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

B. Pradeep, M.D. Jessy, C.M. Krishnakumar and James Jacob

Rubber Research Institute of India, Rubber Board, Kottayam-686 009, Kerala, India

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The hilly regions of Kerala 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 (NR) plantations are mostly located on the undulating and sloping terrains along the foothills of the Western Ghats of the state which are increasingly becoming vulnerable to landslides. Extremely intensive rainfall can destabilize hilly terrains where NR is a popular crop among others in Kerala. To estimate the spatial extent of rubber plantations according to proneness to landslide in Kerala, satellite-based area under rubber (age three years and above) was geospatially analyzed in landslide susceptible zones of the state. Further district-wise extent of rubber plantations susceptible to landslide was estimated. Landslide susceptibility map prepared by Kerala State Disaster Management Authority was utilized for characterizing area under rubber plantations into low, medium and high susceptible zones prone to landslide. Results showed that out of the total rubber plantation area in Kerala, 1.6 per cent (9,485 ha) was in the high susceptible zone, six per cent (32,398 ha) in the medium and two per cent (13,072 ha) in the low susceptible zone. All three zones together account for 9.7 per cent of the total rubber cultivation in Kerala whereas more than 90 per cent of rubber holdings in the state are outside landslide-prone region. Different districts in eastern parts of Kerala (except Alappuzha) have landslide vulnerable regions. Plantation areas under rubber in the high susceptible zone of landslide were the highest in Kottayam district followed by Idukki, Kannur, Palakkad, Pathanamthitta and Kasaragod districts. Substantial area is under medium landslide susceptible zone spread over various districts. Policymakers and planners are devising strategies to minimize the occurrence of natural hazards and mitigate the risks on the background of increased incidences of landslides, flood *etc*. in the recent past. The present information is highly useful for planning appropriate conservation and management strategies for rubber plantations in the highly vulnerable areas. An open source WebGIS portal was developed by integrating landslide susceptibility of rubber plantations in different panchayats in Kerala for easy dissemination of this information to rubber growers. Good agricultural practices are recommended through this platform for adoption at a location according to its vulnerability to landslide as well as avoiding certain cultural operations to minimize the occurrence/impact of landslides.

Keywords: Agricultural practices, Kerala, Landslide susceptible zones, Rubber plantations, Satellite data

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

Correspondence: Pradeep B. (Email: pradeep@rubberboard.org.in)

effects on landslides (Gariano and Guzzetti, 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 Guzzetti, 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 relating 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 foothills 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 policymakers can recommend appropriate risk mitigation strategies to minimise the occurrence of such disasters in future.

MATERIALS AND METHODS

District-wise landslide susceptibility zones 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 geospatially 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 was estimated for all districts in Kerala. Rubber plantations were further prioritized based on slope in the high susceptible zones of landslide using spatial overlay techniques to determine the extent of NR area under the highly vulnerable landslide zone. A WebGIS enabled portal was developed by integrating geospatial data sets of area under rubber in the low, medium and high categories of landslide using open source programs/algorithms.

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 (age three years and above) in Kerala, 1.6 per cent (9485 ha) is in the high landslide-susceptible zone, 6 per cent in the medium and 2 per cent in the low susceptibility zone. Except Alappuzha, landslide susceptible zones were located in all other 13 districts (Table 1). Among the various districts, substantial area under rubber plantations in Kottayam (Fig. 2), Idukki (Fig. 3) and Kannur (Fig. 4) was 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 (age three years and above), two per cent is in high, seven per cent in medium and three 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, high susceptible zones were delineated. The 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 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 ha under rubber is in high landslide susceptible zone and 4961 ha in medium susceptible zone (Fig. 3). High landslide susceptible 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.

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

District	Rubber area (age three years and above) in the landslide susceptibility zones (ha)		
	Low	Medium	High
Trivandrum	162	12	3
Kollam	364	443	90
Pathanamthitta	3814	1668	512
Alappuzha	0	0	0
Kottayam	3266	7491	2371
Idukki	0	4961	2132
Ernakulam	299	900	65
Trissur	0	439	15
Palakkad	0	2479	909
Malappuram	0	2576	287
Kozhikode	0	2903	495
Wayanad	0	495	0
Kannur	0	7976	2121
Kasargod	5167	55	485
Total	**13072 (1.6%)**	**32398 (6%)**	**9485 (2%)**

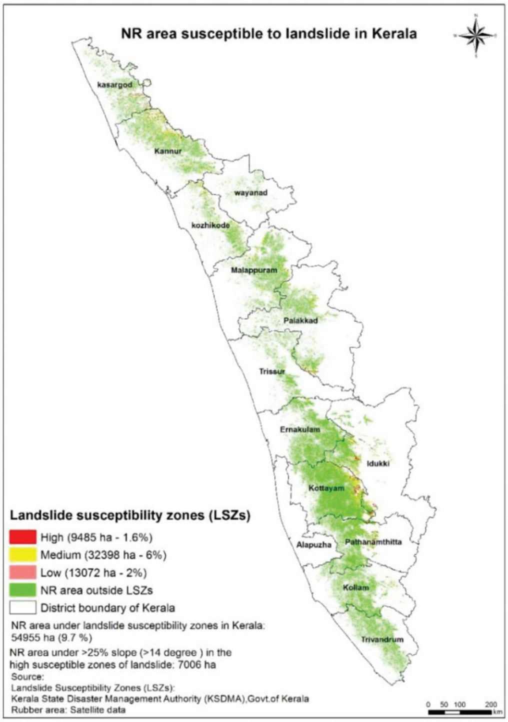

Fig. 1. Geospatial distribution of rubber area under landslide susceptible zones in Kerala

Medium susceptible 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 was in Alacode (383 ha), Udayagiri (360 ha), Cherupuzha (328 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 was observed in Palakkad (909 ha), Pathanamthitta (512 ha), Kozhikode (495 ha) and Kasaragod (485 ha) districts.

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

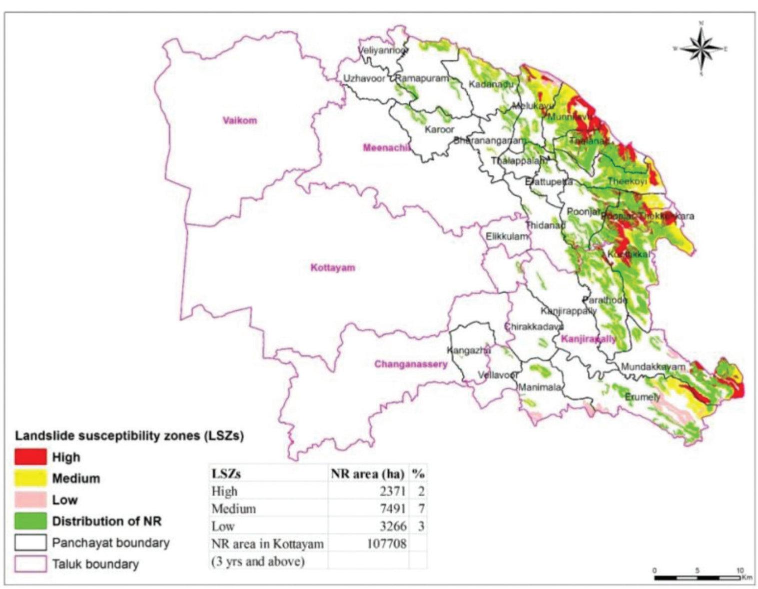

Fig. 2. Geospatial extent of rubber area in the landslide susceptible zones in Kottayam district

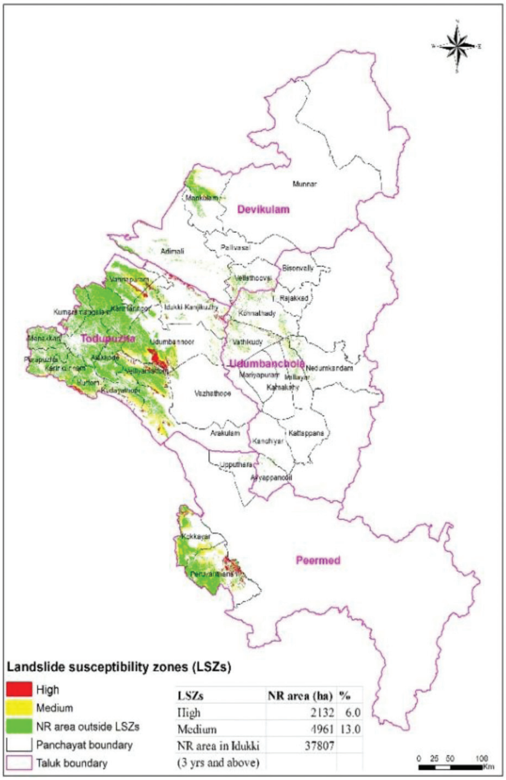

Fig. 3. Geospatial extent of rubber area in the landslide susceptible zones in Idukki district

landslide susceptibility also should be taken into 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.

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 (Fig. 5).

The two devastating landslides which occurred in Kerala during 2019 and 2020 have put tremendous pressure on scientists as well as policymakers to devise strategies

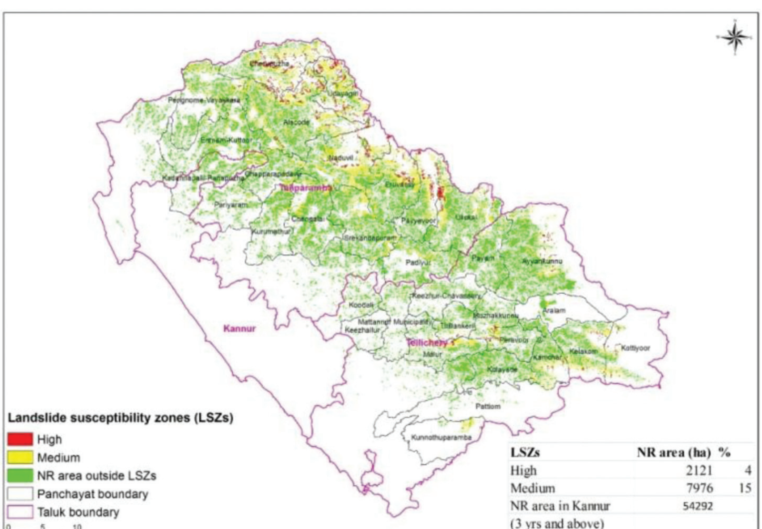

Fig. 4. Geospatial extent of rubber area in the landslide susceptible zones in Kannur district

Table 2. **District-wise area under rubber above 14 degree slope in the high landslide susceptible zones of Kerala**

District	Slope (degree) range in the high susceptible zones of landslide	Rubber area under >25% slope (>14°) in the high susceptible zones of landslide (ha)
Trivandrum	2-47	2
Kollam	1-55	70
Pathanamthitta	1-56	367
Alapuzha	-	0
Kottayam	1-69	1743
Idukki	1-66	1677
Ernakulum	2-61	53
Trissur	2-43	6
Palakkad	2-62	687
Malappuram	1-61	221
Kozhikode	1-64	377
Wayanad	-	0
Kannur	1-60	1469
Kasargod	2-65	334
TOTAL		**7006**

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 (Gariano and Guzzetti, 2016). Still few studies were reported on the effect of land use systems on landslides. Landslide susceptible zones prepared by integrating multiple databases like topographical maps, remote sensing data, ground truth and geotechnical investigations (KSDMA, 2015) categorizes the landslide-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 results 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 reduction in shear strength, 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 Dhakal (2002) 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 and the uncertainty associated with predicting these weather elements (Coe and Godt, 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

Fig. 5. Home page of the WebGIS portal showing landslide susceptibility of rubber plantations in Kottayam district of Kerala. 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 (https://lsz.rubberboard.org.in)

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 attempt only to delineate rubber plantations as per categories of landslide proneness enabling growers to mitigate the risks due to landslides.

CONCLUSION

Rubber plantations in landslide-prone areas in Kerala were delineated and were categorized into low, medium and high landslide susceptible zones. Extent of area under rubber plantations in the high landslide susceptible zones was higher in Kottayam, Idukki, Kannur and Palakkad districts. It is not practical to abandon or avoid economic activity in the landslide vulnerable areas. However, extreme caution is needed to minimise disturbance of ecosystem while cultivating crops and undertaking infrastructure development activities. 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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