A geographic analysis of natural hazard profile of Kerala, India

Dr. R Anil Kumar
Associate Professor (red)
Department of Geography
University College, Trivandrum, Kerala-605033

Dr. V.K Jayalakshmi
Assistant Professoor
Department of Geography
University College, Trivandrum, Kerala-605033

Abstract

Kerala is located in the south western part of India exposes to different types of natural hazards and it is considered as the multi hazard prone state in the country. The state is mainly susceptible to eight natural hazards which include floods, landslides, droughts, lightning, earthquakes, coastal erosions, tsunami and cyclone. Geographical factors have profound influence on the hazard profile of the state. The district-wise hazard profile categorized in Kerala does not seem to be distributed evenly in all districts. The present study attempted to develop and evaluate the districts wise multi hazard susceptibility scale and matrix which assessed the profile of eight natural hazards in the fourteen districts of the state. In accordance with this hazard susceptibility index and district susceptibility index was estimated which further categorized into four divisions as Very High Susceptible, High Susceptible, Medium Susceptible and Low Susceptible. The study reveals that the state exhibits a unique spatial distribution of susceptibility to various natural hazards in the each district. According to the study Thiruvananthapuram, Kollam and Kozhikode are the most susceptible districts while landslide and floods are two hazards which are more susceptible than others. The study would be a first attempt in this kind considering the multi hazard profile of all the districts for assessing districts multi hazard susceptibility of the state.

Key words.1.District index,2.Hazards Index,3.Multi Hazards Profile, 4.Natural Hazards,5.Susceptibility.

1. Introduction

Kerala can be considered as the most unique geographical setting in the country. No other state in the country has dominance as orographic influence and maritime effects over the overall geographical areaas Kerala. It is a narrow strip of land with a mean width of only 67 km borderingtheprecipitous slope of the Western Ghats in the eastern side and eroding coastline of Arabian Sea in the Western side, which is influenced by the Monsoonal climate. The state can be divided into six physiographic units namely, the mountains and peaks (1,800 m), the highlands (600–1,800 m), the foothills (300–600 m), uplands (100– 300 m), undulating midlands (20–100 m) and coastal plains (20 m) (Chattopadhyay and Mahamaya 1995).It is typically a tropical, but monsoon-dominated region which is mostly contributed

by two seasons of rain, viz., South West Monsoon (June–September) and North East Monsoon (October–December). Because of the undulating topography and copious rainfall during the monsoon months most part of the state experience well flourished drainage system consisting fortyfour rivers.

Geographical factors have profound influence on the hazard profile of the state. The low land of Kerala covering about 15% of state's total area is an important physiographic unit mainly prone to floods. The coastline (570 km) of the state is much prone to erosion, cyclone and tsunami. At the same time the Western Ghats of the state coming under highland is identified as one of the major land slide prone areas of the country. The midland region which is also a multi hazard zone is mainly exposed to the hazards like drought, lightning and earthquake.The climate of Kerala influenced by the monsoonal rainfall oscillates between active spells associated with widespread and intense rains and breaks with little rainfall activity (Thomas et al., 2016). This might have an overall influence on the hazard profile of the state particularly on flood and drought incidents of the state. The state is traversed by 44 rivers of which most are short in length with a steep gradient of 1/250 carrying seasonal floods. High density of population in the state coupled with unsustainable land use practices and environmental degradation enhance the overall hazard vulnerability profile. Thus state's geographical location, weather pattern and high population density make it prone to severe natural hazards (Kerala State Disaster Management Plan Profile, 2015). Thus, the state is affected by different types of natural hazard and is considered as the multi hazard prone state in the country where all the 14 districts are exposed to more than one hazard at a time. Flood, landslide, drought and coastal erosion are most recurrent and intensive hazards while lightning and earthquake appear frequently along with the cyclones which also felt its presence in the state. Notably, not many states in the country are as multi hazard prone as Kerala.

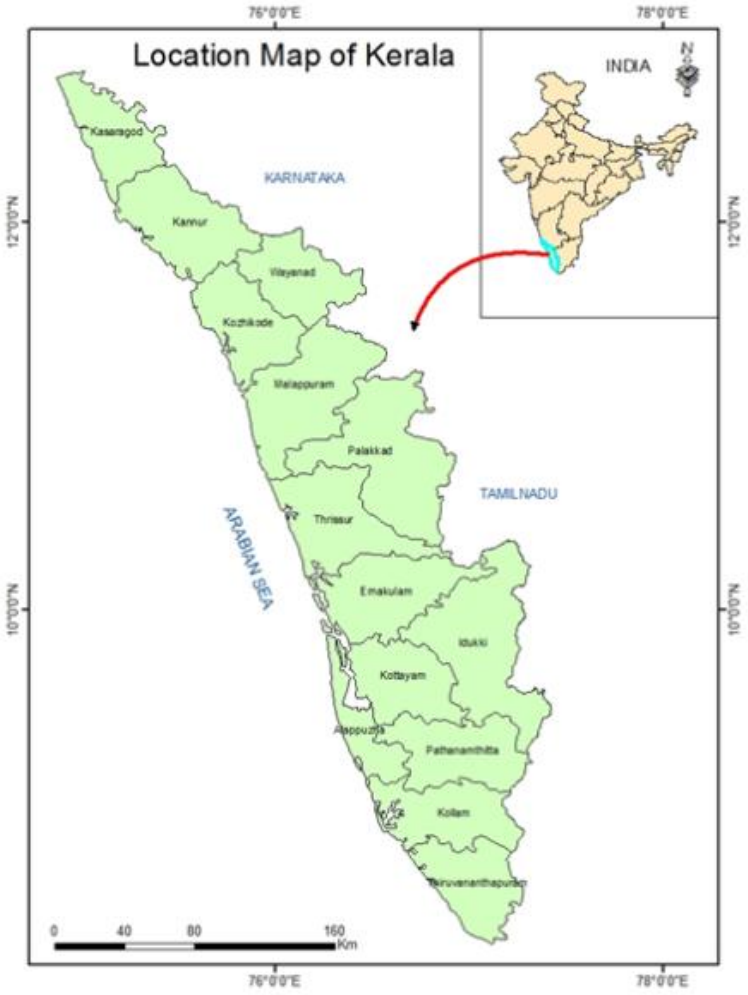
There are many triggering factors behind the hazard profile of the state. Continuous occurrence of high intensity rainfall for a few days is the primary factor contributing to the extremity of floods in the state (Ajinetal., 2013). The state experiences annual floods due to monsoon rains coupled with inadequate drainage systems, flat terrain, unplanned land use, impermeable surfaces, soil texture and high tides.WesternGhatswitnesses landslides very often during the monsoon (Kuriakose et al., 2009;Anbazhagan and Sajinkumar 2011). Landslides in Western Ghats concludes that intense rainfall exceeding 200 mm in 24 hour can trigger debris flow in vulnerable slopes (Thampi et al.,1998). Relatively higher population density and vegetation density result in more causality due to lightning. Accidents caused by ground conduction from trees, which is a special feature of Keralacould be the main attribute of lightning hazards(Das et al., 2004)..The state lies in the peninsular India generally defined as a stable continental region in the context of earthquake productivity (Rajendran et al., 2009).Several of the tremors in the state are spatially associated with the drainage basins of the major rivers, some of which may be fault controlled (RajendranandRajendran, 1996). The 590 km coast of Kerala is one of the most densely populated land area in the country exposed to different types of coastal hazards. The high-steep monsoonal waves cause severe seasonal erosion all along the coast (Kurian et al., 2009). Human activities such as the construction ofharbours, jetties and groynes, mining and dredging can also lead to erosion of certain regions (Kerala State Disaster Management Plan, 2011). The state has 223 coastal villages which has the probability of being affected by cyclone becauseof wind speed and storm surge. Significant spatial variation in the monsoonal rainfall across the state is the major cause of water scarcity which could be one of the major causes behind the drought incident in the state. The decreasing rainfall over the region, late onset of the monsoon, failure of the monsoon, and break in the monsoon in the state lead to many drought situations (Nathan, 2000) The monsoonal rainfall in Kerala is associated with breaks with little rainfall activity. So monsoon season is significant to regional climate, the variability in the onset, withdrawal and quantum of rainfall during

the monsoon season plays an important role in the drought scenario in the state.(Thomas et al., 2016).In the humid tropical climate of Kerala, with more than adequate rainfall, moisture stress is noticed for 14 to 21 weeks.(Vardan 1996). Intolerably long dry spells consequently lead to the occasional drought situations in the state. Thus the overall geographical setting is conducive for triggering the multi hazard susceptibility in the state.

2. Regional Settings

Kerala is one of the smaller states in India with an area of 38,864 sq. km, covering 1.18% of the area of the country, extending between north latitudes 8º17'30" and 12º27'40" and east longitudes 74 º51'57" and 77 º24'47"(Soman, 1997). Location map of Kerala is given in(Fig.1).The state has been administratively divided into 14 districts and each district is geographically unique. Out of 14 districts, 11 arephysiographically divided into three i.e highland, midland and lowland. Remaining three districts are AlappuzhaIdukki and Waynad in which Alappuzha is entirely a coastal district whereasIdukki and Wayanddistricts are located in the highlands. Among the 14 districts, 9 are having long coastline, at the same time exceptthe coastal district Alappuzha all the other districts occupies the most prominent orographic feature of Kerala i.e the Western Ghats. The wholestate enjoys tropical climate except southern most district of Trivandrum where tropical savanna climate prevails. At the same time Palaghat gap in the Western Ghats makes unique climatic influence in the Palakkaddistrictswhere dry condition prevails during the summer.

Figure 1 Location map of Kerala



3. Methodology

From south to north, all the 14 districts were under investigation to assess the multi natural hazards profile of each district. Table.2.give details of the eight natural hazards affecting each district in the state. Among these, flood and landslide are assessedbytheirspatialspread, drought is represented in terms of its intensity in each district, earthquake and lightning are considered from the frequency, coastal erosion as the percentage of exposed coastline, tsunami is based on the inundation and destruction and cyclone represents its proness in each district. This was mainly done by reviewing the

references Multi hazards Maps (NCESS, 2010) and District Disaster Management Plans of all 14 districts). Various studies with regardto the characteristics of individual natural hazards were also taken care such as flood (Ajin et al., 2013, Mayaja et al., 2016) landslide (Thampi et al., 1998, Kuriakose et al., 2010, Sankar 2005, Sreekumar 2009, Sajinkumaret al., 2011) coastal erosion (Thomas et al., 1986, Kurian et al., 1987, Baba et al., 1987;Hameed 1988, Shamjiet al., 2010, Noujas et al., 2015)) lightning Das et al.,2004) drought (Nandan 2009, Gopinath et al., 2015) earthquake (Ranjendran et al., 2009) and tsunami (Narayana et al., 2007, Kurian et al.,2006) and Cyclone (Mohapatra 2015). By reviewing all these studies various characteristics of natural hazards in the state have been derived. A district-wise multi hazard susceptibility assessment has been generatedinGeographic Information System (GIS) platform, which involves the estimation of susceptibility index based on the assessment of District-wise Multi Hazard Susceptibility Matrix. The underlying assumption of this proposed methodology is that multi hazard susceptibility is determined by various characteristics of hazard profiles in a region (district). For this, the selected hazard characteristics and its different perspectives have been taken into consideration for the analysis of hazard susceptibility. The first methodological step was the identification of major natural hazards in the state of Kerala. Based on the available literatures, eight natural hazards were identified which the state is exposed covering flood, drought, landslide, coastal erosion, lightning, earthquake, cyclones and tsunami. A Multi Hazard Susceptibility Scale for each districts was devised based on the assessment of the hazard characteristics (Fig 2). This scale represents the relevance of various hazards in each district with regards to vulnerable areas, past occurrences, risk estimation and proneness. Accordingly, the scale was rated as Very High, High, Moderate and Low Susceptible categories based on the ranking of each hazards in every district in the state. Different observations regarding the nature of each hazards was also taken into consideration for the assessment. The subsequent step was to assign values to the scale that represents each district. Out of the total percentage scale aweightageof 40 was given to Very High category, 30 for High, 20 to Moderate and 10 indicates Low category of susceptibility. Based on this weightage a Matrixwas developed covering 14 districts with 8 natural hazards.(Table 1) The cumulative value of rows in each district gives the corresponding district index while hazards index represent the cumulative value of column of each hazard. Based on the values generated from the District Index, a map was developed which categorize districts into four groups as Very Highly Susceptible, HighlySusceptible, ModeratelySusceptibleand Least Susceptible districts**.** A district wise individual Hazard susceptibility map was also developed for the natural hazards in the state based on the hazard index from the matrix.

Table. 1 District wise hazard profile of eight natural hazards

Hazard	Flood(in % of prone area	Drought (in intensity)	Landslide (% of prone area)	Coastal Erosion (% of coastline affected)	Earth Quake (Number of past events	Lightning (Number of past events)	Tsunami (severity of 2004 Tsunami)	Cyclone (in proneness)
Trivandrum	12.23	A*	7.32	77.85	9	59	MA*	MP*
Kollam	11.41	A*	11.09	81.78	4	257	SA*	MA*
Alappuzha	53.77	A*	0	42.51		51	SA*	MA*

Pathnamthitta	8	SA*	22.45		2	125		LA*
Kottayam	20.95	A*	11.46		28	218		LA*
Idukki	0.89	A*	28.92		9	92		LA*
Ernakulam	23.5	A*	9.5	69.02	7	104	SA*	LA*
Thrissur	22.65	A*	10.71	24.46	41	36	A*	MA*
Palakkad	12.66	VSA*	15.44		14	83		LA*
Malappuram	16.93	A*	13.11	44.86	6	249	A*	MA*
Kozhikhode	12.3	A*	13.44	55.37	10	242	A*	MA*
Wayanad	10.11	A*	14.05		1	19		LA*
Kannur	11.45	A*	14.89	26.34	1	353	MA*	MA*
Kasaraghode	9.99	A*	12.04	22.03	0	108	A*	LA*

Source: Compiled by the author from various sources

A-Affected, S – Severely Affected, VSA Very Severely Affected, MA- Moderately Affected, LA-LeastAffected

4. Results

4.1 Multi Hazard Susceptibility Scale

The state is mainly prone to eight natural hazards which were analysed for each district in the state. The multi hazard susceptibility scale is given in the figure 2. It depicts the susceptibility of exposed hazards in each district and classifies the hazards into four categories as Very Highly, Highly, Moderately and Least Susceptible. It can be seen that each district has a very unique hazard profile.

Figure 2 Multi Hazards Susceptibility Scale

4.2 Multi Hazard Susceptibility Matrix

A Multi Hazard Susceptibility Matrix (Table 2) has been developed. The matrix provides a comparative overview of the susceptibility of the district wise multi hazards. It gives susceptibility outline for all fourteen districts carrying eight natural hazards through district index and hazard index.

Table 2 Multi Hazard Susceptibility Matrix

Districts	Natural Hazards	District

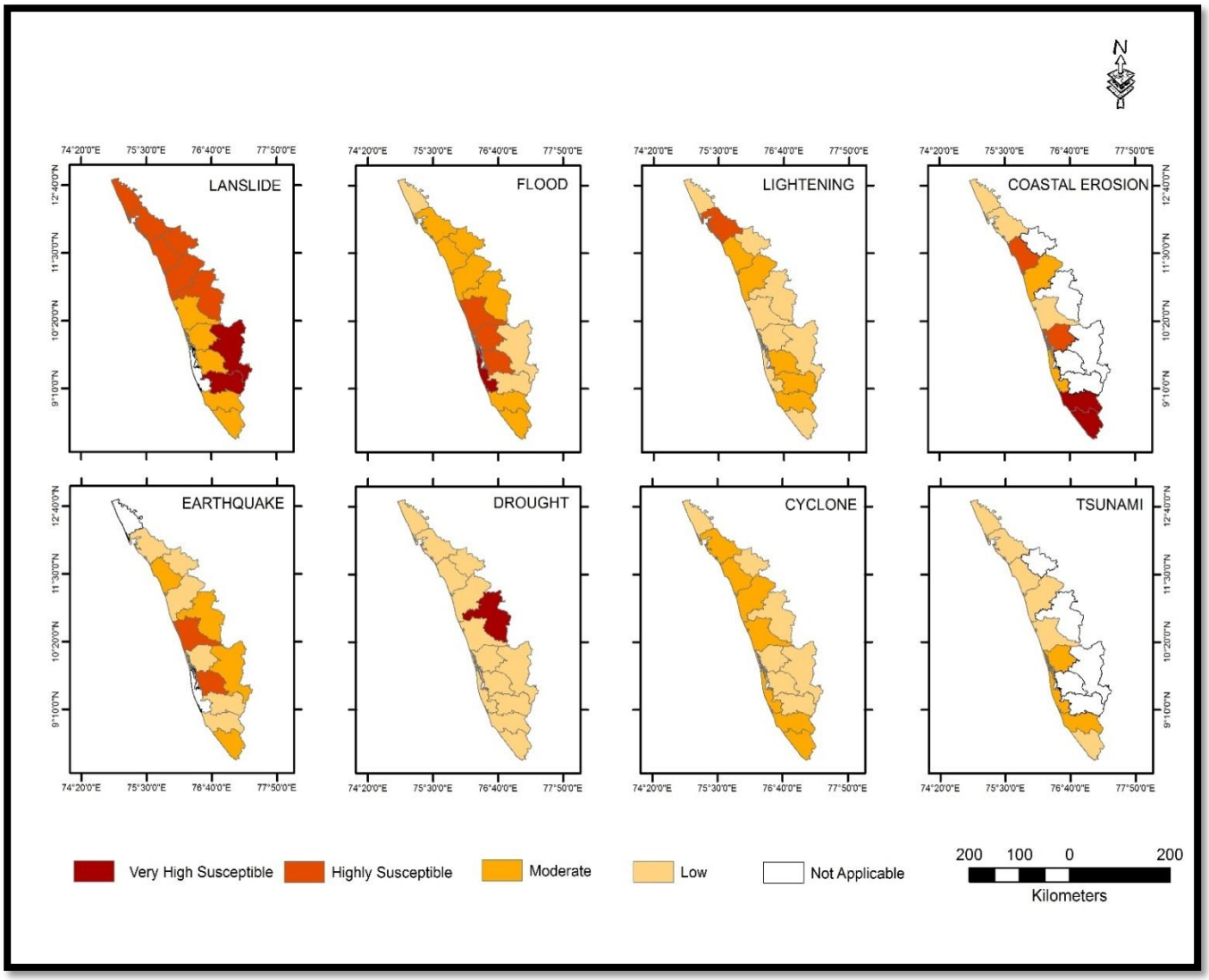
	Flood	Drought	Landslide	Coastal Erosion	Earth Quake	Lightning	Tsunami	Cyclone	Index
Trivandrum	20	20	20	40	20	10	10	20	160
Kollam	20	10	20	40	10	20	20	20	160
Alappuzha	40	10	-	20	-	10	20	20	120
Pathanamthitta	10	10	40	-	10	20	-	10	100
Kottayam	30	10	20	-	30	20	-	10	120
Idukki	10	10	40	-	20	10	-	10	100
Ernakulam	30	10	20	30	10	10	20	10	140
Thrissur	30	10	20	10	30	10	10	20	140
Palakkad	20	40	30	-	20	10	-	10	130
Malappuram	20	10	30	20	10	20	10	20	140
Kozhikode	20	10	30	30	20	20	10	20	160
Wayanad	20	10	30	-	10	10	-	10	90
Kannur	20	10	30	10	10	30	10	20	140
Kasaraghode	10	10	30	10	-	10	10	10	90
Hazard Index	300	180	360	210	200	210	120	190	-

The Hazard Susceptibility Map(Fig.3) outlines the susceptibility and spatial distribution of different types of natural hazard events and it also describes that to what degree they are relevant compared to other hazards.It is clearly evident from the map that landslide is the most susceptible natural hazards in the state. All the districts of Kerala, except the coastal district of Alappuzha, are prone to landslides. In thisPathanamthitta and Idukki comes under Very HighlySusceptible category. Highly Susceptible category was identified in the northern districts of the state including Palaghat, Malappuram, Kozhikhode,Wayanad, Kannur and Kasaraghode and remaining districts falls undermoderatelysusceptiblecategory.

However, it is apparent to note that flood is another most susceptible natural hazard where all the 14 districts are exposed. In this, Alappuzha is the only district in the state which is very highly susceptible to flood whileKottayam, Ernakulam and Thrissurcomes under highly susceptible category. At the same time all remaining districts were also vulnerable to the floods but its susceptibility varies between moderate to low category. Thus among all natural hazards, it can be consideredthat floods and landslide are the most recurrent natural hazards.

It is evident from the hazard map that coastal erosion and lightning have comparatively high hazard index. However, lightning is the most spatially distributed eventand all the districts are susceptible. The entire coastal stretch is vulnerable to coastal erosion while the two southern districts of Thiruvananthapuram and Kollam come under very highly susceptible category. Moreover earthquake has a significant place in the hazard profile of the state despite of its impact and intensity which is comparatively less. At the same time the other hazards such as drought, cyclone and tsunami do not account for such a high proportion to Kerala hazard profile. In spite of the insignificant place occupied by drought in the overall hazard profile of the state, the study reveals that it could not be underestimated. The hazard susceptibility map depicts that Palaghat has very high susceptibilityto drought while all other districts have moderately susceptible. In terms of cyclone susceptibility the entire state comes under moderate to least categories. At the same time, in the case of tsunami all the nine coastal districts in the state are least susceptible.

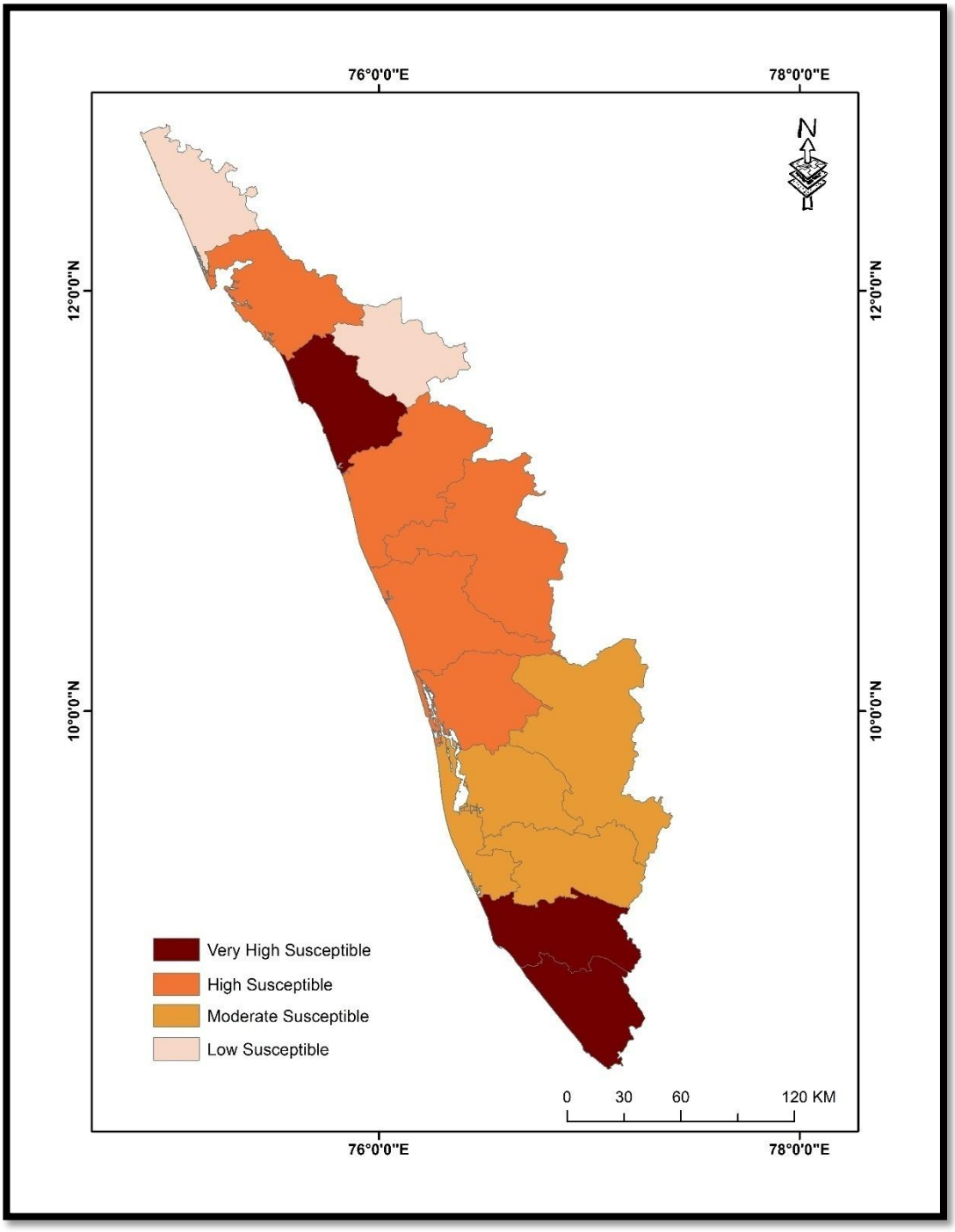
Figure 3Hazard susceptibility map



4.3 District Wise Multi Hazard Susceptibility

From the Multi Hazard Susceptibility Matrix, (Table 2) district index was prepared by cumulating the value of rows in each district. A map was prepared using the district index covering all the 14 districts classified under four categories. The districts in the state have been classified into four classes in the multi hazard susceptibility map of Kerala namely: Very Highly Susceptible districts, Highly Susceptible districts, Moderately Susceptible districts and LeastSusceptible districts. The map(Fig.4) portrays the district wise level of susceptibility in Kerala.

Figure 3. District Susceptibility Map



4.3.1 Very Highly Susceptible Districts

Over and above three districts, Thiruvananthapuram, Kollam and Kozhikode comes under Very Highly Susceptible districts in the state. All the three districts are susceptible to all the seven natural hazards in the state. Significantly few similarities can be observed in these districts with regard to hazard profile. The hazard profile of each district are given below

4.3.2 Highly Susceptible Districts

It can be seen that mainly five districts come under the Highly Susceptible category comprising centrally located districts of Ernakulam, Thrissur, Palaghat and northern districts of Malappuram and Kannur. An outline of individual hazard profile is given below

4.3.3 Moderately Susceptible Districts

The adjoining districts of Alappuzha, Pathanathitta, Kottayam,andIdukkicomes under moderately susceptible category. Geographically these districts have very distinct phenomena. Alappuzha is narrowest and smallest district in the state dominated by coastal geomorphological features. Kottayam and Pathanamthitta have uniform feature both dominated by midland and hilly tracts where Idukki is a mountainous district in the state. Brief hazard profile of each district are given below

4.3.4 Least Susceptible Districts

Low susceptibilityis confined totwo districts i.e. WayanadandKasaraghode. These two districts have distinct geographical features. In this Wayanad is physiographally hilly district whereas Kasarghode is northernmost coastal district of the state

4.4 Conclusions

Considering multi hazard susceptibility in the state three districts, Thiruvananthapuram, Kollam, and Kozhikodebelong to very highly susceptible category. On the other side, Wayanad and Kasaraghode are two districts least susceptible to various natural hazards. The inclination towards multi hazards susceptibility is relatively high in the southern districts compared to centrally and northern part of the state. It is recommended that the disaster risk reduction strategy for the state is to be developed and focused separately for each districts as well as hazards. Accordingly the institutional and policy structure of the disaster management at the district level would be strengthened in the state.

Reference

1. Anbazhagan S, Sajinkumar KS (2011).Geoinformatics in Applied Geomorphology. Geoinformatics in terrain analysis and landslide susceptibility mapping in parts of Western Ghats, India.291–315
2. Chattopadhyay S, Mahamaya C (1995). Report. Terrain analysis of Kerala, technical monograph 1/95. Centre for Earth Science Studies, Government of Kerala, Thiruvananthapuram, Kerala
3. C.P. Rajendran, Biju John , K. Sreekumar and KusalaRajendran (2009).Journal Geological Society of India. Reassessing the Earthquake Hazard in Kerala Based on the Historical and Current Seismicity. 785-802
4. C P Rajendran, Rajendran, K. (1996).Current .Scienc. Low-moderate seismicity in the vicinity of Palghat Gap, south India and its implications..303-307.
5. Disasters in Numbers Fact sheet on Coastal Erosion related losses in Kerala (2002 – 2012) State Emergency Operations Centre, KSDMA, Dept. of Revenue andDisaster Management, Government of Kerala.
6. District Disaster Management Plans, of all 14 districts in Kerala (2015). Alappuzha, Ernakulam, Idukki, Kannur, Kasaraghode, Kozhikode, Kollam, Kottayam, Malappuram, Palaghat.,Pathanamthitta, Thrissur, Thiruvananthapuram

7. GopinathGirish, Ambili G.K., GregorySheryJoseph,AnushaC.K (2015). Journal of Environmental Management .Drought risk mapping of south-western state in the Indian peninsula- A web based application. 453-459
8. Hameed Shahul TS, Kurian NP, Thomas KV, Rajith K, Prakash TN (2007).. Journal Coast Research .Wave and current regime off the southwest coast of India. 1167–1174.
9. Kerala State Disaster Management Plan (2011) Kerala State Disaster Management Authority, Govt of Kerala
10. Kuriakose SL, Sankar G, Muraleedharan C (2009).Environmental Geology. History of landslide susceptibility and a chorology of landslide-prone areas in the Western Ghats of Kerala, India. 57:1553–1568
11. Kurain N P, T.N Prakash, M Baba , N Nirupama (2006).India Odesy.Observation of Tsunami Impact on the Coast of Kerala,. 29:135-145,
12. Kurian NP, K. Rajith, T. S. ShahulHameed, L. Sheela Nair, M. V. Ramana Murthy, S. Arjun, V. R. Shamji (2009). Natural Hazards.Wind waves and sediment transport regime off the south-central Kerala coast, India , 49:325–345
13. DasMurali, S., Kumar Mohan, G. and Sampath, S. (2004).Project Report. Understanding Lightning Accidents to Alleviate the Hazard, , Centre for Earth Science Studies, Thiruvananthapuram,
14. Nathan KK (2006). Report. Characteristics of Drought in Kerala, India. Drought Network News (1994-2001) National Drought Mitigation Center
15. Sankar G (2005).Landslides of Kerala and their management. In: Rajamanickam GV (ed) Proceedings of the National Seminar on Landslides, Thanjavur, India, SASTRA Deemed University
16. Sajinkumar KS, Anbazhagan S, Pradeepkumar AP, Rani VR (2011).Journal of Geological Society of India Weathering and landslide occurrences in parts of Western Ghats, Kerala.. India.249–257
17. Sreekumar S (2009) Journal Geological Society of India.Techniques for Slope Stability Analysis: Site Specific Studies from Idukki District, Kerala.813-820
18. Soman, (1997).Geology of Kerala. Geological Society of India, Bangalore.
19. Thampi PK, Mathai J, Sankar G, Sidharthan S (1998). Evaluation study in terms of landslide mitigation in parts of Western Ghats, Kerala. Research report submitted to the Ministry of Agriculture, Government of India. Centre for Earth Science Studies, Government of Kerala, Thiruvananthapuram, India
20. Thomas, K.V. and Baba, M (1986).Sedimentology. Berm development on a monsoon-influence microtidal beach.537-546
21. Thomas Jobin, Prasannakumar V (2016).Indian Atmosphere. Temporal analysis of rainfall (1871–2012) and drought characteristics over a tropical monsoon-dominated State (Kerala) of India. Journal of Hydrology 534:266–280
22. M Mohapatra(2015). Journal of Earth System Science.Cyclone hazard proneness of districts of India.515–526
23. Narayana AC, R. Tatavarti b, N. Shinu a, A.(2007).Sub Marine Geology.Tsunami of December 26, 2004 on the southwest coast of India: Post-tsunami geomorphic and sediment characteristics.155–168
24. N. A. Mayaja , C. V. Srinivasa (2016). Land Use and Land Cover Changes and Their Impacts on Floods in Pampa River Basin in Kerala: A Remote Sensing Based Analysis , Geostatistical and Geospatial Approaches for the Characterization of Natural Resources in the Environment.779-783
25. R S Ajin, Krishnamurthy R R, Jayaprakash M, Vinod. P G(2013).Pelagia Research Library Advances in Applied Science Research. Flood hazard assessment of Vamanapuram River Basin, Kerala, India: An approach using Remote Sensing & GIS techniques.263-274