubber Research Institute of India, Ministry of Commerce and Industry, Govt. of India,
Rubber Board. P.O, Kottayam, 686 009, Kerala, India
*Correspondence (E-mail): pradeep@rubberboard.org.in

Traditional rubber growing regions of Kerala state contribute around 75 per cent of natural rubber (NR) production in India. The hilly regions of the state witnessed two massive landslides causing many human casualties and serious damages to the environment and properties in the past couple of years. Natural rubber plantations are mostly grown on the undulating and sloping terrains along the foothills of the Western Ghats of the state which are increasingly becoming vulnerable to landslides. Extremely intense rainfall can destabilize hilly terrains where natural rubber is a popular crop among others. To estimate the spatial extent of rubber plantations according to proneness to landslide in Kerala, satellite-based area under rubber (age 3 years and above) was geo-spatially analyzed with landslide susceptible zones of the state and district-wise extent of rubber plantations susceptible to landslide was estimated (low, medium and high). Results showed that out of the total rubber area in Kerala, 1.6 per cent (9,485 ha) was in the high susceptibility zone, 6 per cent (32,398 ha) in the medium and 2 per cent (13,072 ha) in the low susceptibility zone. More than 90% NR holdings are not in landslide prone region. Area under rubber in the highly susceptible zone of landslide was the highest in Kottayam district followed by Idukki, Kannur, Palakkad and Pathanamthitta districts. This information is useful for planning appropriate conservation and management strategies for rubber plantations in the highly vulnerable areas. Rubber farmers can be better advised to mitigate the risks due to landslides. An open source WebGIS based portal was developed for easy dissemination of this information to rubber growers. Good agricultural practices for adoption at a location according to its vulnerability to landslide as well as cultural operations that should not be undertaken are recommended to minimize the occurrence/impact of landslides through this platform.

Key words: Good agriculture practices, Kerala, Landslide susceptible zones, Rubber plantations, Satellite data.

1. INTRODUCTION

It is fairly well recognized that climate change can alter the air temperature and rainfall pattern with higher intensity and more frequent heavy rain events. Rainfall, both prolonged and intense is the most common trigger of landslides. Climate changes also affect the stability of natural and engineered slopes with consequent effects on landslides (Gariano and Guzzeti, 2016). Heavy rain events reduce stability of slope by rapidly raising the water table and by enhancing water drainage through the soil. In addition, intense rainfall can erode surface sediments and higher stream flow can transport more sediment downstream (Borgatti and Soldati, 2010).

A landslide is the movement of mass of rock debris or earth down a slope under the influence of gravity (Hungr *et al*., 2013). Landslides are ubiquitous in hilly environments and play an important role in evolution of landscapes (Gariano and Guzzeti, 2016) and in many areas pose a serious threat to the population (Petley, 2012). There are very few studies on trends in landslides and sediment processes and still fewer have related landslides to climate change. Influence of land use systems on occurrence of landslides is still not clear. Land cover analysis of agricultural and forest land in Poland showed a relatively similar structure of land cover types on areas affected and unaffected by landslides (Kroh, 2016). The author suggested that despite the occurrence of landslides, landslide prone areas can be used for economic purposes without land use changes. Tree cover has been reported to generate a favourable moisture regime and stabilize slopes, but root decay might weaken slopes (Schmidt, *et al*., 2001; Neary *et al*., 2008; Reichenbach *et al*., 2014).

In India, the mountainous and hilly terrains of 16 States and two Union Territories in the Himalayan region, sub Himalayan parts of north east and in Western Ghats are landslide prone. These areas comprise about 12.6 per cent of the India's land mass spreading over 159 districts (GSI, 2017). Kerala, the southernmost State of India is characterised by hilly and undulating terrain with tropical monsoon climate. The State has experienced natural calamities of massive scale in recent years, worst flood of the century in 2018, followed by two destructive landslides in 2019 and 2020 with unparalleled miseries and loss of human lives. There were also landslides of smaller scale in different parts of the state. It is of critical importance to formulate appropriate policy framework to minimise the occurrence of such natural hazards with the collaboration of all concerned stakeholders. Land use systems and practices should be regulated to minimise adverse impacts on the ecosystem. Of the total cropped area of Kerala, around 22 per cent is under rubber and it is mainly cultivated in the foot hills of the Western Ghats on sloping and undulating terrain. The present attempt is to delineate rubber plantations in Kerala in low, medium and high landslide risk categories so that policy makers can recommend appropriate risk mitigation strategies to minimise the occurrence of such disasters in future.

2. METHODOLOGY

District-wise landslide susceptibility zones (shapefiles) available in the platform of Kerala State Disaster Management Authority (KSDMA) were used for the characterization of rubber plantations in Kerala according to landslide proneness (https://sdma.kerala.gov.in/maps). These landslide susceptible zones were prepared by integrating multiple databases like topographical maps, remote sensing data, ground truth and geotechnical investigations (KSDMA, 2015). As per these maps landslide zones of each district in Kerala were classified as low, medium and high susceptible zones. These landslide zones were analysed geo-spatially with satellite-derived rubber plantation maps (age three years and above) and spatial extent of rubber plantations in the different zones were delineated. The spatial extent of rubber plantations in the low, medium and high landslide vulnerable zones were estimated for all districts in Kerala. Rubber plantations were further prioritized based on slope in the highly susceptible zones of landslide using spatial overlay techniques to determine the extent of NR area under the highly vulnerable landslide zone. A web GIS enabled portal was developed by integrating geospatial datasets of area under rubber in the low, medium and high categories of landslide using open source programs/algorithms.

3. RESULTS AND DISCUSSION

The distribution of rubber area in Kerala under various landslide susceptibility zones is shown in Figure 1. Of the total rubber area (3 years and above) in Kerala, 1.6 per cent (9485 ha) is in the high landslide susceptibility zone, 6 per cent in the medium and 2 per cent in the low susceptibility zone. Apart from Alappuzha, landslide susceptible zones were located in all other 13 districts (Table 1). Among the various districts, substantial area under rubber plantations in Kottayam (Figure 2), Idukki (Figure 3) and Kannur (Figure 4) were located in high susceptible zone (Table 1). Rubber plantations in the medium susceptible zones were also mainly located in these districts.

In Kottayam district, of the total rubber area of 107708 ha (3 years and above), 2 per cent is in high, 7 per cent in medium and 3 per cent in the low landslide susceptible zones (Fig. 2). In 25 rubber growing panchayats of Kottayam district, landslide vulnerable areas either in low, medium or high susceptible zones were observed and in 12 panchayats distributed in Meenachil and Kanjirappally taluks, highly susceptible zones were delineated. Highest area in the high susceptible zone was observed in Poonjar Thekkekara panchayat of Meenachil Taluk (659 ha), followed by Mundakayam panchayat in Kanjirappally Taluk (438 ha). Kootickal panchayat in Kanjirappally Taluk also has substantial area in this category (381 ha). Thalanad and Poonjar panchayats in Meenachil Taluk also have considerable area in this category (376 and 209 ha each).

In Idukki district, 2132 hectares under rubber is in high landslide susceptibility zone and 4961 hectares in medium susceptibility zone (Fig. 3). High landslide susceptibility zones were located in 19 panchayats and major share of area in this category was located in Udumbannoor (492 ha), Peruvanthanam (386 ha), Kanjikuzhy (289 ha), Velliyamattom (211 ha) and Alakkode (152 ha) panchayats. Medium susceptibility zones were located in 32 panchayats.

In Kannur district, high susceptible zones were located in 19 panchayats and the major share of area in this category were in Alacode (383 ha), Udayagiri (360 ha), Cherupuzha 9328 ha) and Naduvil (225 ha) panchayats (Fig 4). In 33 panchayats, medium hazard zones were located. Substantial area under rubber in high landslide susceptible zones were observed in Palakkad (909), Pathanamthitta (512 ha), Kozhikode (495 ha) and Kasaragod (485 ha) districts.

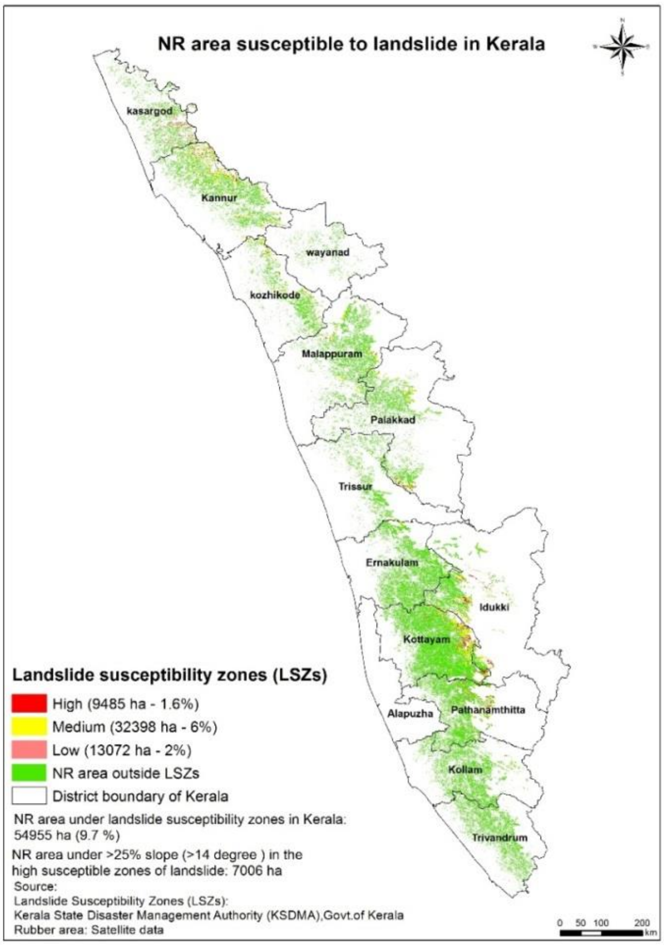

Figure 1. Spatial distribution of rubber area under various landslide susceptibility zones in Kerala.

Table 1. Spatial extent of rubber area susceptible to landslide in Kerala

		Rubber area (age three years and above) in the landslide susceptibility zones (ha)		
Sl.No	**Districts**	**Low**	**Medium**	**High**
1	Trivandrum	162	12	3
2	Kollam	364	443	90
3	Pathanamthitta	3814	1668	512
4	Alappuzha	0	0	0
5	Kottayam	3266	7491	2371
6	Idukki	0	4961	2132
7	Ernakulam	299	900	65
8	Trissur	0	439	15
9	Palakkad	0	2479	909
10	Malappuram	0	2576	287
11	Kozhikode	0	2903	495
12	Wayanad	0	495	0
13	Kannur	0	7976	2121
14	Kasargod	5167	55	485
	Total	13072 (1.6%)	32398 (6%)	9485 (2%)

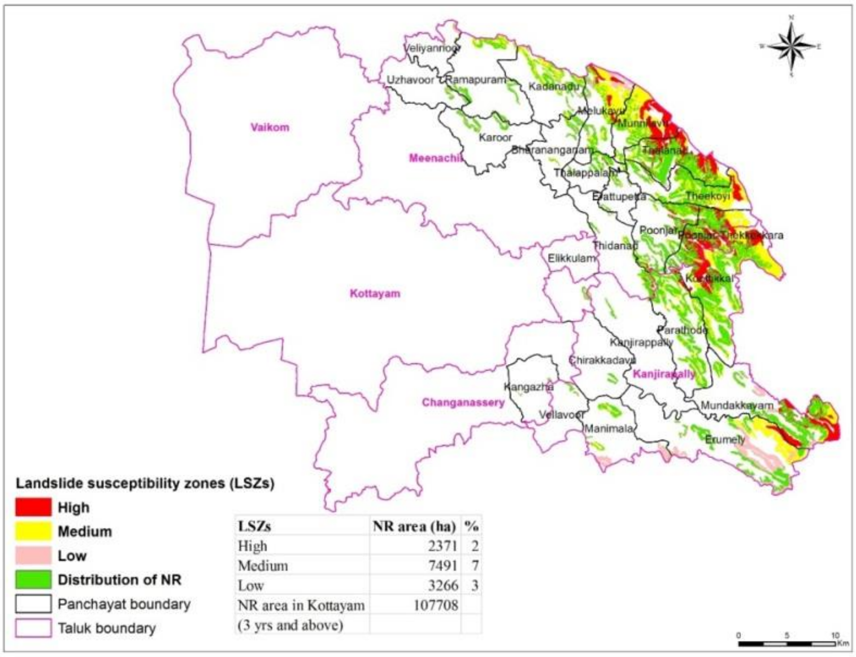

Figure 2. Spatial extent of rubber area in the various landslide susceptible zones in Kottayam district

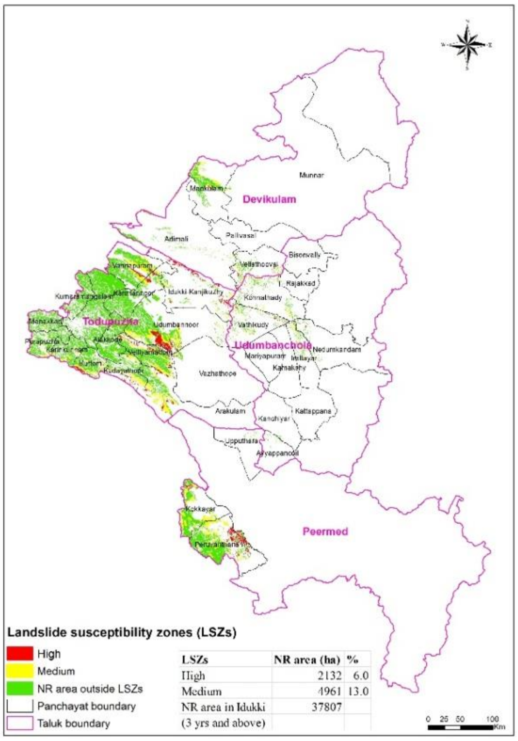

Figure 3. Spatial extent of rubber area in the various landslide susceptible zones in Idukki district

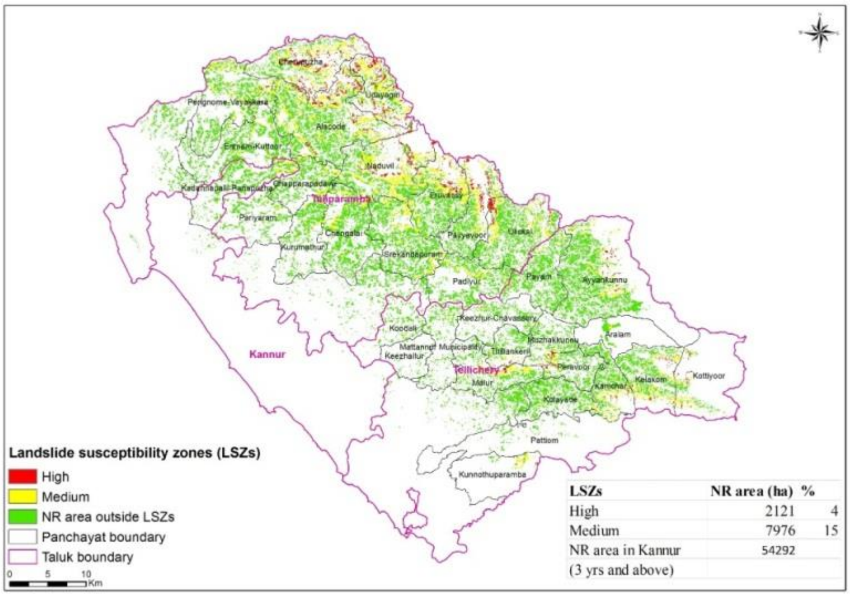

Figure 4. Spatial extent of rubber area in the various landslide susceptible zones in Kannur district

Slope of rubber plantations in the high landslide susceptible zones varied widely, 1-69^{0} and in all districts, this variability was observed (Table 2). However, substantial area under high risk category with respect to landslides was observed above a slope of 14^{o}. Usually, soil and water conservation measures and other cultivation practices like intercropping are recommended based on degree of slope and the data shows that landslide susceptibility also should be taken in to account when these practices are recommended. The data also indicate that degree of slope alone cannot be taken as an indicator of landslide susceptibility of rubber plantations.

Table 2. Slope of rubber plantations in the high landslide susceptible zones

Sl no	**District**	**Slope (degree) range in the high susceptible zones of landslide**	**Rubber area under >25% slope (>14^{o}) in the high susceptible zones of landslide (ha)**
1	Trivandrum	2-47	2
2	Kollam	1-55	70
3	Pathanamthitta	1-56	367
4	Alapuzha	-	0
5	Kottayam	1-69	1743
6	Idukki	1-66	1677
7	Ernakulum	2-61	53
8	Trissur	2-43	6
9	Palakkad	2-62	687
10	Malappuram	1-61	221
11	Kozhikode	1-64	377
12	Wayanad	-	0
13	Kannur	1-60	1469
14	Kasargod	2-65	334
	TOTAL		**7006**

WebGIS portal on landslide susceptibility of rubber growing regions in the study area was developed by integrating geospatial data sets of landslide proneness and agronomic recommendations using an open source leaflet programme/algorithm for the benefit of rubber famers. Geospatial information on landslide susceptibility of rubber plantations at panchayat level was available in the portal. Location-specific agriculture practices and recommendations according to landslide proneness are recommended through the portal https://lsz.rubberboard.org.in

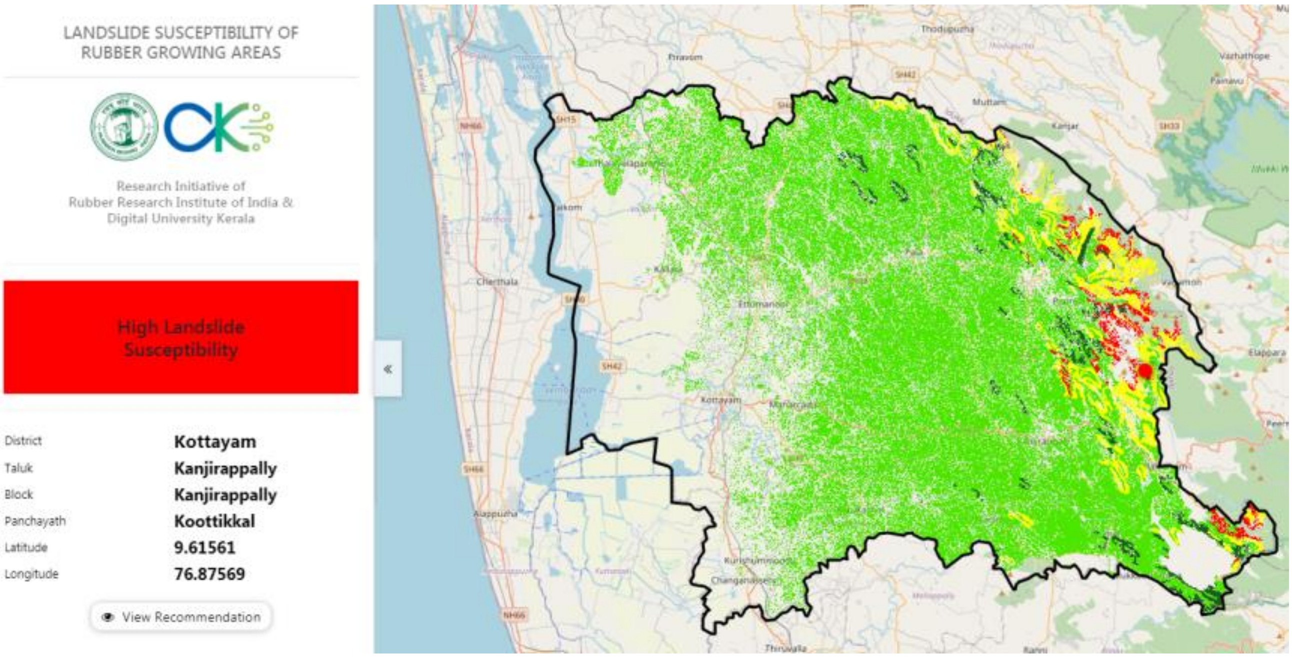

Figure 4. Home page of the webGIS portal showing landslide susceptibility of rubber plantations in Kottayam district of Kerala, India. Red patches are the area under rubber plantations in the highly susceptible zones of landslide. Geographic coordinates, administrative division and agronomic recommendations according to landslide proneness of the region are available in the portal.

The two devastating landslides which occurred in Kerala during 2019 and 2020 have put tremendous pressure on scientists as well as policy makers to devise strategies to minimise the occurrence and mitigate the risks of such natural hazards. Climate change has been attributed as the major factor influencing the distribution, abundance, frequency and occurrence of landslides, but very few studies were conducted in Asia so far on the climate related landslides (Garianno and Guzzetti, 2016). Still few studies were reported on the effect of land use systems on land slides. Landslide susceptible zones prepared by integrating multiple databases like topographical maps, remote sensing data, ground truth and geotechnical investigations (KSDMA, 2015) categorizes the land slide prone areas to low, medium and high categories of proneness and is a vital geo-information for judicious land use planning. Analysis of the documented landslides indicated that antecedent heavy rainfall is the triggering factor in all the cases (Polemio and Petrucci, 2010; GSI, 2017). These are fast tracked by human activities particularly on vulnerable slopes. An increase in total precipitation result in wetter antecedent conditions, which can have multiple negative consequences on slope instability like less rain required to reach a critical level that can cause a slope to fail, higher water table contributing the reduction in shear strength, reduction in soil suction and cohesion and an increase in the wet density of the slope, all leading to slope instability (Tacher and Bonnard, 2007). Analysis of the rainfall pattern showed very heavy rain in Kavalappara in Nilambur during 2019, which might have triggered the landslide on 8th August 2019 (425.6 mm rainfall from 5th to 8th August 2019, Source: Forest Department, Govt. of Kerala). After evaluating the variables and processes affecting landslides, Sidle and Ochiai (2006) concluded that the increase in mean air temperature and changes in regional annual and seasonal precipitation were the most relevant climate variations that may affect landslides. However, there is high uncertainty in predicting rainfall induced shallow landslides occurring due to extreme weather elements due to the uncertainty associated with predicting these weather elements (Coe and Codt, 2012). Polemio and Lonigro (2015) after analysing database on rainfall and temperature concluded that the climatic variations did not justify the observed increase in landslide and flood events between 1918 and 2006.

Climate and landslides operate at different geographical and temporal scales and reconciling the different scales is difficult and uncertain. The type, extent, magnitude and direction of change in the stability of the slopes and on the location, abundance and frequency of landslides are yet not completely clear (Gariano and Guzzetti, 2016). We also do not attempt to relate landslides occurred in Kerala to climate, land use system or any other factors, but only attempt delineating rubber plantations in various categories of landslide proneness so that growers can be better advised to mitigate the risks due to landslides.

4. CONCLUSION

Rubber plantations in landslide prone areas in Kerala were delineated and were categorized in to low, medium and high land slide susceptibility zones. Substantial area under rubber plantation in Kerala is situated in landslide vulnerable areas. Extent of area under rubber plantations in the high landslide susceptibility zones was higher in Kottayam, Idukki, Kannur and Palakkad districts. Substantial area is under medium landslide vulnerable category also and is spread over in various districts. It is not practical to abandon or avoid economic activity in the landslide vulnerable areas. However, extreme caution should be taken to minimise disturbance of ecosystem while cultivating crops or for infrastructure development. Zero tillage practices need to be adopted in landslide vulnerable areas in synchrony with natural processes and systems in rubber cultivation. Indiscriminate use of heavy machinery for land preparation is not advised. Rubber should be planted in small pits just sufficient to accommodate the planting material. Cutting of terraces or digging of silt pits should be avoided in these areas. Proper drainage facilities should be given for draining out excess water. The natural water ways like small streams existing in the plantations should be cleared to provide adequate soil drainage. The natural undergrowth (natural flora) may be retained in rubber plantations throughout the plantation cycle to protect the surface soil, increase water infiltration and reduce run off and sediment flow downslope. In rubber plantations located in the low landslide vulnerable zones also, it is desirable to take extreme caution to minimise soil disturbance. It is advisable to plant rubber in small pits in these areas also, where soil is deep. Cutting of terraces, digging of silt pits and cultivation of soil disturbing intercrops should be avoided. Proper drainage should be provided to drain off excess water from the field. Though there is high uncertainty in predicting rainfall induced landslides due to the uncertainty associated with predicting such rainfall events, technology driven integrated approaches need to be evolved to minimise the impact of such hazards on ecosystem as well as on society. Multi-sectoral synergy in consolidation of best practices and awareness generation with community participation in co-ordinating and implementing mitigation strategies will reduce the scale of such tragedies and it should be a continuous process sharpened by emerging technologies.

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