PROCEEDINGS OF THE SYMPOSIUM ON

LANDSLIDES IN KERALA 2018

HELD AT MUNNAR ON FEB 23, 2019

IEEE KERALA SECTION

COLLEGE OF ENGINEERING MUNNAR 685 612

IEEE Humanitarian Activities Committee

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On behalf of IEEE Kerala Section

MESSAGE

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CHIEF MINISTER

Secretariat
Thiruvananthapuram-695 001

GOVERNMENT OF KERALA

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MESSAGE

I am happy to note that the IEEE Kerala Section and the IEEE Humanitarian Activities Committee are bringing out the proceedings of the symposium on 'Landslides in Kerala 2018', conducted at the Munnar Engineering College earlier this year.

I gather that the proceedings will suggest the mitigation measures to be taken with regard to landslides and also disseminate valuable lessons based on our experiences with landslides last year. I hope that it will be highly beneficial for the public.

My best wishes.

Pinarayi Vijayan

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MESSAGE

Kerala witnessed the worst disaster in almost a century during August 2018. About 500 people have lost their lives due to the flood and aftermath. Reports indicate losses at over 40,000 crore in various forms. As a responsible organization contributing to technological advancement for the benefit of humanity, IEEE volunteers started the flood relief activities from the very beginning. One significant contribution that we have made is the creation and operation of the website https://keralarescue.in in association with IT mission, Govt of Kerala to coordinate the collection and distribution of relief aids, and extending rescue support. Another project that the Section had taken up in the rehabilitation phase is "mission re-connect" aimed at helping flood affected homes with damaged wiring to reconnect to the grid. The Section has come up with a unique design of electrical distribution boards with an ELCB, MCB, plug-sockets and a light, and distributed about 1000 such boards with the help of NIT Trichy, TKM College of Engineering and other institutions and volunteers.

As part of our continued efforts in this direction, Prof. B. Premlet, the Chair for Educational Activities of IEEE Kerala Section has initiated a series of two programs. The first program was a symposium on "Landslides in Kerala 2018" which was conducted at College of Engineering, Munnar on 23rd, February 2019. Many experts in this domain participated and shared their findings during this program. A documentary on landslides happened in Kerala during the floods is also under preparation as part of this series. I am extremely happy to learn that a proceeding that summarizes the deliberations happened in the symposium is being released now. I am sure that this proceeding will serve as reference material for anyone interested to learn about the landslides in Kerala as well as help the authorities to plan the future course of actions to prevent such disasters in the future.

Sameer S. M.
Chair, IEEE Kerala Section

ഉരുൾപൊട്ടൽ പശ്ചിമഘട്ടത്തിൽ
– സി.ഐ. ഗോപിനാഥ്

ചീഫ് റിപ്പോർട്ടർ, മലയാള മനോരമ

(1985 ജൂലൈ 30, 31 തീയതികളിൽ കോഴിക്കോട് നടന്ന ശില്പശാലയിൽ അവതരിപ്പിച്ച പ്രബന്ധം - എഡിറ്റർ)

ഉരുൾപൊട്ടൽ, സാങ്കേതികമായി രണ്ടുവാക്കുകളാണിതെങ്കിലും പ്രയോഗത്തിൽ ഒറ്റവാക്കാണ്. ആ വാക്കുകൊണ്ട് എന്താണ് ഉദ്ദേശിക്കുന്നതെന്ന് അറിയാത്തവർക്കുപോലും കേട്ടാൽ പേടിതോന്നുന്ന എന്തോ ഒന്നായി അത് തീർന്നിരിക്കുന്നു.

പ്രകൃതിയുടെ ഒരു പ്രതിഭാസത്തിന് ഈ പേരു നൽകിയത് സാധാരണക്കാരാണ്. ഭൂമിയെയും അതിന്റെ അന്തരീക്ഷത്തെയും പറ്റി ആധികാരിക വിവരം നൽകാൻ കഴിയുന്ന ശാസ്ത്രകാരന്മാർ ഈ പേരിന് വലിയ അർത്ഥമൊന്നും കൽപിച്ചിരുന്നുവരില്ല. എങ്കിലും ഇന്ന് ഉരുൾപൊട്ടൽ, പ്രയോഗം കൊണ്ട് അംഗീകാരം നേടിയ ഒരു വാക്കായിത്തീർന്നു. ഇതിന്റെ ഉൽഭവമാവട്ടെ അനുഭവത്തിൽനിന്നും.''ദിവസങ്ങളായി രാപ്പകലില്ലാതെ മഴ തുമ്പിക്കൈ വണ്ണത്തിൽ കോരിച്ചൊരിയുന്നു. ദാ കാണുന്ന മലയുടെ നെറുകയിൽ കാർമേഘങ്ങൾ ഉരുണ്ടുകൂടി ഞങ്ങൾ ഇവിടെ നോക്കികൊണ്ടിരിക്കുന്നു. ആ മേഘപാളികൾക്കിടയിൽ ഒരു മിന്നൽപിണർ. അതിഭയങ്കരമായ മുഴക്കം. ഭൂമി ഇടിഞ്ഞു തകരുന്നതുപോലെ തോന്നി. വെടിമരുന്നിന്റെ മണം എങ്ങും വ്യാപിച്ചു. പിന്നെ മലപൊട്ടിയ പ്രളയമായിരുന്നു. ആ മലയിലെ താമസക്കാരിൽ ബഹുഭൂരിപക്ഷത്തിന്റെയും സർവസ്വവും നഷ്ടപ്പെട്ടു. ഈ കാണുന്ന വയലിൽ ആറേഴാൾ വെള്ളം പൊങ്ങി.''

1949–ൽ തൊടുപുഴ താലൂക്കിലെ കൊടിയത്തൂർ മലയിൽ ഉരുൾപൊട്ടിയ രംഗം എതിർ കുന്നിലെ ചിലതാമസക്കാർ വിവരിച്ചതാണിത്.

11 കൊല്ലം കഴിഞ്ഞ് ഞാൻ ഈ സ്ഥലത്തെത്തി ഇതേപ്പറ്റി ഒരു പ്രത്യേക സാഹചര്യത്തിൽ അന്വേഷണം നടത്തിയപ്പോഴാണ് അവർ ഈ രംഗം വിവരിച്ചത്. പരുക്കേറ്റ കൊടിയത്തൂർ മലയിൽനിന്ന് അന്ന് ചീറി അലച്ചൊഴുകിയ നീർച്ചാലുകളുടെ പാടുകൾ കാണാമായിരുന്നു.

കോരിച്ചൊരിയുന്ന മഴയത്ത് കാർമേഘങ്ങൾ മലമുകളിൽ ഉരുണ്ടുകൂടി എന്തെല്ലാമോ പ്രത്യേകതകളോടെ പൊട്ടുന്നു. അതോടെ മലയിടിയുന്നു. പ്രളയം വരുന്നു. സന്ദർഭത്തിൽ നിന്ന് അടർത്തിയെടുത്ത ഏറ്റവും പറ്റിയ വാക്കാൽ മലയോര കർഷകർ അതിനെ വിളിച്ചു, ഉരുൾപൊട്ടൽ. കേരളത്തിലെ പത്രങ്ങളിലും ഉരുൾപൊട്ടൽ എന്ന വാക്ക് സ്ഥാനം പിടിച്ചത് കൊടിയത്തൂർ സംഭവത്തോടുകൂടിയായിരുന്നു എന്നാണ് എന്റെ ഓർമ്മ. അതിന് മുമ്പ് അത്ര പ്രചാരം ഈ വാക്കിന് സിദ്ധിച്ചിരുന്നില്ല.

പിന്നീട് ഉരുൾപൊട്ടൽ ഏതാണ്ട് വർഷകാലത്ത് മലയോരങ്ങളിൽ സർവ്വസാധാരണമായിത്തീർന്നു. ഏറ്റവും അധികം ഉരുൾപൊട്ടൽ ഉണ്ടായിട്ടുള്ളത് കോഴിക്കോട് ജില്ലയിലാണെന്ന് തോന്നുന്നു. ഈ ജില്ലയിൽ ഏതാണ്ട് കാൽനൂറ്റാണ്ടിനുള്ളിൽ ഉരുൾപൊട്ടൽ ഉണ്ടായ മിക്കവാറും എല്ലാ സ്ഥലങ്ങളിലും ഞാൻ പോയിട്ടുണ്ട്. ഒരുവിധം വിശദമായ അന്വേഷണവും നടത്തിയിട്ടുണ്ട്. തൊടുപുഴയിലെ പഴയ വിവരണം തന്നെയാണ് എല്ലാ സ്ഥലങ്ങളിൽനിന്നും എനിക്ക് കേൾക്കാൻ കഴിഞ്ഞിട്ടുള്ളതും. കേരളത്തിൽ വടക്കും തെക്കുമുള്ള മലയോരങ്ങൾ ഉൾപ്പെടുന്ന കാസർഗോഡ്, തിരുവനന്തപുരം ജില്ലകളാണ് ഉരുൾപൊട്ടലിൽ വളരെ പിന്നാക്കം നിൽക്കുന്നത്. ഏറ്റവും മുൻപന്തിയിൽ ഇടുക്കിയും കോഴിക്കോടുമാണ്. ഇതുവരെ കേരളത്തിൽ എത്ര ഉരുൾപൊട്ടലുകൾ ഉണ്ടായി എന്നോ അവയിലെല്ലാംകൂടി എത്ര നഷ്ടം വന്നു എന്നോ വ്യക്തമായ കണക്കില്ലെന്നാണ് അറിവ്.

ഉരുൾപൊട്ടൽ സത്യത്തിൽ വൻതോതിലുള്ള മണ്ണിടിച്ചിൽ തന്നെയാണ്. കേരളത്തിലെ മലയോരം കേംബ്രിയൻ ആണെന്ന് പൊതുവിൽ ധാരണയുണ്ട്. അതായത് ഭൂമിയുടെ ഉത്ഭവകാലത്തോളം (65 കോടിവർഷം) പഴക്കമുണ്ടെന്ന് ചുരുക്കം. ഈ ധാരണ മുഴുവൻ ശരിയാണ് എന്ന് പറയാമോ? ഇടുക്കിയെപ്പറ്റി അടുത്തകാലത്ത് പല പഠനങ്ങളും നടന്നിട്ടുണ്ട്. അവ ഏതാണ്ട് 20 ലക്ഷം വർഷം മുൻപ് കടലിൽനിന്ന് ഉയർന്നുവന്ന ഒരു പ്രദേശമാണെന്നാണ് നിഗമനം. ഇടുക്കിയിൽ പലസ്ഥലത്തുനിന്നും കണ്ടുകിട്ടിയിട്ടുള്ള ഫോസിലുകൾ, അതായത് ജീർണ്ണാവശിഷ്ടങ്ങൾ സമുദ്രജീവികളുടെതായിരുന്നു. ഏതാണ്ട് അക്കാലത്ത് ഇന്നത്തെ കേരളത്തിന്റെ പടിഞ്ഞാറൻതീരം, ഇപ്പോഴത്തെ ലക്ഷദ്വീപ് സമൂഹങ്ങളോളം പടിഞ്ഞാറോട്ട് വ്യാപിച്ചിരുന്നതായി അനുമാനിക്കപ്പെടുന്നു. ഈ അനുമാനത്തെ സ്ഥിരീകരിക്കാൻ ഏറ്റവും പര്യാപ്തമായ തെളിവാണ് ബോംബെ മുതൽ പൊന്നാനിവരെയുള്ള ഭാഗത്തെ കടലിലെ എണ്ണനിക്ഷേപം. ഓയിൽ ട്രഷറികൾ ഈ ഭാഗങ്ങളിൽ ഉണ്ടാകാൻ കാരണം ഒരുകാലത്ത്

നിബിഡ വനങ്ങൾ തന്നെ ഇവിടെ ഉണ്ടായിരുന്നതുകൊണ്ടാണെന്ന് കരുതേണ്ടിയിരിയ്ക്കുന്നു. ഇത്രയും പറഞ്ഞത് കേരളഭൂമി അതിന്റെ ഉത്ഭവകാലം മുതൽ യാതൊരു മാറ്റവും വരാതെ നിലനിൽക്കുന്ന ഒന്നല്ല എന്ന് സ്ഥാപിക്കാനാണ്.

നമ്മുടെ മലയോരങ്ങളിലെ കല്ലുകൾ തന്നെ ഒരേ സ്വഭാവത്തിൽപെട്ടതല്ല. ഒരു സ്ഥലത്ത് വളരെ ഉറപ്പേറിയ പാറ കണ്ടാൽ അതിന് തൊട്ടടുത്തും ആ പാറകളുടെ തന്നെ മറ്റ് പല ഭാഗങ്ങളിലും ഉറപ്പുകുറഞ്ഞ പാറകളും ഇളം പാറകളും വളരെ അധികം വെള്ളം വലിച്ചെടുക്കാൻ പര്യാപ്തമായ പിണ്ണാക്ക് കല്ലുകളും കാണും. അത്രപാളികൾ ഉണ്ടാകും. ഇവയുടെയെല്ലാം ഒരു സംയുക്തമാണ് നമ്മുടെ മലകൾ. എങ്കിലും നമ്മുടെ മലമണ്ണ് ഹിമാലയപ്രദേശങ്ങൾ പോലെ ഉറപ്പു കുറഞ്ഞതല്ലെന്ന് പൊതുവിൽ പറയാം. ഇത്തരം മലകളുടെ ഉന്നതങ്ങളിലും പാർശ്വങ്ങളിലും വെള്ളം കെട്ടിനിൽക്കാൻ കഴിയുന്ന തടങ്ങൾ ഉണ്ടാകും. ഈ മലമ്മലകൾ പൊതുവിൽ വൃക്ഷലതാദികളാൽ മൂടപ്പെട്ടിരുന്നു. അതിന്റെ വേര് മണ്ണിലേയ്ക്ക് ആഴത്തിലിറങ്ങി വലുതും ചെറുതുമായ പല കല്ലുകളെയും മറ്റും തമ്മിൽ ബന്ധിപ്പിച്ചിരുന്നു. എത്ര ശക്തിയായ മഴ പെയ്താലും മണ്ണൊലിപ്പുണ്ടാകാതെ കാത്ത് സൂക്ഷിച്ചിരുന്നത് ഈ വേരുകളായിരുന്നു. വൻമരങ്ങൾ ഇടിയാനിടയുള്ള മലഞ്ചെരിവുകൾക്ക് താങ്ങായും നിലനിന്നു. ചരിത്രപരമായി നോക്കുന്ന പക്ഷം ഏതാണ്ട് 2000 വർഷങ്ങൾക്കു മുൻപുള്ള സംഘകൃതികളിൽ മഴ കൊണ്ടുള്ള യാതൊരു അപകടത്തെപ്പറ്റിയും സൂചനയില്ല. ഇന്നത്തെ കേരളം അടക്കമുള്ള പ്രദേശങ്ങളായിരുന്നു അന്നത്തെ തമിഴകം എന്ന് ഓർക്കേണ്ടതുണ്ട്. ഒൻപതാം നൂറ്റാണ്ടു മുതൽ 14-ാം നൂററാണ്ടുവരെ കേരളത്തിൽ പര്യടനം നടത്തിയിട്ടുള്ള അറബി സഞ്ചാരികൾ സുലൈമാൻ റഷീദുദ്ദീൻ, ഇബ്നു ബത്തൂത്ത, അൽഅബ്സീദി തുടങ്ങിയവരുടെ വിവരണങ്ങളിലൊന്നും മല ഇടിച്ചിലിനെപ്പറ്റി പരാമർശമില്ല. കായലുകളെയും, തോടുകളെയും, പുഴയെയും, മലകളെയും, കുരുമുളകിനെയും, ചക്കയെയും, സുഗന്ധവ്യഞ്ജന വസ്തുക്കൾ കൃഷിചെയ്യുന്ന സമ്പ്രദായത്തേയും, തേക്ക്, ഈട്ടി തുടങ്ങിയ വൃക്ഷങ്ങളെയും, കൊടുങ്കാറ്റിനെയും നദികൾ നിറഞ്ഞ് ഒഴുകുന്നതിനേയും മൂന്നുമാസം പെയ്യുന്ന തോരാത്ത മഴയേയും, അത് കഴിഞ്ഞാൽ ഉണ്ടാകുന്ന കഠിനമായ ഉഷ്ണത്തേയും വർണ്ണിച്ച ഇതിൽ പല സഞ്ചാരികളും മലയിടിച്ചിൽ ഉണ്ടെങ്കിൽ അതേപ്പറ്റി പറയാതിരിക്കുകയില്ല. സംഘകാലത്തേക്ക് മടങ്ങിയാൽ കേരളത്തിന്റെ ഭൂപ്രകൃതിയെപ്പറ്റി വിശദമായി പാടിയ സംഘകവികൾ ഈ വിനയെപ്പറ്റി മാത്രം കണ്ണടയ്ക്കാൻ ന്യായമില്ല. അന്ന് ജനസംഖ്യ വളരെ കുറവായതുകൊണ്ട് വൻമലകളിൽ നടക്കുന്ന ഉരുൾ പൊട്ടലുകൾ ജനവാസകേന്ദ്രങ്ങളിൽ അറിയാനിടയില്ല എന്ന് കരുതാനും തരമില്ല. കാരണം ഇന്നത്തെ തമിഴ്നാടുമായി മലമ്പാതവഴി നിരന്തര സമ്പർക്കമുണ്ടായിരുന്നു. കോഴിക്കോട് തുറമുഖത്ത് വെച്ച് 300 പേർ കയറി ചൈനയിലേയ്ക്ക് പോകാൻ നിന്ന ഒരു കപ്പൽ പെട്ടെന്ന് കൊടുങ്കാറ്റിൽപെട്ട് തകരുന്ന രംഗം ഹൃദയസ്പൃക്കായ നിലയിൽ വർണ്ണിച്ച ഇബ്നു ബത്തൂത്ത പറയുന്നത്, തെളിഞ്ഞ അന്തരീക്ഷത്തിൽ ശാന്തമായി കിടക്കുന്ന കടൽ പെട്ടെന്ന് ക്ഷോഭിക്കുന്ന പ്രത്യേകത കോഴിക്കോട്ടപ്പോലെ മറ്റെങ്ങും താൻ കണ്ടിട്ടില്ലെന്നാണ് കേരളത്തിലെ പ്രകൃതിയുടെ വികൃതികളെപ്പറ്റി വളരെ ഏറെ വർണ്ണിച്ച ഈ മൊറോക്കോക്കാരൻ മലയിടിച്ചിലുണ്ടെങ്കിൽ അത് കണ്ടില്ലെന്ന് നടിയ്ക്കാൻ തരമില്ല. ബ്രിട്ടീഷ് ഭരണകാലത്ത് വൈസ്രോയിയുടെ റിപ്പോർട്ടറായിരുന്ന ഫ്രാൻസിസ് ബുക്കാൻ മലബാറിലെ സകല പ്രശ്നങ്ങളെയും പറ്റി എഴുതിയിട്ടുണ്ടെങ്കിലും ഉരുൾപൊട്ടൽ കെടുതികൾ ഒരിടത്തും പറഞ്ഞിട്ടില്ല. ലോഗൻസ് മാനുവലിലും അതില്ല. പുരുക്കത്തിൽ മലകളെ മനുഷ്യൻ ആക്രമിച്ചതോടെയാണ് ഈ ദുർവിഷ്യത്തും ഇത്ര ഭയാനകമായ നിലയിൽ ജന്മമെടുത്തത്.

30 കളിലെ മലബാറിലേക്കുള്ള കർഷക കുടുംബങ്ങളുടെ കുടിയേറ്റവും തിരുകൊച്ചിയിലെ മലയോരങ്ങളിലേക്കുള്ള അവരുടെ വ്യാപനവും ആവശ്യാനുസരണമായിരുന്നു എന്ന് സമ്മതിക്കാതെ വയ്യ. പിന്നീടുള്ള 30 കൊല്ലങ്ങളിൽ ഈ ന്യായീകരണം നിലനിൽക്കാവുന്നതാണ്. വീണ്ടും സംഘടിതമായ, രാഷ്ട്രീയ പ്രേരിതമായ, ഇന്നും തുടരുന്ന വനം കൊള്ളയാണ് നമ്മുടെ മലകളെ ഇത്തരത്തിൽ നഗ്നമാക്കിയതും ആക്കുന്നതും. ഇന്ത്യയ്ക്ക് വേണ്ടതെന്ന് കരുതുന്ന 32 ശതമാനം വനം കേരളത്തെ സംബന്ധിച്ചിടത്തോളം 12 ശതമാനമായി കുറയാനുള്ള ഒരു പ്രധാനകാരണവും അതാണ്. 32ൽ നിന്നും 12 ലേക്കുള്ള ഈ മാറ്റം 1960 ന് ശേഷമുണ്ടായതും ഇന്നും നടക്കുന്നതുമായ വനം കൊള്ളയുടെ ഫലമായിട്ടാണ്. മരം മുഴുവൻ വെട്ടിയിറക്കിയപ്പോൾ വേരുകളുടെ സംരക്ഷണം മണ്ണിന് നഷ്ടപ്പെട്ടു. അടിവേരുകൾ പിന്നീട് അഴുകി ദുർബലമായി. വെള്ളം കുടിച്ച് കുതിർന്ന മണ്ണ് മലയുടെ ഉച്ചിയിലും പാർശ്വങ്ങളിലും കെട്ടി നിൽക്കുന്ന വെള്ളത്തോടൊപ്പം തടസ്സമില്ലാതെ ഇടിഞ്ഞു താഴോട്ടു

വീഴുന്നു. ഇതാണ് ഇന്നത്തെ അവസ്ഥ.. നിബിഡ വനങ്ങൾ ഉണ്ടെങ്കിൽ ദീർഘനേരം തുള്ളികളായ മഴയാണ് പെയ്യുക. മുമ്പെല്ലാം നമ്മുടെ മലകളിൽ പെയ്ത 80 ശതമാനവും അത്തരം മഴയായിരുന്നു. ഇന്ന് വനമില്ലാത്തതിനാൽ മഴ കോരിച്ചൊരിയുന്നു. ഒരു മാസം കൊണ്ട് പെയ്യേണ്ട മഴ ചിലപ്പോൾ ഒരു ദിവസം കൊണ്ട് പെയ്യുന്നു. വൻതോതിൽ ഇത് മല ഇടിച്ചിലിന് കാരണമാകുന്നു. തുമ്പിക്കൈ വണ്ണത്തിൽ പെയ്യുന്ന മഴയത്ത് മലയുടെ ഉച്ചിയിൽ കാർമേഘപാളികൾക്കിടയിൽ ഇടിമിന്നൽ ഉണ്ടായാൽ അതും മല ഇടിച്ചിലിന് സഹായകമാകുമോ എന്ന കാര്യം ഇനിയും പഠിയ്ക്കേണ്ടതുണ്ടെന്ന് തോന്നുന്നു. മീറ്റിയോറളജിസ്റ്റുകളുടെ സഹകരണം കൂടി ഇതിന് ആവശ്യമാണ്.

കടലിലെ അഗ്നിപർവ്വതക്ഷോഭവും അതിശയകരമായ അടിയൊഴുക്കുകളുടെ ആഘാതവും ന്യൂനമർദ്ദത്തിന്റെ കൂടുതലും മൂലം കടലിൽ മേഘത്തൂണുകൾ പ്രത്യക്ഷപ്പെടുകയും അതിലൂടെ വെള്ളം മേലോട്ട് വലിച്ചെടുക്കപ്പെടുകയും പെയ്യാറുണ്ടെന്ന് ഒട്ടധികം കപ്പലോട്ടക്കാർ വിവരിച്ചിട്ടുണ്ട്. അവരും ഈ പ്രതിഭാസത്തിൽ വെള്ളം കത്തിജ്വലിക്കുന്നത് കാണാറുണ്ട്. വെള്ളത്തിലെ ഹൈഡ്രജൻ വേർപിരിയുന്നതാവാം കാരണം. ആന്ധ്രയിലെ അതിശയകര കടൽക്ഷോഭത്തെപ്പറ്റിയുള്ള വിവരണങ്ങളിലും കടലിൽ തീനാളങ്ങൾ ഉയർന്നതായി കാണുന്നുണ്ട്.

മലമ്പ്രദേശങ്ങൾ ജനവാസകേന്ദ്രങ്ങളായി മാറുന്നതോടെ ധാരാളം റോഡുകളും മററും വേണ്ടിവരുന്നു. യാതൊരു വിവേചനവുമില്ലാതെയാണ് റോഡുവെട്ടുന്നത്. അത് വെറും ഒരു സിവിൽ എഞ്ചിനിയറിംഗ് വിഷയമായി സർക്കാർ കണക്കാക്കുന്നു. കിഴക്കാംതൂക്കായ മലകളിലേക്കുള്ള റോഡുകൾ, കൂപ്പുറോഡുകൾ ഇവയെല്ലാം വൻതോതിൽ മണ്ണിടിച്ചിലിന് വഴിതെളിക്കുന്ന ഘടകങ്ങളാണ്. ഇത്തരം പ്രദേശങ്ങൾ വെട്ടിത്താഴ്ത്തുകയോ കെട്ടിപ്പൊക്കുകയോ ചെയ്യുമ്പോൾ ആ പ്രത്യേക ഭാഗത്ത് മാത്രമല്ല ബന്ധപ്പെട്ട പരിസരങ്ങളിലും സമതുലിതാവസ്ഥയ്ക്ക് മാറ്റംവരുന്നു. മീറ്ററുകൾ ഉയരത്തിൽ കാണുന്ന ഭൂമിയുടെ അടിത്തറ തന്നെ ചിലപ്പോൾ ഭാഗികമായും ഇതുകൊണ്ട് ഇളകിപ്പോകും. മലയോര റോഡുകളെപ്പറ്റി ഇന്ന് പഞ്ചായത്തും, കാട്ടുകാരും മറ്റുമാണ് തീരുമാനമെടുക്കുന്നത്. എത്ര പ്രയാസകരമായ പ്രദേശങ്ങളിലും റോഡ് വെട്ടുന്നത് എഞ്ചിനിയർമാരുടെ കഴിവായി പ്രകീർത്തിക്കപ്പെടുന്നു. ഇത്തരം റോഡുകൾ ഉണ്ടാക്കുന്ന ഇക്കോളജിക്കൽ ഇംപാക്റ്റിനെപ്പറ്റി ചിന്തിയ്ക്കാനുള്ള സംവിധാനങ്ങൾ ഇല്ല.

അണക്കെട്ടുകളുടെ കാര്യവും അതുപോലെതന്നെയാണ്. വൻകിട അണകെട്ടുകൾക്ക് ഒരു ജിയോളജിക്കൽ റിപ്പോർട്ട് വേണമെന്നുണ്ട്. അത് പേരിന് മാത്രമാണ്. റിപ്പോർട്ട് എന്തായാലും സർക്കാർ ഉദ്ദേശിച്ച സ്ഥലത്ത് അണക്കെട്ടുകൾ ഉയർന്നുവരും. വിശദമായ ഒരു ഭൂവസ്തു പഠനത്തിന് ശേഷമായിരുന്നെങ്കിൽ ഇടുക്കി അണകെട്ട് അവിടെ വരുമായിരുന്നില്ലെന്ന് ഇപ്പോൾ ഇതെപ്പറ്റി വിവരമുള്ളവർക്കറിയാം. സ്ഥിരമായി കെട്ടിനിൽക്കുന്ന വെള്ളത്തിന്റെ സമ്മർദ്ദം കിലോമീറ്ററുകൾ അകലെപ്പോലും ഭൂമിയെ ഭാഗികമായി തള്ളിനീക്കാൻ പര്യാപ്തമാണ്. വിവേചനരഹിതമായ ഇത്തരം നിരവധി പ്രവർത്തനങ്ങളുടെ ഫലമായി ബലക്ഷയമായ ഭൂമിയിൽ കനത്തതോതിലുണ്ടാകുന്ന മഴ മല ഇടിച്ചിലിന് ആക്കം കൂട്ടുന്നു. നമ്മുടെ അണക്കെട്ടുകളിലെല്ലാം കൂടി വർഷകാലത്ത് ഏതാണ്ട് 11 ലക്ഷം കോടി പൗണ്ട് വെള്ളം കെട്ടിനിൽക്കുന്നു എന്നാണ് അറിവ്. അത് ഭൂമിയുടെ ഐസോസ്റ്റസിയെ ബാധിക്കുകയില്ലെന്ന് എങ്ങിനെ പറയാം കഴിയും

കൊല്ലവർഷം 1057 ലാണ് നമ്മുടെ (1881) അറിവിൽപ്പെട്ടിടത്തോളം ഏറ്റവും വലിയ വെള്ളപ്പൊക്കമുണ്ടായത്. ബ്രിട്ടീഷുകാർ ആ കൊല്ലം മുതലാണ് ഇവിടെ മഴ അളക്കാൻ തുടങ്ങിയതും. ആ കൊല്ലം കോഴിക്കോട് 191 ഇഞ്ച് മഴ പെയ്തു. 1890 ഒഴികെ പിന്നീടുണ്ടായ 30 കൊല്ലങ്ങളിൽ ശരാശരി 150 ഇഞ്ച് മഴ പെയ്തു എന്നാണ് കണക്ക്. 1890ൽ വെറും 92 ഇഞ്ച് മഴയേ പെയ്തുള്ളു. എന്നിട്ടും വലിയ മലയിടിച്ചിലുകളെപ്പറ്റി റിപ്പോർട്ടുകളില്ല.

വനനശീകരണം മൂലമുണ്ടാകുന്ന ഉരുൾപൊട്ടലുകൾ മണ്ണൊലിപ്പിന് ആക്കം കൂട്ടുന്നു. കേരളത്തിലെ ആകെ കൃഷിസ്ഥലമായ 55 ലക്ഷം ഹെക്ടറിൽ 20 ലക്ഷവും ഇന്ന് മണ്ണൊലിപ്പ് ഭീഷണിയിലാണ്. 4 കോടി ടൺ മണ്ണ് കൊല്ലം പ്രതി ഒലിച്ചുപോകുന്നുണ്ടത്രെ. ഈ കണക്കിനുപോയാൽ കേരളത്തിൽ വരുന്ന 20 കൊല്ലം കൊണ്ട് വലിയ തോതിൽ റോക്ക് ഫോർമേഷൻ നടക്കുമെന്ന് ചില റഷ്യൻ വിദഗ്ധൻമാർ ചൂണ്ടിക്കാണിച്ചിട്ടുണ്ട്.

ശബരിഗിരി അടക്കം പത്തനംതിട്ട ഭാഗത്ത് മുമ്പ് 590 ചതുരശ്രകിലോമീറ്റർ വനമായിരുന്നു. ഇപ്പോൾ അത് 200 ചതുരശ്ര കിലോമീററിൽ ഒതുങ്ങി നിൽക്കുന്നു. തൃശൂർ ജില്ലയിൽ ഷോളയാറിനും പറമ്പിക്കുളത്തിനും ഇടയിൽ വനം ചുരുങ്ങുകൂടി കിടക്കുന്നു. പാലക്കാട് ജില്ലയിലെ മുതുകുളം റിസർവോയറിൽപ്പെട്ട ശിരുവാണി ഭാഗത്ത് 1982 മുതൽ 700 ഹെക്ടർ നിത്യഹരിതവനം

നശിപ്പിച്ചു. മലപ്പുറം ജില്ലയിലെ ചുങ്കത്തറയ്ക്ക് പടിഞ്ഞാറും വടക്കും ഏതാണ്ട് നിന്ന പ്രദേശത്ത് 30 കോടിരൂപയുടെ തടികാണും. ഈ ഭാഗത്താണ് സ്വർണ്ണം നിക്ഷേപമുണ്ടെന്ന് പറയുന്നത്. അത് കുഴിച്ചെടുക്കുന്ന പരിപാടി ഇട്ടാൽ ആദ്യം തകർക്കുന്നത് ഈ മരമായിരിക്കും. സ്വർണ്ണനിക്ഷേപം ആദായകരമായി കുഴിച്ചെടുക്കാൻ കഴിയില്ലെന്ന മറ്റൊരു റിപ്പോർട്ടും നിലവിലുണ്ട്. അതോടെ ചാലിയാറിന്റെ കഥയും കഴിയും. കോഴിക്കോട് ജില്ലയിൽ കുറ്റ്യാടി മലവാരത്ത് മാത്രമാണ് കുറെ വൃക്ഷക്കൂട്ടങ്ങൾ ഉള്ളത്. കൊട്ടിയൂരെ ചെറിയ ഒരു ഭാഗം ഒഴിച്ചാൽ കണ്ണൂർ ജില്ലയിൽ വനം തുടച്ചു നീക്കപ്പെടും. വയനാട് ജില്ലയിൽ ആകെയുള്ളതിന്റെ രണ്ടര ശതമാനം 83 മുതൽ 2 കൊല്ലം കൊണ്ട് കുറഞ്ഞു. തിരുവനന്തപുരം ജില്ലയിൽ നെയ്യാർ എന്ന തെക്കൻ മണ്ണിന്റെ അക്ഷയപാത്രം ക്ഷയിച്ചു. അഗസ്ത്യാർകൂടത്തിൽ നിന്ന് ഉത്ഭവിക്കുന്ന ഈ നദി പടിഞ്ഞാറോട്ട് ഒഴുകുന്നതാണ് നെയ്യാർ, കിഴക്കോട്ട് ഒഴുകുന്നത് താമ്രപർണിയും. 1988 ൽ കേരളത്തിൽ കടുത്ത വരൾച്ചയുണ്ടായപ്പോഴും താമ്രപർണിയിൽ വെള്ളം കുറഞ്ഞില്ല. തമിഴ്നാട്ടുകാർ, ആ ഭാഗത്തെ വനം നശിപ്പിച്ചില്ല എന്നാണ് ചുരുക്കം.

ഉരുൾപൊട്ടൽ തടയാൻ മലയോര കർഷകർ തന്നെ മുന്നോട്ട് വരണമെന്ന് തോന്നുന്നു. ഇതുകൊണ്ട് ഏറ്റവും കൂടുതൽ നഷ്ടം അവർക്കാണ്. അവർ സംഘടിതമായി എതിർത്താൽ വനനശീകരണം നിലയ്ക്കും. മറ്റൊരു കാര്യം ഉരുൾപൊട്ടൽ ഉണ്ടാകാവുന്ന പ്രദേശങ്ങൾ അടയാളപ്പെടുത്തുന്ന അത്തരം ഭാഗങ്ങളിൽനിന്ന് ജനങ്ങളെ മാറ്റണം. അതിന് പഞ്ചായത്തുകൾക്ക് മുൻകൈയെടുക്കാൻ കഴിയും. അത്തരം സ്ഥലങ്ങളിലേക്കുള്ള കുടിയേറ്റവും നിരോധിച്ചേ തീരൂ.

REBUILD A NEW KERALA - A DISASTER RISK MANAGEMENT PERSPECTIVE

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Kerala is a state highly vulnerable to natural disasters and the changing climatic dynamics given its location along the sea coast and with a steep gradient along the slopes of the Western Ghats. Kerala is also one of the most densely populated Indian states (860 persons per square kilometers) which makes it even more vulnerable to damages and losses on account of disasters. Floods are the most common of natural hazards that a?ects the State. Nearly 14.5% of the State's land area is prone to floods, and the proportion is as high as 50% for certain districts. The State lies in seismic zone III which corresponds to Moderate Damage Risk Zone (MSK VII). The State falls under Moderate Damage Risk Zone for Wind and Cyclone (Vb=39 m/s). As per IMD data for the period 1877-2005, the state witnessed six cyclonic storms and five severe cyclonic storms. The state also witness high incidence of lightning, especially in the months of April, May, October and November. Lightning strikes cause heavy loss of lives in the State.

Landslides are a major hazard along the Western Ghats in Wayanad, Kozhikode, Idukki and Kottayam districts (as seen in the weather led disaster that occurred in 2018).The western flank of the Western Ghats covering the eastern part of Kerala is one of the major landslide prone areas of the country. 1500 sq.km. in the Western Ghats is vulnerable and every year with the onset of monsoon, and landslides are reported. The mountain regions experience several landslides during the monsoon season (Kuriakose, 2010) leading to road collapse, silting of river beds and creating heavy damages on public and private assets. 14.8% of the state is prone to flooding (CESS, 2010). The coastline is prone to erosion, monsoon storm surges and sea level rise. Land subsidence due to tunnel erosion or soil piping is a slow hazard that has recently been affecting hilly areas.

The coast line of Kerala (590 km) is one of the most densely populated land areas in the country. More than half of the area of the State is only 4 meters above sea-level and encroachment by the sea severely affects the economy of the State. A substantial part of population not only lives close to the coastline but also lives off it and they belong to the vulnerable sections of the society. This coastline is exposed to high waves, storm surges and Tsunamis. Sea erosion is one of the recurring natural hazards affecting the coastline in the State, as part of the erosion - accretion cycle. It is feared that with the predicted rise in sea level, as a result of the greenhouse gas effect, the rate of beach erosion and loss of coastal properties are on the rise. The state has taken efforts to reduce the erosion with multiple interventions such as coastal sea walls, breakwaters/spurs jetting into the sea, under water sand filled geo-textile tubes to reduce the intensity of the waves, etc. Coastal erosion has resulted in loss of life and property of the coastal fisher-population who are among the most economically backward communities in the State. Apart from loss of lives, hundreds of houses and public infrastructure are damaged due to the fury of the sea. Almost all fisher families prefer to live along the coast and very few of them tend to have landed property or houses further inland. Therefore, their vulnerability to the vagaries of sea waves and magnitude of the following disasters have been increasing, damaging livelihoods and properties of the fishermen community.

Kerala experiences seasonal drought conditions every year during summer months. Kerala experienced 66 drought years between 1881 and 2000. More than 50% of Kerala's land area is moderately to severely drought susceptible. After the drought years of 2002-2004, 2010, and 2012, Kerala State was officially mapped as mild to moderately arid by the Indian Meteorological Department (IMD). In 2017, the IMD stated that the year brought the worst drought in 115 years. Increasing incidence of drought is mainly due to weather anomalies, change in land use, traditional practices and lifestyle of people.

Other natural hazards faced by the states includes forest fires, soil piping, swell waves and tsunami.

Almost three-quarters of the population lives in urban areas, urban sprawls and fast urbanizing rural areas. Kerala's mountainous topography and hydrological features increase their vulnerability to natural hazards. Communities regularly face low-severity, high-frequency disasters such as floods, rains, landslides, flash floods due to intense precipitation and mudflows. Many rural households whose male heads are working abroad are vulnerable, although household members left behind have mobility, but interrupted exposure to disaster-related information and limited participation in community awareness-raising activities and training.

With high density of population and major establishments along the sea coasts, large investments are required to undertake protection measures and other mitigating measures, based on scientific data.

The heavy monsoon of 2018 brought widespread flooding to several districts of Kerala state and triggered a large number of small to big landslides. The extreme and prolonged rainfall spell in August 2018 led to the worst flooding in Kerala in nearly a century impacting almost 5.4 million people - one-sixth of the State's population. Several districts were inundated for more than two weeks due to heavy rains induced floods. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the State, adding to the impact of floods. Nearly 341 major landslides were reported from 10 districts. Idukki district was ravaged by 143 landslides. 1,260 out of 1,664 villages spread across its 14 districts were affected. Seven districts were worst hit: Alappuzha, Ernakulam, Idukki, Kottayam, Pathanamthitha, Thrissur and Wayanad where the whole district was notified as flood affected. The devastating incident delivered a total of 435 casualties, with 6,85,000 families being affected with loss of assets and property forcing them to temporarily move to relief camps during the peak of the disaster. The Government conducted timely and efficient rescue and relief operations to save many lives, heavily supported by affected communities mobilizing on their own, and effective application of information technology and social media by voluntary youth groups to support rescue operations. The people of Kerala also showed remarkable resilience in the face of the adversity to the extent that within one week of flood waters receding, most people returned to their homes to rebuild their lives.

Risks in the State: Disasters are awakening calls leading to detailed analysis of the causes and forecasts. KSDMA in its Disaster Management Plan (DMP) has identified 39 hazards that the State is susceptible to. These were categorized under two broad heads i.e. Naturally Triggered Hazards (Natural Hazards) and Anthropogenically Triggered Hazards (Anthropogenic Hazards).

Disaster risks are exacerbated by a critical factor that has been silently increasing in the State, which is the land use pattern and practices. Land use regulations are limited to multiple, incongruent acts, orders and rules. All these orders do not ideate into a single land management policy/regulation for enforcement agencies to pursue. A commonality of law for land use is absent, due to which business and habitation zones has overlapped over the years, leading to establishment of compelling public infrastructure to service these areas. This is further compounded by high density of population of 860 people/km2 (2011 Census), narrow roads, dense and intrinsic road network, density of coastal population and the general higher standard of living of the public as compared to the rest of the country.

Changing climatic conditions, unsustainable exploitation of natural resources, lack of awareness of disaster risks, inadequate hazard detection infrastructure by central agencies and nationally laid protocols respectively and slow roll out of civil defense compound to increasing the vulnerabilities. These factors, combined with limited consideration of disaster risk within social and economic sectors, because of competing demands on limited financial resources, underpin the high disaster risk levels in Kerala.

The widespread flooding in urban and semi-urban areas of Kerala has reaffirmed absence of risk-informed urban planning, non-compliance to design standards, and non-incorporation of resilient features in urban infrastructure. Rapid urbanization influenced habitations into uncontrolled expansion on both banks of the rivers/water bodies thereby encroaching into water channels/bodies and constricting the floodplains. Inadequate storm water drainage and silting of minor storage ponds and flood plains in urban and urban sprawl areas have increased flood risks. Urban master plans are still awaiting comments and feedback from the local bodies to enable review/appropriate rectification and issue of notification of approval of the master plans for the respective local bodies.

Changing climate: The impacts of climate change are largely present through increases in the intensity and frequency of extreme weather events, unpredictability of precipitation, and changes to water regimes and peak seasonal runoff, caused in part by erratic precipitation, and rising temperatures. The state has also had its share of droughts with critical droughts in the years of 2013, and winters of 2017. These impacts are aggravated by lack of risk informed planning of the state. Another impact being witnessed is progressive coastal erosion affecting nearly 63% of the state's 580 kms coastline.

Disaster risk information: KSDMA, for the first time in the history of any SDMAs in the country, released landslide and flood susceptibility maps of Kerala in Geoinformation file formats for public use in its website. This has adequately empowered public to deal with risk informed environmental litigations. The State Disaster Management Plan has stipulated restrictions in hazard zones and have laid checklists for risk assessment, to be followed by the implementing department prior to approving any infrastructure development projects.

The collection and availability of disaster risk information, including hydro-meteorological data, is limited and scattered across multiple agencies, which, is often not shared between agencies. This reduces the scope of terrain, weather and hydrology informed planning. The official meteorological agency, the India Meteorological Department has only 11 automated weather stations. An underlying issue is the prevalent protocol of information sharing which is subjected to receipt of forecast data from a single source – Indian Meteorological Department (for weather) and Central Water Commission (for floods), leading to lower scale of accuracies and lesser duration available for the state to undertake emergency response measures. The Government of Kerala had requested IMD to improve and downscale weather predictions to village level and increase the observation network. Unfortunately, due to lack of response, the Government has approached Indian Space Research Organisation for adequate support who has responded positively to the request.

Legal framework: The Kerala State Disaster Management Authority (KSDMA) established under the Disaster Management Act 2005 (Central Act 53 of 2005), in the aftermath of December 2004 Indian Ocean Tsunami, identifies disaster risks as one of the main challenges to Kerala's development aspirations. Although prevention is clearly articulated as a role to be performed by the KSDMA, its facilitating role in pre-disaster risk management and its relationship with sector departments and other related agencies, were not clearly articulated and enforced. While State Disaster Management Plan lays clear guidelines for various departments, compliance is limited to implementation of centrally sponsored projects.

Institutional setup for disaster management in the state has an enabling legal and policy environment in place. KSDMA started to function as envisaged under the Disaster Management Act, 2005 only from 2012. Until Cyclone Ockhi in 2017, KSDMA had only 9 staff. Additional multi-disciplinary scientific staff was infused into KSDMA post Cyclone Ockhi.

Having said that, KSDMA has fairly fulfilled its mandate over the years in promoting awareness on disaster risks faced by the State and building scientific evidence-base to support risk informed development planning, though not applied by the agencies. For disaster response Civil Defence Institute at Thrissur has been established with the assistance of Government of India and land for a Regional Response Centre of National Disaster Response Force has been allotted in Ernakulam in 2016.

Kerala's minimum relief code is the highest in the country. In most cases, the amount of relief offered is almost 30 times greater than the national minimum relief code. Kerala is the only state to have instituted a vulnerability linked relocation scheme totally funded by the State Government. Under this scheme, the State provides Rs. 4 lakhs for house and Rs. 6 lakhs for purchasing 3 to 5 cents of land for those families who are certified to be living in non-livable terrains. Further, the State also provides the same amounts to those living within the high tide line to 50 meters inward into the land, to relocate themselves to a land chosen by them beyond the 50 meters.

The Disability Inclusive DRR programme of KSDMA has been referred to as the national model for developing the National Disaster Management Guidelines - Disability and Disasters. The programme yielded results during Kerala Floods where NGOs trained by KSDMA on the domain conducted special rescue missions for persons with disabilities.

Multiple government agencies and departments deal with Disaster Risk Management (DRM) directly or indirectly. The existing institutional arrangements for DRM mainstreaming is complex. Risk governance, capacity, and funding limitations indicates that DRM mainstreaming efforts have not been fully embedded in core sector activities in the state.

As per the approved stakeholder responsibilities of the National Disaster Management Plan, the responsibility of early hazard detection is vested upon various central agencies namely India Meteorological Department (IMD), Central Water Commission (CWC), Geological Survey of India (GSI), Indian National Centre for Ocean Information Services (INCOIS) etc. The responsibility of the KSDMA is to support the central initiatives which KSDMA has done significantly.

The State Disaster Management Plan mandates a checklist for all infrastructure projects to follow, prior to acceptance for financing by the State. However, this mandate is not seen complied by the departments.

Under the existing governance structure, KSDMA and DDMAs are placed to support DRM across various government departments and agencies in the state through its coordination and facilitation mandate. However, to play its role in DRM, protocols for relationships and links between the KSDMA and other agencies that produce and analyze DRM related data and information, the sector departments and agencies, need to be developed with clearly defined roles for each institution. For eg. the roles and responsibilities of the Department of Water Resources and agencies under it responsible for flood protection infrastructure and hydrological activities, needs to be clearly articulated and strengthened. The KSDMAs and DDMAs existing information management capacity needs to be substantially expanded and strengthened to integrate their services with all relevant data sources. Capacity for analysis, planning, and development of evidence-based emergency response actions and investment decisions needs to be strengthened. The Fusion Centre of KSDMA when completely made functional will contain necessary Decision Support Tools for State level decision making. Measures are already contemplated to develop it further and provide the ability to districts. A high power committee constituted by the Government has recommended additional measures to reinforce KSDMA, which is currently under the consideration of the Government.

KSDMA has recommended that the state should consider options to develop a data analyzing and clearing house function in the State, preferably under the Kerala Spatial Data Infrastructure (KSDI).

Financing DRM: is a key constraint as hazards are unprecedented and random.

KSDMA has an annual budget of Rs. 5 crores and State Disaster Mitigation Fund as deemed necessary from time to time by the State Executive Committee.

For response purposes, Kerala utilizes National Disaster Response Fund (NDRF) and State Disaster Response Fund (SDRF). The contribution pattern to SDRF is 90% from Government of India and 10% from Government of Kerala.

The state draws its finances for institutional capacity development schemes of NDMA and United Nations Organisations. Tsunami Rehabilitation Project was implemented with the support of multi-lateral agencies. Presently, Kerala is implementing National Cyclone Risk Mitigation Project with the financial support of World Bank.

Guidelines are in place for establishment of flexi-funds, that enables 10% of the CSS schemes budget to be undertaken for disaster mitigation/restoration activities by the respective implementing agencies in the State, for DRM in the respective sectors. Kerala has already approached the 15th Finance Commission to enhance its abilities in Disaster Risk Reduction.

There are large projects such as (a) Integrated Coastal Zone Management Program (ICZMP); (b) National Hydrology Project (NHP) to strengthen hydrological activities and improve capacities for data processing, and (c) Dam Rehabilitation Implementation Project (DRIP), which covers rehabilitation/repair of dams in the state. These projects have a component of Risk Reduction by its nature and subject itself. However, even in such large scale projects direct consultations with the Disaster Management Authority is not mandated by the funding agencies.

Kerala needs, a coherent long-term investment plan and sustainable risk financing mechanism to finance institutionalization and implementation of disaster resilient measures in all investments across sectors. The State government upon approval of Government of India, may institute a "disaster cess" on the Goods and Service Taxes (GST) for three years to finance rebuilding activities in Kerala.

Many natural and anthropogenic catastrophic events that occur are not listed as calamities entitled for claims under NDRF/SDRF and also does not come under the ambit of Disaster Management Authorities - National, State or District. Issues like drowning deaths, work place deaths etc. are unfortunate events that requires attention. Hence, matters such as these that are related to Public Safety may be brought under the ambit of a Public Safety Authority.

The 15th Finance Commission has recommended that a Public Calamity Insurance Scheme be funded by Govt. of India, with an allocation of an initial grant-in-aid for premium payment for the first 5 years and may subsequently be taken up by the State Government through a suitable and or varying funding mechanisms to finance mitigation interventions. A separate additional share/provision may be recommended for addition to the SDRF to meet this expenditure for the first 5 years.

Integrated disaster risk assessments, disaster management information system and operationalization of early warning system are needed for both pre and post-disaster management. Central agencies should strengthen their monitoring and early hazard detection systems. Additional staff as recommended by the High Power Committee may be sanctioned to KSDMA for strengthening its capacity. The disaster management information system with its inventory of assets at risk, could play a pivotal role in informed decision making for DRM. Such a fundamental list is provided in the State Disaster Management Plan.

A wide range of equipment would be required to be installed by IMD, CWC, GSI and INCOIS for early detection of possible hazardous events. KSDMA, DDMA and sectoral responsible departments needs additional last mile connectivity systems for communicating actionable directives to general public living in disaster prone areas as notified by the respective technical central agencies from time to time. Building the capacity of vulnerable communities and civil defence through nonstructural community-based DRM interventions, and awareness raising of youth on DRM through educational institutions, could play a vital role in reducing losses caused by disasters.

Way forward

The Floods 2018 has now presented an opportunity to Kerala to accelerate implementation of priority actions and risks from Centrally notified and State notified disasters. The broad activities that may be undertaken are broadly detailed as follows:

Risk Identification and Technical Studies

i) Landuse categorization studies

ii) Comprehensive 1:10,000 scale land use mapping and terrain linked land use zoning

iii) Detailed state wide vulnerability assessment of critical public infrastructure and assets to site/location specific hazards

iv) Multi-hazard disaster risk mapping and impact assessments including hazard zoning and mapping high risk zones/urban areas based on protocols and methodologies laid by the concerned central agencies

v) Establishment of last mile hazard communication systems and updation of existing SOPs for triggering preparedness and emergency response actions

vi) Implementation of State-wide civil defense and capacity building for the civil defence volunteers

Risk Governance

i) Creation of a comprehensive risk informed landuse plan, landuse act and rules considering the ecology, sociology, and social milieu of human being are important. This may be lead by

Department of Planning with the help of Landuse Board and Kerala State Remote Sensing and Environment Centre. Government may issue a guiding document with negotiable and non-negotiable of the preparation of the landuse plan.
ii) Restriction of use of forest land for any commercial or residential or further construction activity with the exception to the existing rights of the tribal communities living in the forest areas.
iii) Land Revenue Department may be notified as the implementing and enforcement authority of the Landuse plan - a reorientation and renaming of the department as Land Administration and Management may also be considered.
iv) All urban local bodies may be directed to immediately approve and notify their master plans.
v) Improve design standards for basic public services taking into consideration the multi-hazard susceptibility, flooding extent of a 1 in 30 year return interval and landslide/land subsidence events;
vi) Consider amendments to Kerala Municipal Building Rules and Kerala Panchayath Building Rules in light of National Building Code and IS Codes.
vii) Improve compliance of all new critical infrastructure projects to safer standards and specifications, and apply third party structural and safety audits to ensure compliance
viii) Increase the scope of vulnerability linked relocation plan of the State and provide incentives to constructions that comply with safety standards and have considered site specific hazard susceptibilities
ix) Development of Emergency Action Plan and update Operational & Maintenance Manuals for Dams to facilitate improved dam management
x) Formulation of a long-term Coastal Zone Disaster Mitigation Plan, a comprehensive Coastal Development funds package (as announced 2018-19 state budget) on a year-to-year basis for investments in coastal protection works/activities

Mitigation Infrastructure and Measures
i) Construction of multi-purpose emergency shelters and improved access to such shelters that are handed over to the communities with corpus fund for operation and maintenance.
ii) Contingency crop planning should be developed to deal with climate variations, to ensure sustainable livelihoods in areas of recurrent climate risks by promoting supplementary income generation
iii) Popularize crop insurance schemes
iv) Construct all new schools located in hazard-prone areas to higher standards of hazard resilience; retrofit schools in high risk zones to increase safety; carryout technical audit of private schools, direct and provide guidance for retrofitting measures.
v) Incorporate elements of Disaster Risk Reduction in all subjects from the subject specific perspective
vi) Conduct vulnerability assessment of hospitals in hazard-prone areas, promote hazard resilient construction of new hospitals and create intrinsic and extrinsic disaster management plans for hospitals
vii) Flood mitigation options to be considered/developed comprising major works which are to be evaluated in terms of their hydraulic efficacy in delivering the required degree of flood mitigation
viii) Conduct vulnerability assessment of all critical public buildings and carryout necessary/appropriate mitigation measures to increase safety. Promote hazard resilient construction of new buildings with conformity to National Building Code

Landslides Management Strategy
i) Development of an integrated approach involving land use planning, good land management practices in cropping, grazing and forestry, terrain depended road construction, terracing and other contour-aligned practices in fields and plantations, and participation of local communities.
ii) Initiate major shift in Landuse policies demarcating certain areas as ‘no development zones and construction restricted zones’.
iii) Landslide hazard zonation maps to be made available in a scale (1:10,000 at least) appropriate for planning at local level for all Municipalities and Panchayats in the Hilly areas
iv) Local Self Government may be directed to consult the Soil Conservation Department, Mining and Geology Department and Ground Water Department before implementing infrastructure development projects to assess landslide risks
v) Promote the use of bio-engineering solutions along slopes to prevent landslides

Resilience in Urban and Rural Development

The following specific interventions may be considered for building urban resilience in Kerala:

i) Revise urban planning norms to conform with the hazard mapping and zoning mandatory as part of the city master plans and regulations to ensure compliance by local governments with the planning norms and guidelines

ii) Develop a guiding/policy document for preparation of Master plans with negotiables and non-negotiables, with parameters for critical mass management for urban local bodies (ULB) eg. 600K to 800K population/ULB. The guidelines should also include identification of urban sprawl areas and measures to curtail the same be legalized in the Master plan for approval and enforcement.

iii) Develop design guidelines for climate resilient municipal infrastructure and ensuring proper enforcement for all the physical construction works to improve the quality of infrastructure being developed for municipal services.

Building Resilience

The new, resilient Kerala may be based on six pillars of Disaster Risk Management, they being:

Pillar-1: Legalizing and enforcing a pragmatic landuse management institutional mechanism

Pillar-2: Mainstreaming disaster risk management into development planning

Pillar-3: Improving emergency response systems

Pillar-4: Creation of Civil Defense

Pillar-5: Road map for risk financing

Pillar-6: Strengthening KSDMA and DDMAs

Detailed plans are being drawn in line with each of these broad pillars of resilience and the Government and KSDMA is committed to building a 'new and resilient Kerala'.

LANDSLIDE 18 KERALA - A REPORT

Dr.Premlet B.
Chair,Educational Activities
IEEE KeralaSection

Introduction

The south Indian state of India, Kerala lying in the lap of the mountain range of Western Ghats faced one of its most devastating disasters during the landslides of 2018.

The unabated rain from June to August of 2018, triggered thousands of debris flow, landslips, landslides, mud slips, soil piping and subsidence in 12 out of 14 districts of Kerala. Death toll reached 155. Many economic sectors, mainly the agricultural sector faced an irrevocable loss.

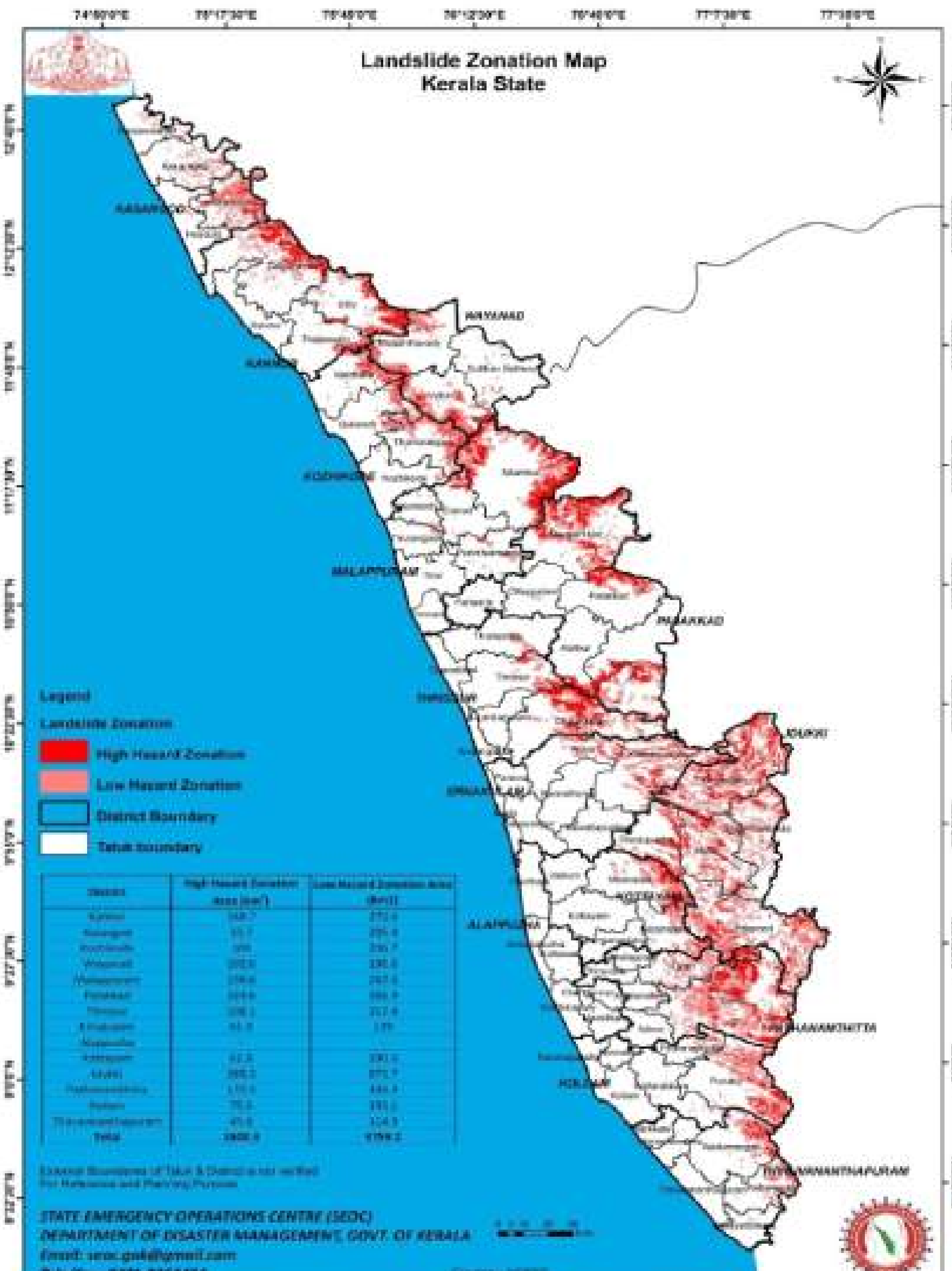
Landslide in Kurichyar Mala, Wayanad

The Western Ghats running throughout the length of Kerala, suffers from frequent landslides during the monsoon season which happens twice a year (South West monsoon and North East monsoon). About 8% of area in the Western Ghats have been identified as critical zones for landslides.

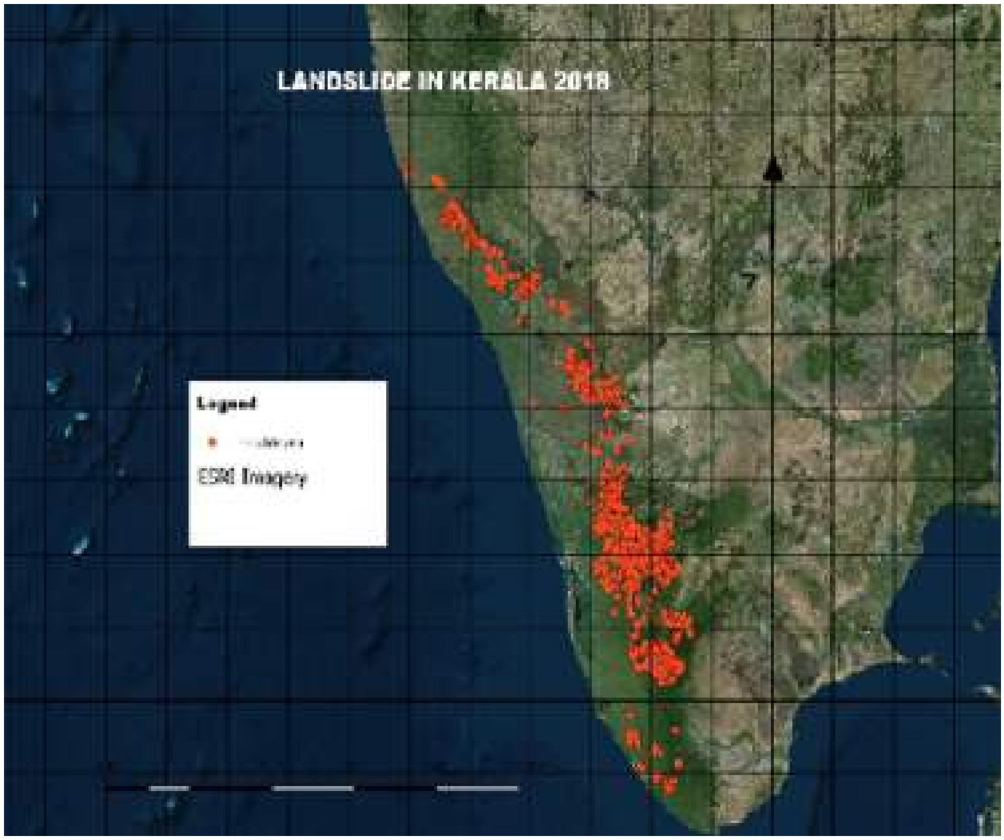
The annual rainfall in Kerala is about 3000 millimetre whereas it exceeds 5500 millimetre in highlands. Between June 1st and August 26th of 2018, rainfall was 24% more than the usual value for that period. Unlike other natural hazards landslides are caused by many factors like slope failure, heavy rainfall, soil depth, earthquake, clap of thunder and anthropogenic activities. Anthropogenic factors include loading crest of the slope, excavation at toe of the slope, deforestation, quarrying, mining and land use pattern. However the principal triggering factor is the rainfall.

The first officially recorded flood in Kerala occurred in 1881 and the oldest known landslide in Kerala happened on 4th October 1882 at Meladukkam, Kottayam. The word *Urulpottal* in Malayalam (Debris flow) was coined by dwellers in Kodiyathoor, near Kottayam , India in 1949 after a landslide in the hilly area.

More than 5000 major and minor landslides occurred in Kerala in trimester of 2018. More than 3000 landslides happened in the districts of Idukki and Wayanad alone during June-August 2018 flood season. The death toll due to landslides alone was 155. The sum total loss in various damages in infrastructure and other properties is estimated to be 40,000 Crores INR excluding the incredible topsoil loss in thousands of hectors of fertile land in the state especially in Wayanad and Idukki districts.



Landslide zonation map of Kerala: In the landslide zonation map the portions marked red show the highly critical areas for landslides according to studies.



Landslides occurred in Kerala (2018)

District	Number of deaths
Tvpm	1
Kllm	0
Ptta	6
Allp	0
Idukki	47
Kttym	5
Erkm	0
Thrissur	27
Palakkd	13
Malappuram	28
Wayanad	5
Kozhikode	18
Kannur	5
Kasargode	0
TOTAL	**155**

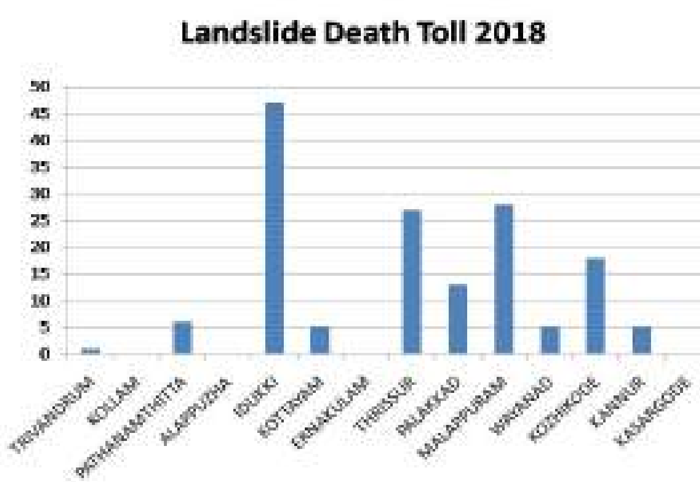


Fig.1: Death toll: district-wise, from 1/06/2018 to 31/08/2018 (source: KSDMA)

Types of landslides in Kerala

The movement of a mass of rock, earth or debris down a slope is scientifically called a mass wasting. Landslide is one of the types of mass wasting observed in nature. Debris flow, landslips, rock fall, slab slide, soil piping, land subsidence etc. are some other types that happened in the state. In Kerala, the most commonly observed types of mass wasting are debris flow (*Urul pottal*) and landslips (*Mannidichil*). We use the term landslide as a generic term hereafter. The various types of mass wasting that happened in Kerala in 2018 are shown in fig.2.

	NUMBER
DEBRIS FLOW	516
LANDSLIP	683
SHALLOW PLANAR FAILURE	22
ROCK CUM DEBRIS FLOW	15
DEBRIS FLOW INDUCED BY CUT SLOPE FAILURE	3
ROCK FALL	3
ROCK CUM DEBRIS	17
STREAM BANK EROSION	1
STREAM BANK FAILURE	6
SUBSIDENCE	20
DEBRIS SLUMP	1
EARTH SLIDE	10
DEBRIS SUBSIDENCE	22
SOIL SLIDE	62
DEBRIS CUM SOIL FLOW	1
ROCK CUM DEBRIS SLIDE	12
RIVER CUT OR BANK FAILURE	1
SOIL FLOW	1
ROCK SLIDE	1
EARTH FLOW	4
EARTH SUBSIDENCE	3
CHANNEL EROSION	1
EARTH CREEP	2
ROCK CUM DEBRIS TOPPLE	1
CRACKS	9
SOIL SUBSIDE	1
SOIL PIPING	1
DEBRIS FLOW(MULTIPLE)	2
SOIL SUBSIDENCE	6
BANK EROSION	1
SLUMP	1

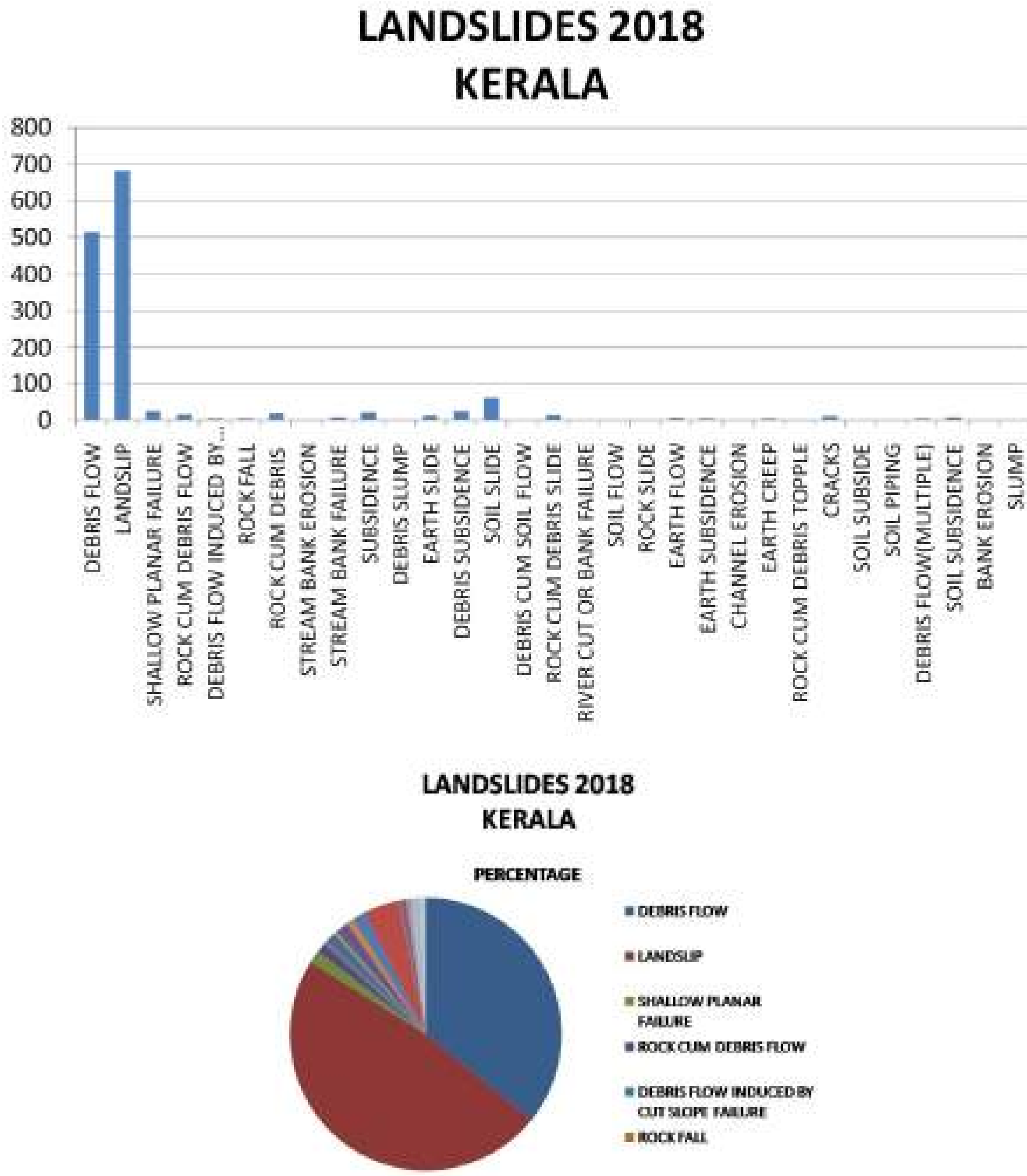


Fig.2. Types of mass wasting in Kerala 2018

The major types of slope failures in Kerala are the following:

Debris flow (*Urul pottal*) is the flow of rock, sand, silt and water down a hill under gravity.

Landslip (*Mannidichil)* is the downhill motion of a part of a hill.
Slab slide (*Bhumi pilaral*) is the formation of crack on the surface of the earth.
Landslide (*Sila thennimaral*) occurs when there is a displacement of rock sections.
Rock fall (*Sila pathanam*) is the fall of rock from a hilltop.
Ground subsidence (*Bhumi idinjuthazhal*) occurs when there is a depression of the ground.

Of the various forms of these natural destruction process the most widespread were landslip and debris flow. Debris flow is the geological phenomena in which water-laden masses of soil and fragmented rock rush down mountain slides. Landslip occurs when a part of hill itself moves down.

The phenomena of Soil Piping plays an important role in inducing landslides. The surface material seen in the hilly parts of Kerala are unconsolidated and unsorted. The underground flow removes the clay content and causes the formation of tunnels which gets interconnected in due course of time. These interconnected tunnels act as path for water discharge and soil erosion, called piping. Such pipe-like parts may lead to the occurrence of landslides. Hence the phenomenon of soil piping is an indicator of landslide risk (Fig.3). This scenario is existing in many places; for instance, in Ettamkallu of Thrissur District.

Fig.3. Soil piping in Muttil Mala, Wayanad

Fig.4. Slab slide occurred in Wayanad district (2018)

Fig.5. Landslide at Munnar Arts college in 2005 and 2018

Young landslides : Recently in many places a series of small step like subsidence (a vertical offset of say 15 cm) is found to appear in sloppy terrain during rain. Also many places witnessed the phenomenon of criss-cross cracking of the ground. They were 3 to 4 m deep cracks running for 30 to 40 m length with width less than 1 m. These cracks and offsets were found to appear in different parts of a big slope, and in later years the whole mass is washed out (Fig.6). This phenomenon observed in many places over the years was described as 'young landslides' by Dr. S. Chandrakaran.

Fig.6. Young landside (2018)

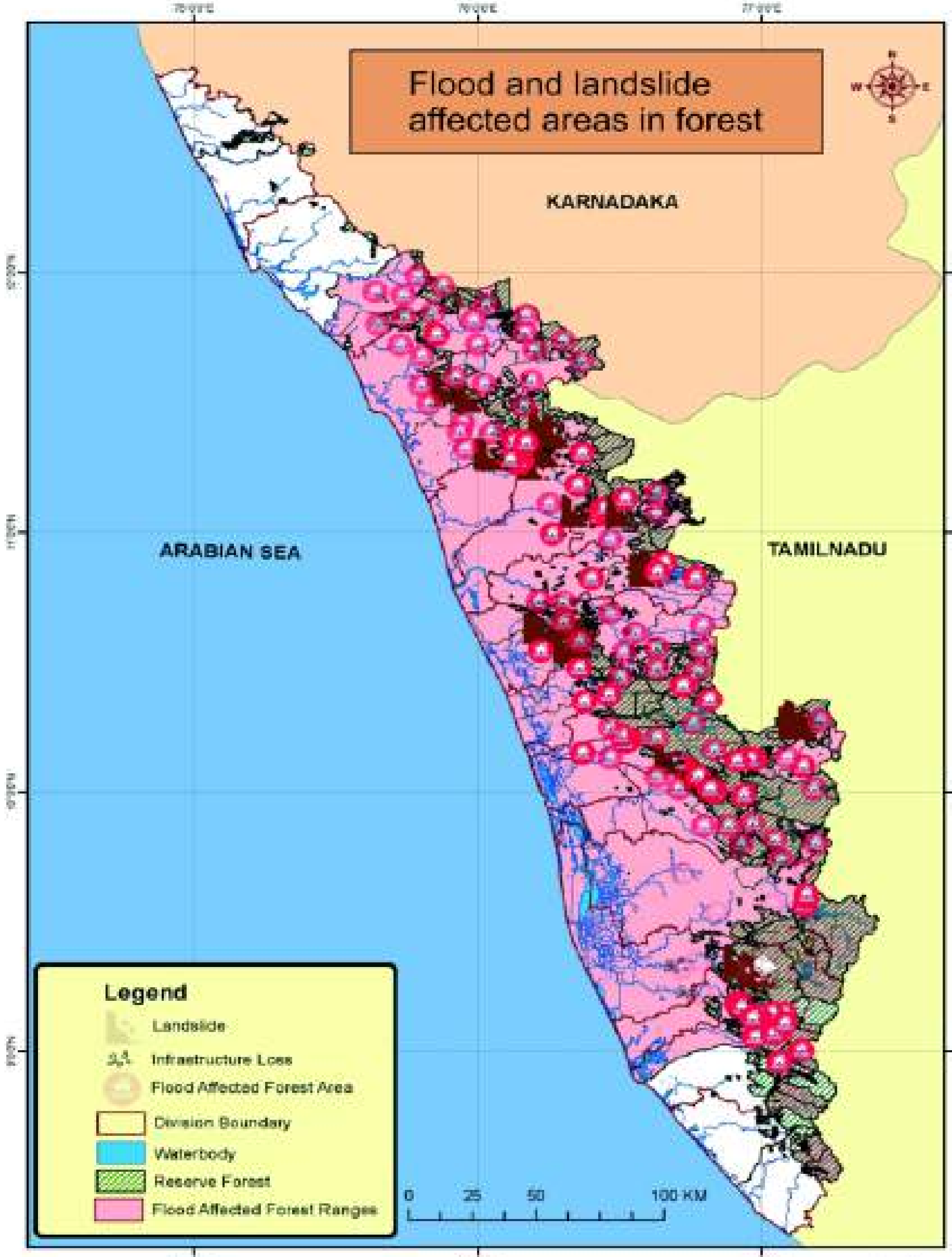
A landslide had occurred behind the Government College, Munnar on 25th July 2005. A portion of the college building was destroyed. Being a holiday, no casualties happened in the campus.

The college was restarted in the same premise after five years. However extensions for the college building were being built without considering geology or slope stability engineering. In February 2017 K.S. Sajinkumar and the team published a research work in the journal GEOLOGICAL SOCIETY OF INDIA. They predicted that in the event of high rainfall, the land could fail, as there was no toe support, and since the slope angle was greater than 40º. This area was adjacent to the college building and in the event of any further landslide, the consequences could be high. Slope stability analysis reveals that the entire area occupied by the college and the adjacent areas are unstable even in dry conditions. The prediction came true in 2018 landslides when Munnar got hit by the heavy rainfall.

Landslides in Forest Regions

Being part of Western Ghats about 296 forest places out of 119 ranges were affected by landslides and flood of 2018. It destroyed roads, bridges, office buildings, suspension bridges, protective walls, farms, Govt. vehicles, camera traps, solar fences, timber depot, teak plantations and caused the death of 8 elephants, 2 tigers and many other animals and reptiles.

Fig.7. Landslide in Kottiyoor forest area


Flood and landslide affected areas in forest
KARNADAKA
ARABIAN SEA
TAMILNADU
Legend
Landslide
Infrastructure Loss
Flood Affected Forest Area
Division Boundary
Waterbody
Reserve Forest
Flood Affected Forest Ranges
0 25 50 100 KM

Conclusion

Torrential rainfall triggered thousands of landslides in Kerala in 2018. However, landslide prone areas had been clearly identified using landslide Zonation map years ago. Also, almost all landslides did happen in the critical areas. Events reveal that quarries, vertically cut slopes, inappropriate building construction, destruction of natural streams and deforestation exacerbated the landslide disaster in Kerala in 2018.

What can be done to avoid the recurrence of this grave disaster?

- Stringent laws must be enacted for the construction of infrastructure in the high lands.
- Land use pattern in high lands must be closely monitored.
- Efficient early warning systems need to be built to mitigate disastrous landslide events.
- Best of all, environment-friendly human settlements with the least impact on pristine earth must be encouraged.
- Some control on human habitation in areas prone to landslides needs to be evolved so that loss of human life can be avoided.
- These call for a proper land use plan to be evolved and implemented with a fair degree of conviction.

The landslides and the flood of 2018 was an episode which urged the people and the Government of Kerala to rethink policies from an environmental perspective. It shows the need to preserve nature and protect the lives and livelihoods of the people of Kerala, in the lap of Western Ghats.

"Stop hiding behind the tide
When life sweeps like landslides"

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RAINFALL THRESHOLD ANALYSIS: A POSSIBLE WAY OF THWARTING LANDSLIDES

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The Southern State of Kerala in India experienced extreme rain in August from the 1st to the 20th, 2018. The state received a cumulative rainfall of 771 mm during that period, which is 140% more than the normal for that time period. The extreme rain event led to flooding and landslide hazards leading to 483 deaths and severe destruction of property (Vishnu et al., 2019). This exemplifies that rainfall-induced landslides are one of the most common types of hazards occurring in areas characterized by tropical climate (Sajinkumar and Oommen, 2019). Thus, an understanding of rainfall pattern will aid in providing a holistic knowledge of an imminent landslide and can device subsequent ways to thwart its effects. The likelihood of different trends of rainfall based on observation and subsequently developed models can shed light on forecasting rainfall and that leads us to approach the concept of Rainfall Threshold (RT). RT is defined as the minimum intensity or duration of rainfall required to trigger a landslide (Crozier, 1997). The concept of RT for landslide hazard was developed by Caine (1980) building on the work of Campbell (1975) and Starkel (1979). It can be obtained by studying rainfall conditions that have resulted in landslides in an area.

The number of antecedent days can vary from three for shallow landslides to 30 days for deep landslides (Aleotti, 2004; Zezere et al., 2005), which purely depends upon the geologic and geomorphic conditions of that particular area. The type of landslide which occurs in this tropical region like Kerala is shallow debris flow, which suggests only a few days antecedent rainfall required for developing the pore-water pressure regime. Thus this study showcase a few landslides occurred in Kerala and how RT comes handy in thwarting landslides.

Rainfall Threshold Analysis for Amboori and adjacent areas

Amboori (8°30′28.2″N; 77°11′20.4″E), a small hamlet at the foothills of the Western Ghats in Thiruvananthapuram district, Kerala state, India (Fig 1) is chosen for this study. Amboori presents a suitable test site to evaluate the applicability of rainfall-induced landslide threshold models in a tropical climate, considering it receives significant amounts of rainfall (~3000 mm per year) and its slopes are covered with a veneer of soil (2 to 3 m thick) (Shruti Naidu et al., 2017). Amboori has witnessed several landslides over the years, all to date have occurred during the monsoons and most of them belong to the debris flow category which are shallow in nature. The one which was particularly devastating occurred on November 9th, 2001 that had a death toll of 38 and remains a blot among the landslide events of Kerala.

The other important landslides occurred near Amboori are the landslide at Chellanthikuzhi, occurred on 8th June 1988 and the one at Nulliyode on 2nd October 2000. The landslides at both Chellanthikuzhi and Nulliyode occurred in the same fashion exhibiting all characteristics of a shallow slope failure induced by monsoons. These landslides also exhibit terrain and conditioning factors similar to Amboori.

Initially, 21-day rainfall data for each landslide event totaling 63 days is selected viz., ten days before the landslide, on the day of landslide, and ten days after the landslide. Additionally, 2, 3, and 5-day antecedent rainfall was obtained for all 63 days. The antecedent rainfall calculation was limited to a maximum of five days, based on

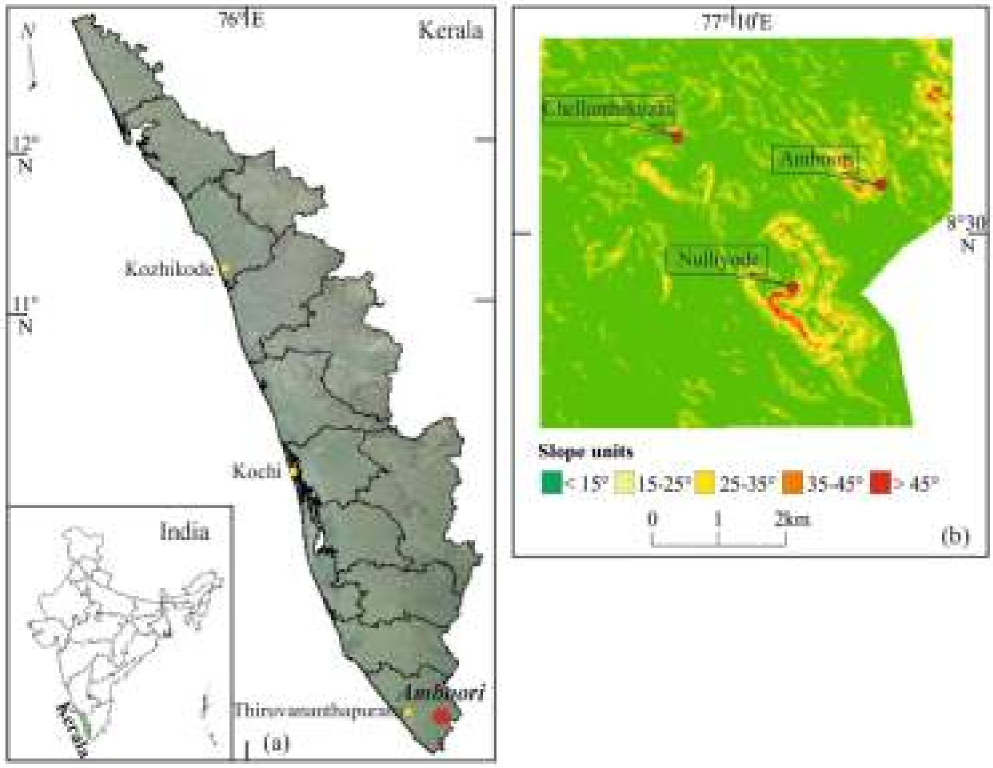

Figure 1 Location map of the study area (a) Arc Earth map of Kerala with India in inset (b) Slope map, derived from SRTM 30 m resolution DEM, of Amboori highlighting the three landslides

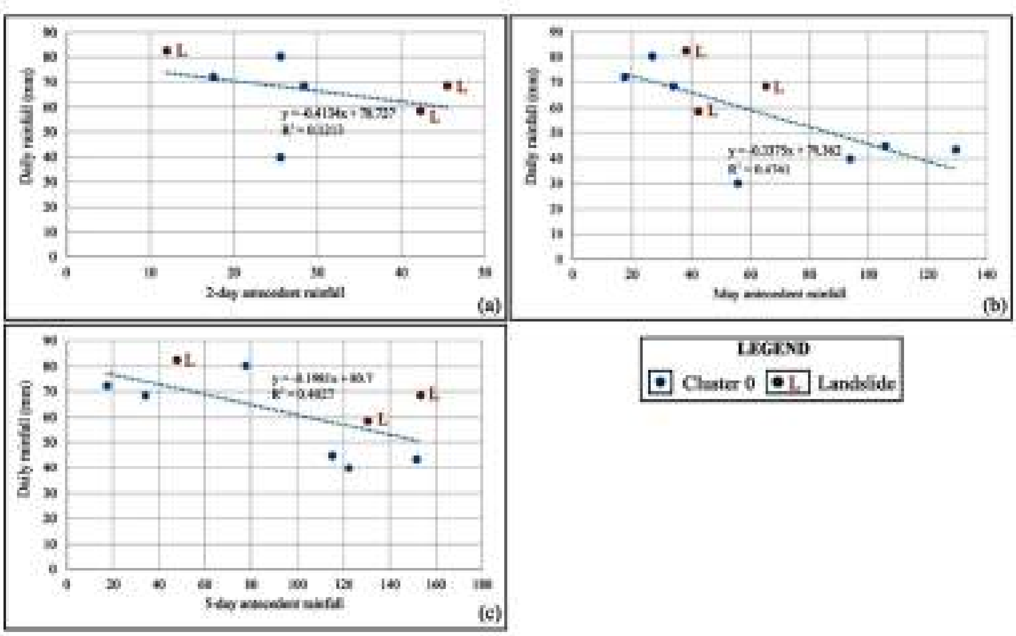

Figure 2 Linear trend line for landslide (a) 2-day antecedent vs. daily rainfall (b) 3-day antecedent vs. daily rainfall (c) 5-day antecedent vs. daily rainfall. 'L' indicates landslide incidence.

previous studies by Sajinkumar et al. (2014, 2015, 2017) and the authors' field experience on slopes with similar hydraulic conductivity and overburden of ~2 m that could saturated the overburden in a short period. Scatter plots were generated for 2, 3, and 5-day antecedent *vs.* daily rainfall. Figure 2 shows the scatter plot for all the three antecedent conditions with limited number of rainfall dates. Of the three different trend lines obtained, the 5-day antecedent vs. daily rainfall trend line is observed to have all three landslide events above the trend line. Hence this trend line is recommended as the rainfall threshold equation for the study area:

$$y = 80.7-0.1981x \qquad (1)$$

It is important to note that trend lines from 2, 3, and 5-day antecedent rainfall (Fig 2) all have intercept values in the range of 78.7 to 80.7 mm. This indicates that in the absence of antecedent rainfall, a daily rainfall event *i.e.* approximately ≥ 78 mm could trigger a landslide in the Amboori region. The negative coefficient of antecedent rainfall, in all three equations (Fig 2), indicates that an increase in cumulative antecedent rainfall results in a decrease in the amount of daily rainfall required to trigger landslide. The contribution of antecedent rainfall to rainfall threshold varies from approximately 40% for 2-day to 20% for 5-day. Thus the equation (1) can be used to predict landslides since, when the antecedent rainfall value is known, daily rainfall predicted based on the equation can be compared with the weather forecast. Considering rainfall intensity measurement is lacking for the Amboori region, it is important to have a conservative threshold equation as presented in equation (1).

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LANDSLIDE WARNING SYSTEM BASED ON ARDUINO

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Abstract—Landslides can occur mainly due to three factors. Earthquakes, heavy rainfall and manmade causes like mining or cutting. This work mainly focuses on using low cost soilmoisture sensors to give early warning of landslide occurrence due to rainfall. Recent calamities occurred in Kerala has prompted to demonstrate the use of this sensors and to advocate the use of this in future for early evacuation of residents in the landslide prone area. There are many landslide monitoring systems based on GIS, GPS, satellite imaging, inclinometer and strain gauges. In this paper a sufficient low cost warning system was developed using the soil-moisture sensors which works based on Arduino micro controllers.

Keywords—Landslides, Sensors, Arduino micro controller.

INTRODUCTION

Landslide is a major disaster in the recent history of Kerala. Mainly it is caused by heavy rainfall because Kerala is one of the states having more than 3000 mm of annual average rainfall. The destructive capacity of landslides are immense, the level of danger and property damage is high. According to the local news paper, in the recent calamity of Kerala, the state has witnessed 25 landslides in three days. More than 101 houses were completely destroyed. Landslide is the large movement of soil mass, which can be caused by the internal erosion of soil due to seepage of water. The internal erosion is the movement of soil or rock that takes place due to the force exerted by seeping water and this creates a shape of hollow cylindrical pipe inside the earth. This phenomenon is called soil piping[1]. In the recent events in Kerala, especially in the Puthussery area of Palakkad district [2], the affected area is located on the south facing slope of a hill ridge with a maximum elevation of 1110 m above MSL. Landslide was caused by soil internal erosion. Such landslides occur because, the portion of land gets isolated due to the soil pipes inside the ground. A sensor pillar embedded in to the soil will be a viable solution for detecting the problem. The sensors will be programmed such that, it will give the warning to the respective authority to stop and evacuate that area whenever a particular soil moisture level occurs and this level of critical moisture content depends on the slope stability of the area and type of soil, which has to be predetermined before installing the sensors in the ground.

To understand parameters affecting soil internal erosion, a modified hole erosion test setup was made. Partly cohesive soils like laterite have a higher probability of soil piping. But it also happens with clay as well[1].

The sensors are based on Arduino, which is an opensource electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects. It is also a low cost method for making electronic equipments that can be programmed to do a specific task. It is basically a micro controller with operating voltage 5V and 32 kB flash memory. The advantages of using this sensor pile method are the following.

- Low cost method.
- Very durable and can be used for a longer period.
- Maintenance is very easy.
- No problems of oxidation and weathering conditions.
- Can be used for any depth.
- Range of data transmission can be varied with respect to site conditions and antenna capacity.
- But the installation of such a pile in a pre-existing structure would be challenging.

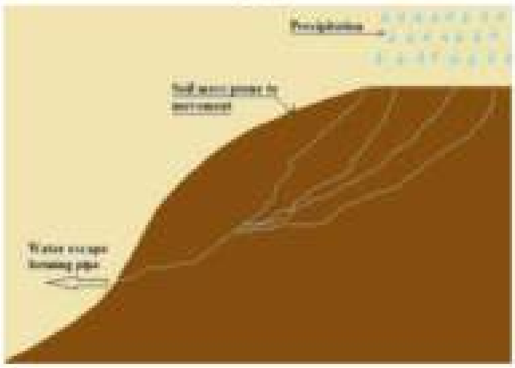

Fig. 1. General mechanism of landslide.

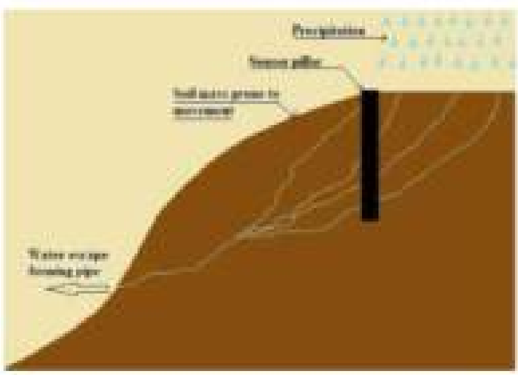

Fig. 2. Sensor pillar installed in ground.

DEVELOPMENT OF THE WARNING SYSTEM

There are already different methods existing for the continues monitoring of the Landslides like GPS, GIS, satellite imaging, strain guages and Inclinometers etc for continuous monitoring [3]. There are also landslide zonation maps available for identifying the landslide prone areas [4] where the sensor pillars can be installed effectively.

A. Introdution to Hole erosion test

A modified hole erosion test is carried out to find the coefficient of soil internal erosion (ker)[5]. It contains a sample tube of 30 cm overall length with two ball valves at the ends. The pressure gauges (100 psi range) are used to measure the head of water. Well compacted soil samples placed inside this tube and a guide hole is made with 8mm diameter steel rode. The test initiates as the pipe is connected with the water source. Initially the valves will be closed. Then the water pressure is measured and recorded. Then the inlet valve is opened. The water will pass through the sample and will reach the outlet side. The time is measured from opening the inlet valve and till the pressure gauge at the outlet shows the same value as the inlet pressure gauge. Then the outlet valve is opened and water is allowed to pass through. The time taken is used to find the ker value[5].

Fig. 3. Modified hole erosion test

From the test, it can be concluded that the internal seepage of soil can be occurred time depended. Lower pressure of water means higher time requirement for the complete percolation and vice-versa. The relationship between water pressure and time taken to completely percolate the given sample length seems to be almost linear

TABLE. 1: COEFFICIENT OF SOIL INTERNAL EROSION

Water pressure (Psi)	Time (sec)	Length of sample (m)	K_{er} = (Time / Length of sample) (Sec/m)
10	130	0.35	371.429
20	107	0.35	305.714
30	75	0.35	214.286
35	67	0.35	191.429

B. Requirements for the sensor

Arduino UNO R3 x 2

Circuit Breadboard & wires

RF transmitter x 1

RF receiver x 1

Moisture sensors (as per requirement)

Computing system

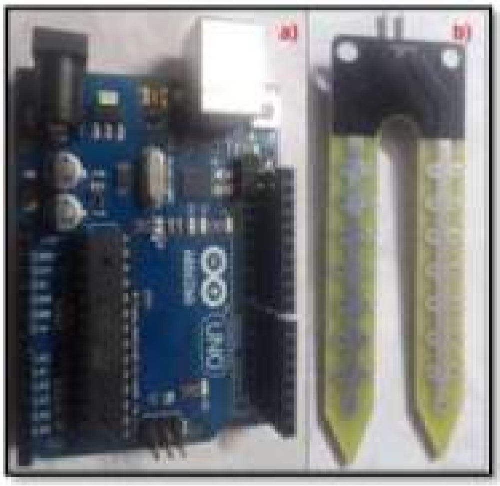

Fig. 4. a) Arduino UNO developer board. b) Soil moisture sensor.

The detection technique should be such that it should be continuous for a longer period of time. Hence sensors buried in soil are the best and economical option. As it is mentioned there is no soil piping without the presence of water, so soil moisture sensors are used for detecting underground seepage. These sensors are corrosion free and durable in underground. These are available in market for very low cost. The Arduino Uno board with soil moisture sensor is used and found out that further calibrations are required for a more precise prediction as the land parameters are different by each location. It can be used for a longer period and the value seems to be almost accurate. A liner pile like structure filled with sand should be perfect as the vessel for the sensor as the natural sand has a filter behaviour the seepage water tends to flow towards it and this could be helpful for the sensor inside to give some early detection of the seepage water through the embankment that may cause soil internal erosion. And these sensors should be provided at constant intervals to make it more precise.

Two Arduino development boards are programmed such that, one is programmed for taking the reading of all the sensors and only the sensor with maximum reading is taken as result. Also it is programmed to transmit this result to the next Arduino board using a RF transmitter. Transmitter module will be fixed on top of the sensor pillar as the sensors will be wired to it. Second board will be programmed to receive the data transmitted by the first board using a RF receiver. And it will show this value on the LCD screen or Arduino serial monitor in the computer. At this time, the second board will be programmed to give an alert signal to blink LEDs to give a warning at a particular moisture content of the underground seepage. This percentage of moisture content will be determined according to the slope stability, soil type and landslide probability of the selected location. The readings of the sensors can be transmitted up to a length of 10m radius. The range can be further extended according to the power of antenna installed. Also it is possible to send these values through internet and make a centralized data acquisition to make the agencies to do real time monitoring. Also it will be programmed to show the readings in a real time graph using MATLAB software. Research is initiated and continuing in School of Engineering CUSAT.

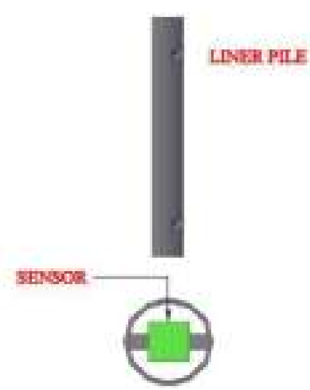

Fig. 5.Sensor pillar illustration.

SUMMARY & CONCLUSIONS

The Prototype is fabricated. Different software like Arduino IDE, MATLAB etc was studied and concluded that the sensors have a very great future in the field of civil engineering. This technique can be implemented as a warning system for landslides and other seepage failures. Also the sensors can be calibrated such that it can be used to identify the Index properties of soil. Further research includes the implementation of temperature sensors in the liner piles for more precise prediction techniques.

Fig. 6.Sensor pillar modal.

Also during the development stage of the wireless communication of sensor data, it was found that the transmitting of analogue voltage data from the sensors, takes different lag time for reaching the RF receivers. This can be attributed to the presence of different obstacles in between. Also it is seen that, with the presence of moisture, the time taken for data transmission increases. This can be utilised in a real-time study using MATLAB to identify the presence of moisture content inside soil. But the R&D requires more time than developing a simple Arduino system. The dependence on such electronic systems and software suggests considerable modifications for conventional methods of civil engineering and latest technologies should be adopted in the further studies for the betterment of the future of civil and geotechnical engineering.

ACKNOWLEDGMENT
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CASE STUDY ON KERALA FLOODS AND AN APPROACH TO CONSTRUCTION OF FLOOD RESILIENT BUILDINGS

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INTRODUCTION

Kerala, famed for its beauty and called as God's own country faced the wrath of gods during the 2018 floods. The Kerala floods in 2018 was a grave page in our history books. Major loss in lives and wealth were suffered by the people of the state. Over 483 people died, and 14 are missing. About a million people were evacuated, mainly from Chengannur, Pandanad, Edanad, Aranmula, Kozhencherry, Ayiroor, Ranni, Pandalam, Kuttanad, Malappuram, Aluva, Chalakudy, Thiruvalla, Eraviperoor, Vallamkulam, N Paravur, Vypsin Island and Palakkad. All 14 districts of the state were placed on red alert. The rescue missions to save Kerala was the top priority for the nation, with several indivuals stepping in the rescue and rehabilitation work. But none of this rehabilitation mattered to the people who had lost their lives in this, what can be only said as the biggest calamity in the nation's history, with numerous families losing their beloved ones, houses and livelihood.

CAUSE FOR FLOOD

Kerala received heavy monsoon rainfall, which was about 75% more than the usual rain fall in Kerala, on the mid-evening of August 8, resulting in dams filling to capacity; in the first 24 hours of rainfall the state received 310 mm (12 in) of rain. Almost all dams had been opened since the water level had risen close to overflow level due to heavy rainfall, flooding local low-lying areas. For the first time in the state's history, 35 of its 54 dams had been opened. The deluge has been considered an impact of the global warming.

IMPACT

A state official told AFP that 370 people have died, while The Economic Times has reported that 33,000 people were rescued. The Kerala State Disaster Management Authority had placed the state in a red alert as a result of the intense flooding. A number of water treatment plants were forced to cease pumping water, resulting in poor access to clean water, especially in northern districts of the state. Over 3,274 relief camps have been opened at various locations to accommodate the flood victims. It is estimated that 1,247,496 people have found shelter in such camps.

RESCUE

Being instructed by the Cabinet Secretary, senior officers of Defense Services, NDRF, NDMA and secretaries of Civilian Ministries conducted meetings with Kerala Chief Secretary. Following the decisions taken during these meetings, the Centre launched massive rescue and relief operations. In one of the largest rescue operations 40 helicopters, 31 aircraft, 182 teams for rescue, 18 medical teams of defense forces, 58 teams of NDRF and 7 companies of Central Armed Police Forces were pressed into service along with over 500 boats and necessary rescue equipment.

The fishermen from across Kerala were engaged in flood rescue missions. According to the government's estimate, a total of 4,537 from the fishermen community participated in the rescue operation with 669 fishing boats. They managed to rescue more than 65,000 people from various districts. Pinarayi Vijayan honoured the fishermen and the Fisheries Minister J. Mercykutty Amma said that the government will provide financial aid to repair the fishing boats which were partially damaged in the rescue operations while new ones will be provided for those boats which were completely destroyed. According to estimates, seven boats were completely destroyed, while 452 were partially destroyed.

ANIMAL RESCUES

Sally Varma of Humane Society International arranged for animals to be rescued and transported to special shelters that housed affected animals. Social media has been used to highlight the rescue of multiple animals - dogs, cats, goats, cows, cattle, ducks and snakes, with animal food and medicine transported to affected areas.

NEED OF THE HOUR

Could we have stopped this from happening had we foreseen this calamity? We couldn't the stopped the rain pouring from the skies but we could have had more than just roofs to cover us from the downpour of the skies. But it's never too late to change. With the current trend in climate change of the globe not in favour for us, we need to brace ourselves for another calamity, this time prepared to face it. And to achieve that, we need to ensure that we design and construct the future buildings smartly, keeping the thought in mind that the buildings must withstand such a calamity, if history repeats itself.

BASIC SAFETY PRECAUTIONS

The easiest step in this process is to build the buildings above the flood stage. Flood stage is the level at which a body of water's surface has risen to a sufficient level to cause sufficient inundation of areas that are not normally covered by water, causing an inconvenience or a threat to life and/or property-related. It is better to start the building above the flood stage as in this case, the water seepage inside the buildings can be prevented.

Flood Resistant Materials

Building materials are considered flood-resistant if they can withstand direct contact with floodwaters for at least 72 hours without being significantly damaged. "Significant damage" means any damage that requires more than low cost, cosmetic repair (such as painting). Flood-resistant materials should be used for walls, floors, and other parts of a building that are below the flood level.

Commonly available flood resistant materials

Flooring Materials

Concrete and concrete tile

Ceramic, clay, terrazzo, vinyl, and rubber tile

Pressure-treated (PT) and naturally decay-resistant lumber

Wall and Ceiling Materials

Brick, concrete, concrete block, glass block, stone, and ceramic and clay tile

Cement board

Polyester epoxy paint

PT and naturally decay-resistant lumber

PT and marine-grade plywood

Closed-cell and foam insulation

SELF-RAISING FLOOD WALL

Introduction:

This is a project about an underground barrier frame which rises due to the expansion of a closed cell polyurethane foam when brought in contact with water. We have proposed this project with a motive of preventing flooding in houses and the loss of lives and valuable

Working:

This is an underground system where an elevated spillway is present through which the water enters after a certain level of water has been reached. This level is determined the HFL (Highest flooding level) of a place. The water entering the spillway reacts with the water activated polyurethane present underground which expands and rises the barrier frame and thus preventing the water from flowing in.

Major Chemical Components:

HYPERSEAL®-25LM-S

HYPERSEAL®-25LM-S is a novel low modulus expansion joint sealant, especially formulated to contain both PU and silylated-PU technology, thus giving rise to a sealant which includes the best of both technologies. It has been modified in order to give enhanced thixotropic properties. It cures by reaction with atmospheric humidity to produce a joint sealant with a 50% joint movement accommodation factor and excellent adhesion on substrates traditionally problematic for PU sealants, e.g. glass, aluminium, steel, polycarbonate, etc. Additionally, the gunnable sealant has been modified in order to have extrusion profile identical to hybrid PU or MS technology. The extrusion rate and tooling of the sealant remain the same throughout a very wide range of temperature and humidity conditions.

WATERFOAMTM-1K-LV

WATERFOAMTM-1K-LV is a component of polyurethane, hydrophobic resin, which reacts with water to produce a grout suitable for water proofing and sealing cracks and joints of concrete surfaces, and for effectively stopping water leaks.

Benefits:

1.This system is completely mechanical and doesn't need electricity which makes it a perfect option for places with no reliable power source and for unmanned places.

2.The foam generated in this process can be recycled and used for mattresses, sofas and other stuff which can be used for the people in need during the floods.

3. This foam is highly buoyant which helps it lift heavy weights.

Scope:

This system has a huge scope in places with inadequate drainage facilities and with an estimated meagre cost of installation of Rs. 9000 per house, this project can save many lives and property worth millions.

Design:

Conclusion:

Nature has never ceased to surprise mankind, be with something as evolution or with something as destructive as floods or other common disasters. All that we can do is to anticipate what might be in store for us and learn from the past. While we can to nothing to bring back the brothers and sisters of our nation who we lost in the flood, it is our responsibility to work to our fullest potential that not another life is lost to a flood in future.

BHAUMIKA-
A LOW COST LIFE SAVING DEVICE

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Landslides cause enormous casualties and severe economic losses worldwide. The survival chances for persons caught in landslides are dependent on several factors. Studies show that 1 person per 10 million losing their lives in landslides every year. Survival chances after the landslide subsides depends on whether the victim is able to breath, and in case of a critical burial (head and the upper part of the body in the earth), how fast the victim is dug out. If the airway of the buried person is not clear and if there is no air pocket round the victim, after 35 minutes the chances of survival is negligible. However, with a clear air way and an air pocket, it is possible to survive longer. Survival of totally buried persons is also influenced by hypothermia and other unknown co-factors. Data show approximately 75% of landslide fatalities are due to asphyxia, *15 to 20%* due to deadly trauma and *5 to 10%* due to hypothermia and other factors. A high risk to life is in the first *18 to 35* minutes of burial [1]. This demands life-detecting systems to be available immediately on the spot after the disaster. Transporting the life detecting systems from far places cause adverse delay in rescue operations.

Chance of survival over time in a complete landslide burial is not linear. *See Figure 1*. In a complete burial situation, there are phases where the survival rate drops very rapidly - a high risk to die in the first *18 to 35* minutes of burial (asphyxia phase) - and phases with an almost stable survival rate – a greatly reduced risk to die between *35 and 90* minutes of burial (*the latency phase*)[1]

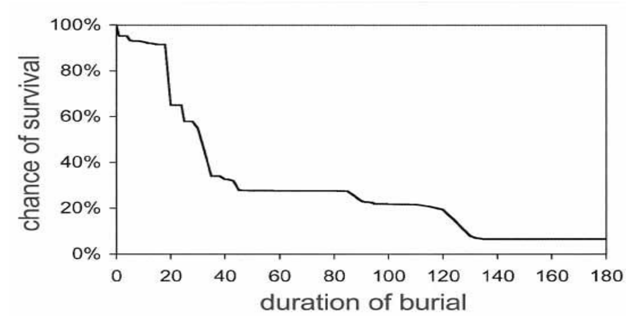

Fig 1. Survival chance of persons buried completed due to landslides [1]

In principle, by reducing the burial time, mortality can be reduced. The effectiveness of this strategy depends on which phase of the survival curve is affected. Safety equipment is especially effective when the steep parts of the survival curve are affected.

This shows the importance of availability of life-detecting systems immediately in the spot after the disaster. Transporting the life detecting systems from far places is not an effective solution. So a better solution is many units of these instrument distributed in the landslides prone area. In the case of developing countries the major limiting factor in procuring the high technology instrument like radars using ultra wideband (UWB) technology is the capital involved and the availability of trained technicians. This paper presents a low cost life saving device bhAUMika – based on Blind Source Separation (BSS) and Ground Borne Vibrations. The low cost , easy to operate and portable instrument; bhAUMika make multiple deployments easier.

The Principles of Operation

BSS techniques are based on statistical concepts and aim at revealing the independent components hidden within a set of measured signal mixtures. In BSS, a situation is considered where there are many number of signals emitted by some physical sources. These signal sources could be, e.g., different brain areas emitting electric signals or several people talking simultaneously in the same room. Furthermore, it is assumed that there are several sensors which are located at different positions. Therefore, each sensor acquires a slightly different mixture of the original source signals. Therefore, the problem of BSS refers to finding a demixing system whose outputs are statistically independent[2]. The prototype uses effective BSS algorithms developed for ground borne vibrations namely WASOBI-DECONV, SYMWHITE-DECONV or FASTICA-DECONV [3][4] based on signal types

The Prototype

The device prototype is developed based on the study of ground borne vibrations and BSS. This technology helps to trace lives buried in the cadaver following a landslide or an earthquake. The safety equipment reduces burial time by detecting the life buried and helps us to identify the required area to be dug. The basic idea behind this low cost disaster management instrument is recording or examining the ground borne vibration signals picked up from earth's surface or pits by high sensitive sensors[5]. The captured signals are conditioned and source separated. The visual and audio indications help to trace the lives buried.

Theoretically we can examine for motion as slight as shallow breathing, heartbeat[6], small voice made by the victim, sounds of the movements of limbs etc. we can detect through wood, brick, concrete; virtually any material. The captured signals can be cleaned and source separated to get rid of various noises including the noise created by humans and machinery during the rescue operations[7]. The output can be analyses to predict human lives buried in the affected area.

The basic block diagram of the system is shown in the figure 2

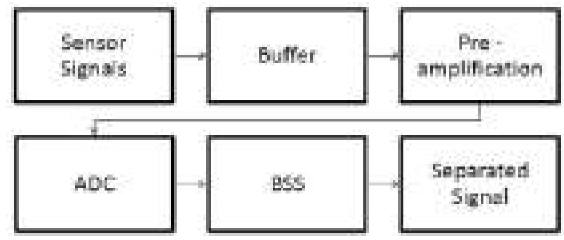

Figure 2. The basic block diagram

Various advantages of the prototype systems include; low cost, simple technology, detection of vibration caused by movement of limbs or shallow breathing, Detection through virtually any material, Ease of mobility over a site, Low-power requirements, little or no maintenance, Unaffected by odors or other bio-sensitivities that can affect detection, Ease of use and deployment, Maximum effectiveness in adverse physical conditions, Maximum effectiveness in minimal time, Intuitive operation requiring minimal training. The disadvantages include; efficiency decrease in noise environment and Short range of operation.

Conclusion

The basic idea behind this low cost instrument is recording or examining the ground borne vibration signals picked up from earth's surface or pits by very high sensitive sensors. The low cost device reduces the burial time and reduces the mortality. This safety equipment is effective when the device is put in operation during the first *18 to 35* minutes of burial (asphyxia phase). For making the instrument operational during the asphyxia phase, we have to ensure the local availability of the instrument. The low cost of this equipment help multiple deployments

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LANDSLIDE ZONATION MAPPING OF TEEKOY REGION IN WESTERN GHATS

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Keywords— Landslide, Landslide Susceptibility Index (LSI), , M5 Model Tree, Digital Elevation Model (DEM), Zonation

Abstract—Landslides are one of the many natural processes that induce the shaping of the surface of the Earth. It becomes a major geological hazard when it threatens mankind, causing loss of life and damages to manmade structures. It is a natural phenomenon causing vast devastation around the world, especially in the hilly areas in tropical countries during rainy season. Western Ghats in Indian subcontinent is one of the areas most vulnerable to landslides. A new hybrid Soft Computing modeling strategy in a Geographical Information Systems (GIS) platform is used in this study, to model the complex non-linear relationship between landslide and its causative factors. Geotechnical parameters (cohesion, angle of friction, bulk density, and permeability) and two geological parameters slope angle and soil thickness are considered as potential causative factors and the spatial distribution maps of these are prepared using the GIS. The spatial distribution of Landslide Susceptibility Index (LSI) for the study area is obtained by adding the reclassified maps of different parameters, prepared based on the weights calculated using the popular Statistical Index (SI) method, which is considered as predictant in this study. M5 Model Tree is used for prediction of shallow landslide susceptibility of Teekoy region in Western Ghats, Kerala, India. The results of the predicted LSI values helped to prepare the zonation map of the area. The overlay of landslide inventory map for the area indicated that the results are satisfactory.

I. INTRODUCTION

Landslides are one of the many natural processes that induce the shaping of the surface of the Earth. It is a natural phenomenon causing vast devastation around the world, especially in the hilly areas in tropical countries during rainy season. The study of landslides has drawn global attention mainly due to increasing awareness of its socio-economic impacts as well as increasing pressure of urbanization on mountain environment.

Based on the type of movement that displaces the earth and the type of material displaced, landslides may be classified into many types as given in Table 1 [1]. The schematic illustration of the different types of landslides is given in Fig 1.

Landslides during the heavy monsoon rains is a common phenomenon in the Western ghats of South India. In the devastating rainfalls that occurred in the state of Kerala during August 2018, hundreds of landslides occurred in different parts of the state. This work describes the process of landslide hazard mapping, and specifically applies it to the Teekoy region in Western Ghats, Kerala, India.

In Kerala, the most common mode of landslide is Debris Flow, whose schematic representation is shown in fig 2.

A debris flow is also known as mudflow, mudslide, or debris avalanche and is called as ‘Urul Pottal’ in Malayalam. It is a rapidly moving

TABLE II : IDENTIFICATION AND CLASSIFICATION OF CAUSATIVE FACTORS

SET 1(8 layers)	SET 2 (6 layers)	SET 3 (13 layers)	
Slope angle	Slope angle	Slope angle	Cohesion
Aspect	Cohesion	Aspect	Friction
Curvature	Friction	Curvature	Permeability
Slope length (m)		Slope length (m)	Density
Distance from drainage (m)	Permeability	Distance from drainage (m)	Soil thickness
Distance from lineament (m)		Distance from lineament (m)	
Land use	Density	Land use	
Geomorphology	Soil thickness	Geomorphology	

TABLE I : LANDSLIDE CLASSIFICATION SCHEME [1]

Type of movement		Type of material		
		Bedrock	Engineering soils	
			Predominantly coarse	Predominantly fine
	Falls	Rock fall	Debris fall	Earth fall
	Topples	Rock topple	Debris slide	Earth slide
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
	Lateral spreads	Rock spread	Debris spread	Earth spread
	Flows	Rock flow (deep creep)	Debris flow	Earth spread
	Complex	Combination of two or more principal types of movement		

slurry of water, mud, rock, vegetation and debris. This type of failure is described as the most dangerous and destructive of all types of slope failures [2].

It is usually seen that larger debris flows are capable of moving trees and large boulders on its way. This type of failure is especially dangerous as it moves at great speeds and strike with very little warning.

Fig 1. Schematic Illustration of the major types of Landslide Movements. [1]

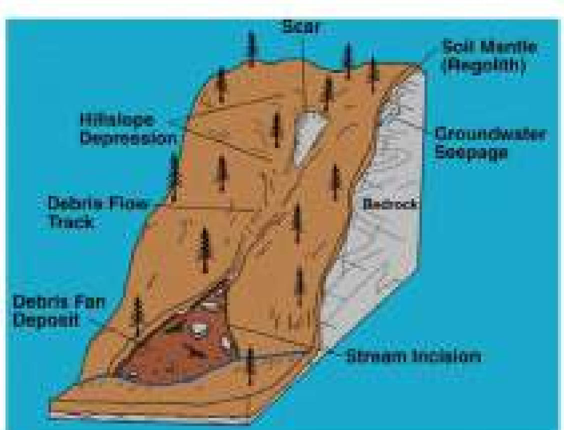


Fig 2. A typical example for Debris flow. [3]

As with soil slips, the development of debris flows is strongly tied to exceptionally lengthy storm periods of prolonged rainfall. Failure occurs during an intense rainfall event, following saturation of the soil by previous rains, as shown in Fig 3 [3].

Fig 3. Origin of Debris flow. [3]

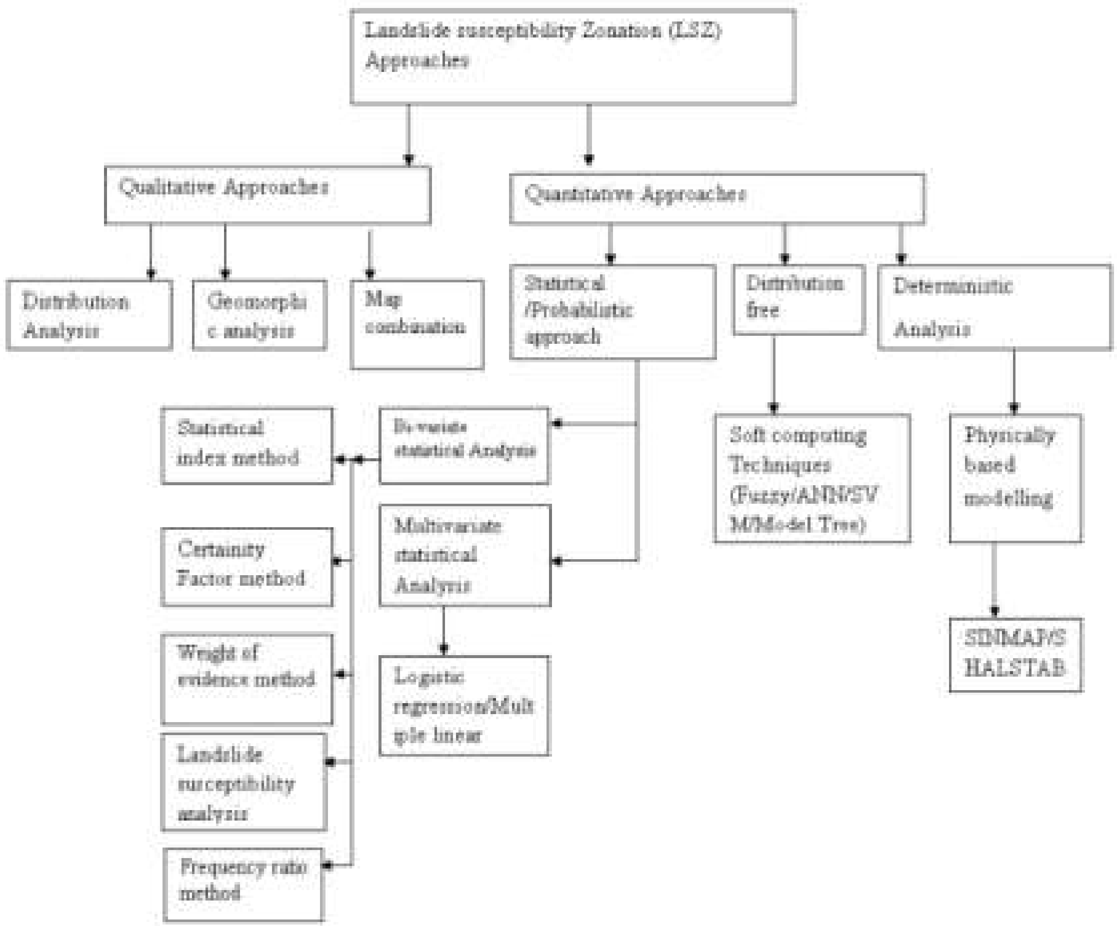
The peculiar characteristics of debris flows are long stretches of bare, generally unstable, stream channel banks that have been scoured and eroded by the extremely rapid movement of water-laden debris.

II. BACKGROUND

Both geological and geotechnical factors are important in the development of landslides. Hence, considering both factors are important in the study and prediction of landslides.

A. Landslide Susceptibility Zonation

Landslide Susceptibility Zonation (LSZ) is a geo-technical method that facilitates the identification of landslide-prone areas. This process is essential for safer strategic planning of future developmental activities. The term Landslide Hazard Susceptibility Zonation applies in a general sense to divide the land surface into discrete zones and rank them according to the degrees of actual or potential hazard from landslides or slope instability [4].



Landslide Zonation Mapping – Different Approaches

Landslide susceptibility is defined as a function of the degree of the inherent stability of the slope (as indicated by the factor-of-safety or excess strength) together with the presence and activity of causative factors capable of reducing the excess strength and ultimately triggering movement [5]. The relative ranking of slope stability of different portions of an area in categories that range from stable to unstable is shown in a landslide susceptibility map.

The past and present are keys to the future [4]. This implies that landslides in future are more likely to occur under similar geological, geomorphologic, hydro-geologic and climatic conditions, which were and are responsible for the occurrence of past and present landslides. This is why Landslide susceptibility maps are useful to make generalisations for any given area, as a few parameters can tell the risk of landslides associated with the area.

There are various approaches to Landslide Susceptibility Zonation (LSZ) mapping as shown in fig 4.

In order to reduce losses resulting from landslides, either the hazard event itself must be modified, or human vulnerability to it must be brought down. Both philosophies require the natural hazard to be zoned. Landslide Susceptibility Zonation (LSZ) facilitates the identification of landslide-prone areas and thus is essential for safer strategic planning of future developmental activities.

B. Estimation of Landslide Susceptibility Index Using Soft Computing Techniques

The major difficulty associated with the process of Landslide Zonation mapping is the tedious calculation and mapping process which makes it time consuming and difficult to be manually done. Meanwhile, a rigid algorithmic or mathematical method is not suitable for this, as hazard zonation of landslides involves a prediction modelling which requires approximations and probabilistic methods.

The difficulty of modelling can be overcome by adopting a soft approach, by tolerating the imprecision, uncertainty, approximation and partial truth, to arrive at a solution which may not be exact but reasonably acceptable. Computational methods adopting this approach are called soft computing.

"Soft computing is an emerging approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision". The fields such as neuro-computing, genetic computing, probabilistic computing, data mining techniques are examples of soft computing families.

To model the complex non-linear relationship between landslide and its causative factors, a new hybrid Soft Computing modelling strategy in a Geographical Information Systems (GIS) platform can be used. The shear parameters, bulk density, permeability (geotechnical parameters), slope angle and soil thickness (two geological parameters) are considered as potential causative factors and the spatial distribution maps of these are prepared using the GIS. The prepared maps are reclassified based on the weights calculated using the popular Statistical Index (SI) method.

The preparation of reclassified maps of the different parameters and their subsequent addition gives the spatial distribution of Landslide Susceptibility Index (LSI), which is considered as predictant denoting the vulnerability of the area towards landslides. The results of the predicted LSI values help to prepare the zonation map of the area and the overlay of landslide inventory maps for different cases indicates the superior performance of soft computing models.

C. M5 Model Trees

Model tree is an emerging machine learning technique used for solving regression problems through classification and decision making, and was originally proposed by Quinlan in 1992 [6]. Model Trees follows a modular approach so that the entire domain is divided into sub-domains and multi-linear regression models are developed for each sub domain. It therefore formulates many piecewise linear (and hence non-linear) models to approximate the non-linear relationship between the predictors and the predictant.

The first stage in Model Tree method, model preparation, involves in using a splitting criterion to create a decision tree. Depending upon the method of splitting of the domain, there are different learning algorithms for model trees. The one which uses standard deviation reduction (SDR) as the splitting criteria is called as M5 learning algorithm [7].

In this work, M5 Model Tree is being used for the prediction of shallow landslide susceptibility of Teekoy region in Western Ghats, Kerala, India. M5 Model Tree is also capable to perform the predictions without demanding fixation of algorithm specific control parameters and is capable of giving the predictor-predictant relationship as a set of explicit expressions. The use of M5 model tree does not require setting of any user-defined parameters [8]. The other major advantage of M5 model tree is that it combines several simple linear relations and hence more transparent and acceptable by decision makers. It is very fast in training and always converges [9].

In this method the standard deviation of the class values that reach a node is treated as a measure of the error at that node and the expected reduction in this error as a result of testing each attribute at that node is calculated.

III. DATA AND METHODS

The study area chosen for this work is Teekoy region in Western Ghats, Kerala. Teekoy is a southern Indian village which has a mixture of features of both midland countryside and the hill area, enveloped in greenery with a clean and unpolluted atmosphere. Teekoy as a village is medium- sized but as a panchayat is quite long. It covers many areas such as Aniyilappu, Mavadi, Vellikulam, Thalanad and Adukkom, stretching about 20 kilometers and reaching up to Vagamon town, at about three thousand feet above sea level. The place is known for its agriculture and landscape. It is full of hills and valleys in the middle of which flows the Meenachil river.

A. Preparation of landslide zonation map in the study Area

1) Preparation of Digital Elevation Model of the Study Area

The Digital Elevation Model of the study area which shows the variation in elevation levels is modelled using GIS technology (Fig 5).

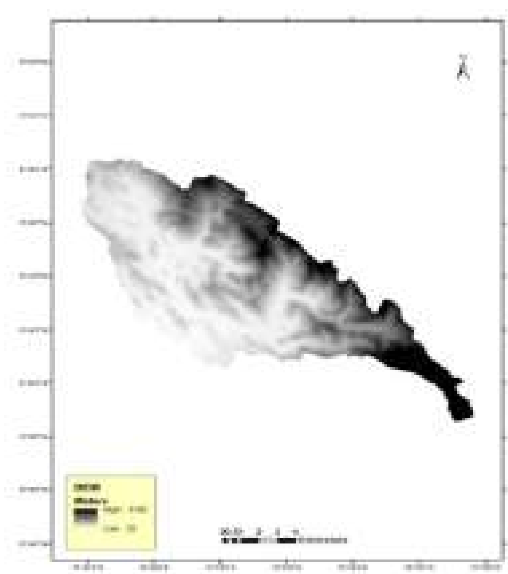


Fig.5. Digital Elevation model of study area

2) Preparation of Landslide Inventory Map

In order to establish the statistical relation between the distribution of existing landslide points with the causative factors, it is essential to prepare the landslide inventory map of the study area. The landslide initiation points were located in the field by systematic field investigations using the Global Positioning System (GPS). A total of seventy landslides were identified from the study area and the Map showing the distribution of landslides over DEM is shown in Fig 6.

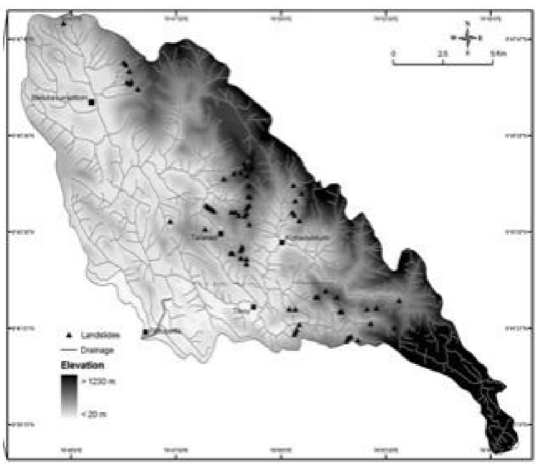


Fig.6. Study Area Location Map and Landslide Locations with Digital Elevation Model

3) Identification and Classification of Causative Factors

13 parameters were identified and divided into three sets as given in Table 2. Parameter maps are prepared for the study area in order to know the spatial distribution of the parameter. Weights are assigned for each parameter.

4) Maps are reclassified

In order to list the most influential parameter, a comparison is done by studying the effect of different parameter combinations. The angle of internal friction map reclassified using the process explained below.

1. The landslide occurrence map for the study area is prepared from aerial photographs and field visits.
2. The weight value for each class of each parameter is calculated by statistical index method.
3. Reclassified maps of each parameter are prepared by assigning the weight values to each class in each parameter map.
4. The integration of reclassified maps is done to get the spatial distribution of Landslide Susceptibility Index (LSI). After conducting three trial combinations of map integration, the potential parameters are identified as slope angle, permeability, density, soil thickness, cohesion and angle of internal friction.
5. The required properties (input) are generated from the thematic layers from distributed latitude and longitude. The Output parameter i.e., LSI value or $\sum$ WIJ is obtained from the LSI map for the same locations.
6. After identifying the potential causative factors, the data required for Model Tree analysis are extracted from the final LSI map and the original thematic layer maps before reclassification

B. Soft Computing Techniquesand M5 model tree

The essential requirement of soft computing based regression models is a reliable predictor-predictant dataset. The geotechnical properties and slope angle are identified as the potential predictors.

M5 Model Tree also is implemented in a similar manner by utilizing the data set used in SVM. Initially, the standard deviation reduction (SDR) is used as splitting criterion to create a decision tree. The splitting continued till the class values of all the instances that reach a node varies negligibly or only a few instances remain. Here a pruned and 'smoothed' version of model tree is invoked in the WEKA software platform, as it was reported that these operations smoothing increases accuracy of prediction. The use of M5 model tree does not require setting of any user-defined parameters.

C. Landslide zonation map

The class boundary is fixed by considering the mean (m) and standard deviation(s) as given in Table 3.

TABLE III: CRITERIA OF ZONATION

Sl no.	Class range	Class value	Zone (susceptibility)
1	s to (m+s)	5.85 to 2.95	Very high
2	(m+s) to (m+0.5s)	2.95 to 0.028	High
3	(m+0.5s) to m	0.028 to 2.89	Moderate
4	<m	<2.89	Low

IV. RESULTS

The reclassified internal friction map is shown in figures 7 and 8.

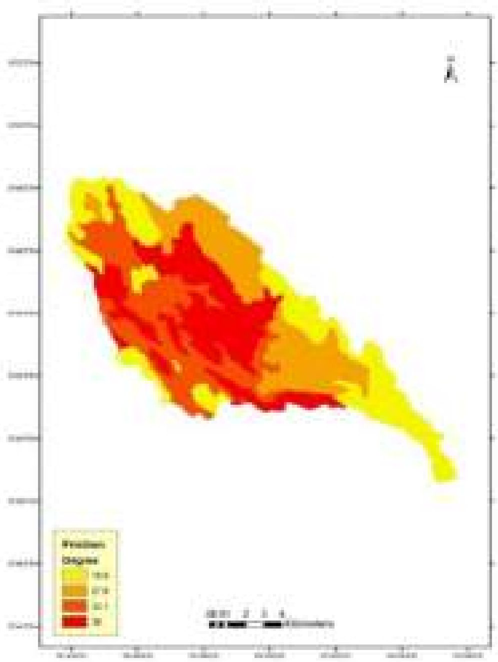


Fig.7. Angle of Internal Friction map

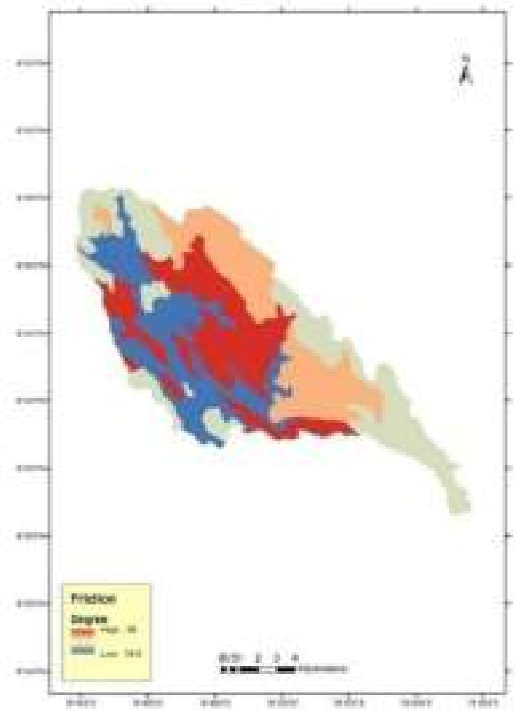


Fig.8. Angle of internal friction map reclassified

Figure 9 shows the LSI map modelled using the M5 model. The final Landslide zonation map for the Teekoy region is shown in figure 10.

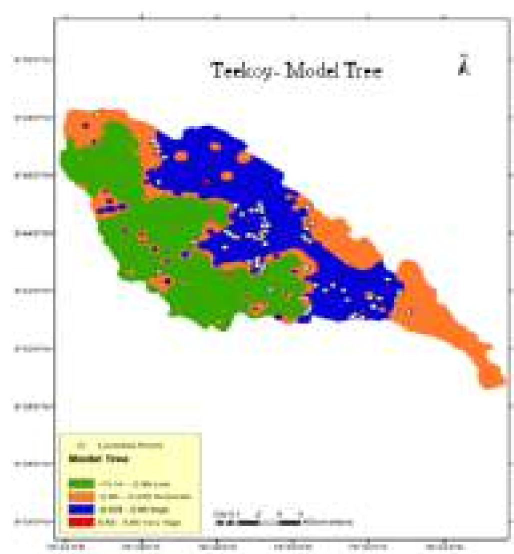


Fig.8 LSI Map MTree

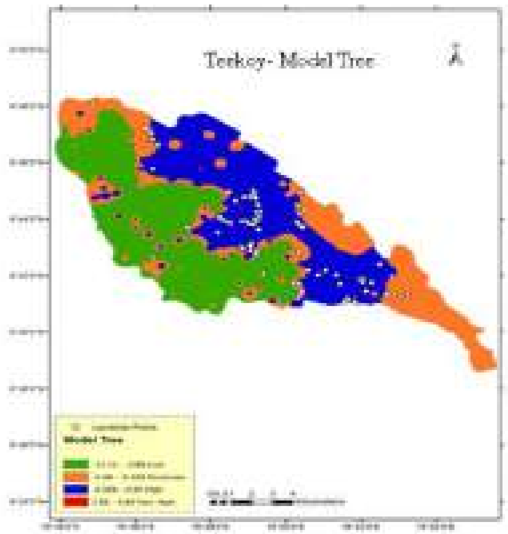


Fig.9 landslide zonation map-Teekoy

V. DISCUSSION

The overlay of Landslide inventory map and the map of predicted LSI show excellent performance with 92% successful prediction in the Poonjar area, where the location is geographically similar to that of Teekoy, the study area. The predictions are fairly successful (82% and 77%) in Kozhikode and Wayanad districts. Based on the applications of M5 Model Tree based model for different regions it can be concluded that the overall capability for prediction of the developed model is excellent for geographically similar regions, and is reasonably good performance for other regions.

VI. CONCLUSION

The developed methodology is capable to estimate the shallow landside susceptibility reasonably well with popular geo-spatial database and easily measurable geotechnical parameters alone. Apart from the traditional hybrid soft computing based modelling strategies, the major difference in the proposed approach is that, in this method the spatial distribution of LSI is considered rather than the consideration of the LSI values at inventory locations alone. The encouraging results by the proposed methodology infer that the same methodology can be adopted to develop region specific models at other areas of interest of study in Western Ghats or elsewhere.

VII. ACKNOWLEDGMENT

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A CASE STUDY ON LANDSLIDES OF THRISSUR DISTRICT

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Abstract: Landslides are now a common phenomenon during monsoon on the slopes of Western Ghats. This monsoon Kerala witnessed a huge number of landslides except in its low lying coastal district of Alappuzha. In Thrissur District also many landslides happened in its various forms. Four Panchayats were selected for the study namely Pananchery, puthoor, Madakkathara, Nadathara. Twelve undisturbed soil samples were collected altogether. Soil samples from failed slopes tested in the laboratory for Identification and Strength tests. Direct shear test was conducted to dout the shear parameters Cohesion (C) and Angle of Internal Friction (φ). Factors contributing for the initiation of the landslides were also critically analysed in this paper. It included natural processes like weathering, soil piping, liquefaction together with manmade events like terracing of the slope, vertical cutting of the slopes, quarrying, closing natural drains like 1st order farming, clearing the natural vegetation of the slopes etc. Keywords: Landslide, Factors affecting landslide, Slope stability analysis, Shear strength Parameters

1. Introduction

In India two sensitive zones of landslides are Himalayan Region and Western Ghats. Slopes of Western Ghats have been witnessing the landslide series in various places. Abundant rainfall sometimes incessant rainfall, Thinner overburden thickness, Steepness, Clayey and silty soil nature are some of the important natural reasons that promote landslides. Landslides have been a process of natural evolution. But unscientific and ruthless anthropogenic interventions in the slopes has made this as a natural hazard with increased risk and increased frequency of occurrences. For developing settlements, building infrastructure and transportation facilities and even for agriculture site preparation was accomplished by disturbing and sometimes clearing the slopes themselves. In this way natural slope and natural drainages were hampered in the name of the development. Natural drainages were in the slopes to discharge the excess rainfall water through it. One major problem of these was that they are perennial and will soon dry out after rain cesses. So these streams were conveniently closed or blocked. In this course building or something will be constructed. This led to the prevention of the water to escape from soil slopes during heavy rains. Water finds its way in to the soil itself. This socked the soil underneath. Entering of excess water in the soil led to the loss of soil grain to grain contact. Geotechnical properties of the soil including strength properties were changed significantly. Loss of strength was in terms of reduction of Cohesion and Angle of friction.

Western Ghats last monsoon our Kerala witnessed a series of landslides. In Thrissur district also many landslides have taken place. Some of the aspects of those landslides are discussed in this paper.

1. Study Area Thrissur taluk of Thrissur district is the study area. Slides happened in panchayats of Puthoor, Madakkathara, Pananchery and Nadathara were studied. Study is conducted in association with NCESS.

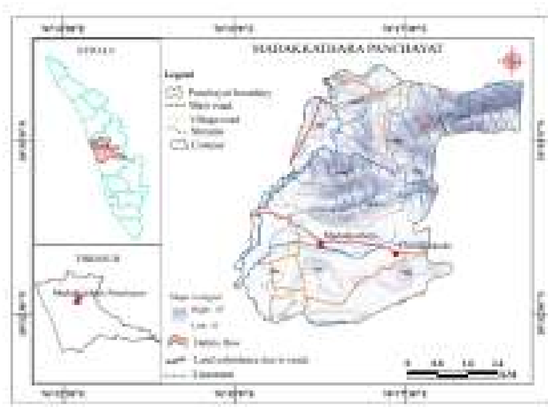

Fig.1 Location map of the landslide and land subsidences occurrences in Puthur Panchayat

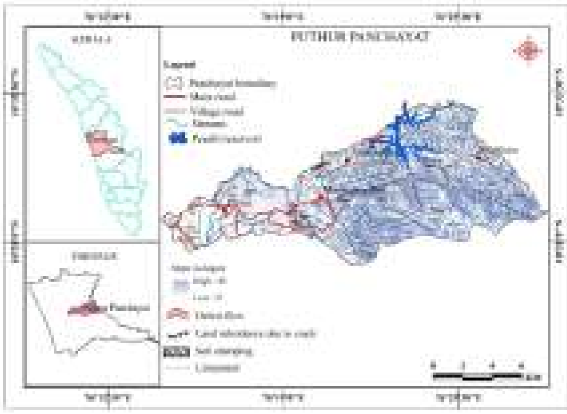

Fig.2 Location map of the landslide and land subsidences occurrences in Madakkathara Panchayat

Fig 3. Location map of the landslide and land subsidences occurrences in PanancherryPanchayat

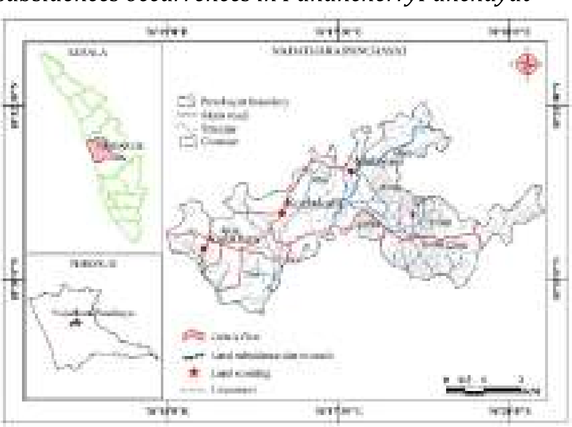

Fig 4. Location map of the landslide and land subsidences occurrences in Nadathara Panchayat

2. Methodology

Soil tests were performed on the samples on the sample. Soil properties were estimated. Tests performed are Atterberg limits estimation, particle size distribution test and Shear strength(Direct Shear test) test are performed. GEOSTUDIO 2019 is used to model the slopes and to find out the factor of safety. Results of the laboratory experiments and slope stability analysis are also included in the paper.

Fig.5 Undisturbed Sample Extracted from core cutter

4. Results and Discussion

Table 1. Location details of collected Samples

PIT NO.	LOCATION	LATITUDE	LONGITUDE
1	Puthenkadu	N10029'15.5"	E76019'20.6"
2	Kokkathukunnu Colany	N10036'1.6"	E76017'10.8"
3	Kollamkundu	N10030'43.7"	E 76°20'3.8"
4	Ayodu	N10°33'48.7''	E 76°26'35.9''
5	Poovanchira	N10°34'18.9''	E 76°20'16.4''
6	Vattappara	N10°31'5.7''	E 76°18'40.0''
7	Vattappara	N10°31'5.7''	E 76°18'40.0''
8	Anand Nagar	N10°34'15.7''	E 76°16'17.5''
9	Vattappara	N10°30'58.0''	E 76°18'36.3''
10	Payyanam	N10°30'12. 6''	E 76°20'10.7''
11	Pattlankuzhi	N10°34'49.1''	E 76°21'15.5''
12	Kannara	N10°31'17.1''	E 76°20'15.2''

Table 2. Density and moisture content

Pit No.	Location	Bulk Density in kN/m^3	Moisture Content in %	Dry Density in kN/m^3
1	Puthenkadu	18.0	13.63	15.8
2	Kokkathukunnu	15.0	10.46	13.6
3	Kollamkundu	15.0	21.50	12.3
4	Ayodu	15.6	15.34	13.5
5	Poovanchira	14.1	28.23	10.9
6	Vattappara	19.0	17.36	16.2
7	Vattappara	15.0	25.36	11.9
8	Anand Nagar	13.4	12.71	11.9
9	Vattappara	15.0	8.22	13.9
10	Payyanam	15.0	16.65	12.9
11	Pattilankuzhi	12.0	13.63	10.6
12	Kannara	15.5	18.72	13.1

Table 3. Atterberg's Limit

LOCATION	LIQUID LIMIT	PLASTIC LIMIT	I_p
Puthenkadu	41.8	23.97	17.83
Kokkathukunnu	40.3	23.89	16.41
Kollamkundu	NA	NA	0
Ayodu	47.6	31.03	16.57
Poovanchira	60.7	38.27	22.43
Vattappara	46	29.09	16.91
Vattappara	64	40.06	23.94
Anand Nagar	42	23.81	18.19
Vattappara	28.7	17.92	10.78
Payyanam	46.13	25.57	20.56
Pattilankuzhi	42.71	23.97	18.74
Kannara	NA	NA	0

Table 4. Details for slope stability analysis

Sl. no	Location	Angle of friction °	Cohesion in kPa	Dry density kN/m³	Slope °	Height of the slope m	Factor of safety
1	Puthenkadu	48.74	10	15.8	28	51	0.882
2	Kokkathukunnu	23.3	30	13.6	21	75	0.742
3	Kollamkandu	26.56	40	12.3	20	34	1.366
4	Ayodu	29.68	40	13.5	23	160	0.692
5	Poovanchira	26.56	40	10.9	22	56	0.941
6	Vattappara	30.96	20	16.2	21	38	1.816
7	Vattappara	27.69	70	11.9	NA	31	NA
8	Anand Nagar	30.75	40	11.9	26	78	0.676
9	Vattappara	35.75	30	13.9	17	26	1.818
10	Payyanam	25.4	40	12.9	18	95	0.894
11	Pattilankuzhi	13.49	10	10.6	18	68	0.265
12	Kannara	26.1	50	13.1	17	49	1.425

NA – Not Applicable

With increase in water content during incessant rain will considerably reduce the cohesion and the angle of internal friction. This is also a reason to cause the landslide due to the reduced resisting force. Important observations made from laboratory results

1. Densities of the soil samples are having lower value as 10.6 kN/m3 .Maximum value is 16.2 kN/m3. Very loose sample likely like as found in Poovanchira has highest % of clay+ silt, Liquid limit and lower value of strength parameters (c = 40 kPa, φ = 26.560) 2. Pretty high are the clay + silt contents of each sample (i.e, more 48% in all samples and upto 74%). It favours the sliding.

3. Cohesion value and Angle of friction is found to be of average strength. But as a result of incessant rain on saturating condition there is a reduction of the values. When it happens sliding happens at point when driving force overcomes this reduced force. Cohesion values are in the range 10 kPa to 70 kPa. This proves the soil to be of silty nature.

So sample sites are having soil with more of silty and clayey nature. Finer soils with higher liquid limit, lower strength parameters and comparatively lower densities are making slopes made of such kind soils prone to failure on the continuous saturation. Factor of Safety of all slopes analysed were found to be less than 2, with maximum and minimum value as 1.818 and 0.265 respectively. All values are in agreement with the failure of the slope..

3. Factors causing Landslides

5.1 Weathering

Weathering is a natural process. Exposed parts of rocks and soil will continue to weather. Weathered products migrate downward to settle above the bedrock. So the boundary between bedrock and overburden soil is always with clay content. During rains if the water infiltrates and socks the overburden soil, that delicate layer of clay is prone to be washed out. If it happens that zone will acts as a sliding surface and the overburden soil will slide.

5.2 Liquefaction

Soil liquefaction occurs when a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress such as shaking during an earthquake or other sudden change in stress condition, in which material that is ordinarily a solid behaves like a liquid.

Test results show cohesion and Angle of friction is not too low. Still the slopes failed because of the sudden change in the stress condition in terms of pore water pressure.

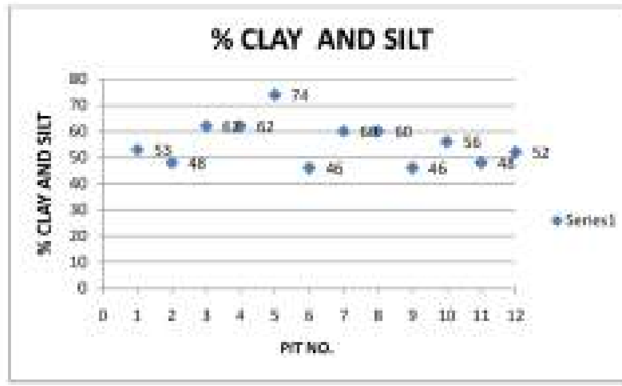

Fig 6. % clay + Silt for each sites

Test data proves the fine nature of the soil with a maximum of even 74% of silt + clay. So there is every chance of occurrence of Liquefaction also to cause Landslide.

5.3 Terracing and Cultivation

Another factor is the clearing of the slope for cultivation of cash crops like rubber. This large scale cutting itself instabilises the slope. Roots of later grown trees are not as deep as naturally growing trees of the slope many times. Many short rooted plants grown are leading to the socking of the upper layer of soil since water will find its way through the vicinity of the roots. Another aspect is the terracing of the land. It hampered the smooth flow of drains, which is way to discharge rainwater and thus preventing stagnation and infiltration. These lead to soaking of the soil and make soil slope saturated and pore pressure built up.

Fig.7 Rubber plantation of Vattapara

5.4 Channels and rainpits

Unlined canal and small furrows made for irrigation makes the slopes unstable. Rainpits are also a way of weakening the slope by making water to stand and infitration to soil.

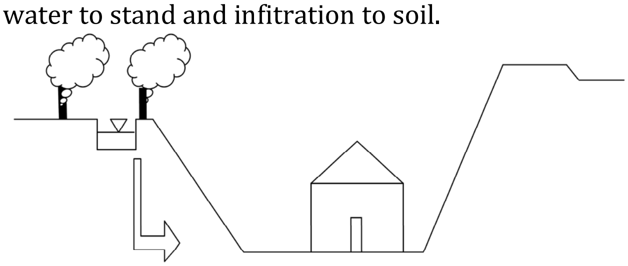

Fig.8 Similar to Site at Vattapara

5.6 Soil piping

Subsurface flow through soil pipes can also instabilize a slope. It leads to the continuous internal erosion. Finer soil like clay and silt are prone to erosion and it is left unnoticed from the surface. Electrical resistivy methods are used to study on the presence, length and distribution of this conduits. They are one of the major reasons of the slope failures.

Fig.9 Piping formed at Puthenkadu

4. Conclusion

Soil samples from twelve sites of four Panchayats of Thrissur were collected and tested for strength parameters. All factors that contributed to the landslides were studied. Geometry is expressed in terms of Slope and the height of the slope. Strength parameters estimated from tests done on Geotechnical engineering laboratory from NIT Calicut.

Most of the suspicious reasons for initiating a landslide are evident in selected slopes. Landslide is the result of the interplay between all forces like Porewater pressure, Gravity etc. Landslides are predictable if we monitor and critically analyse susceptible locations that are indicated by one or more factors discussed in this paper. Factor of Safety of all slopes analysed were found to be less than 2, with maximum and minimum value as 1.818 and 0.265 respectively.

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Symposium on landslides in Kerala 2018 held at Munnar Engineering college on 23 Feb 2019.

The Symposium was inaugurated by The member secretary Dr. Shekar Lukose Kuriakose, Kerala State Disaster Management Authority. The overview of the program was presented by Dr.B.Premlet, the organising secretary and Chair, Educational Activities, Kerala Section.The presidential address was delivered by Prof.V.K. Damodharan, Life senior member, IEEE(NY).

Inaugural session and panel discussion

A panel discussion was conducted. Scientists, Engineers and Politicians were took active part in the topic of discussion:"Precaution Measures against Landslide disaster”.


LANDSLIDES
IN KERALA 2018