



Government of Karnataka

Landslides in Western Ghats and Coastal Karnataka:

Prevention and Mitigation Strategies



FINAL STUDY REPORT

Landslide Study Committee

**Department of Forest, Environment & Ecology
Govt. of Karnataka**

March 2021

Forward



The ecological and economical significance of Western Ghats is very well understood today. The mosaics of various types of precious ecosystems and rich biodiversity make it an ecologically significant habitat for the entire south India. The water and livelihood security of the peninsula in general and Karnataka in particular depend on these mountain ranges, as many perennial rivers take birth here. Highly productive agriculture, horticulture, fishery etc. ensure the livelihood of millions who live here, but also contribute to the state economy. Hence, protection of ecologically fragile Western Ghats assumes paramount significance, considering its ecological and economical importance.

But, a lot of challenge is being faced by this sensitive landscape in recent decades. Frequent landslides that are happening from last decade also major ones among them. Starting from Kadwada village landslide that took place in Karwar taluk of Uttara Kannada district in 2009, series of landslides are happening in one or the other river valley in *Malanad* and coastal belt. Its frequency and magnitude increased further since 2018 monsoon. It is unfortunate that it has become a regular phenomenon now during every rainy season, causing huge damage to life and property of people in western part of Karnataka.

Recognising these emerging threats, many experts as well as public had been appealing the govt to bring in a holistic landslide prevention policy in the state. Taking cognizance of this need, Karnataka Biodiversity Board had also appealed Hon. Chief Minister of Karnataka Sri B.S. Yeddyurappa to look into this matter on priority in December 2019. Hon. Chief Minister found merit in this appeal and formed a high level committee under my chairmanship in April 2020. The committee had official members from different govt. departments like Dept of Forest, Environment & Ecology, Mines & Geology, and Revenue etc. It had non-official expert members of different expertise domains, representing premier institutions like ISRO, Geological Survey of Indian, India Institute of Science, Karnataka Natural Disaster Monitoring Centre (KSNDMC) and others. The committee identified its objectives and framed its mode of functions by series of consultations. It has now completed its task accordingly. As part of this exercise, the committee had series of internal meetings, consultation with experts and representatives from different govt agencies, review meetings at district levels in the presence of Deputy Commissioners, visits to landslide affected areas, interaction with various stakeholders in the field including the affected families and individuals and so on. Based on all those insights and inputs, this final report is prepared now even though delayed a bit due to Covid challenges. The same is being submitted now to the Karnataka State Government.

The committee has tried understanding three basic questions. First one is about the extent and magnitude of the landslides in recent years, especially since 2018. The second question is about what are those reasons behind disaster. The third one is on what should be the overall preventive and mitigation methods to be adopted in coming days. The findings of the committee on all these vital questions are given in this final report.

Being the Chairman of this committee, I appeal the Govt to accept the recommendations of this report, which are arrived at after wide consultations and deep scientific understanding of the issue. As we understand from the assessment by Karnataka State Natural Disaster Monitoring Centre (KSNDMC), more than 13% of the land area of Karnataka is facing this grave problem, which is not negligible. These vulnerable zones are spread over in *Kodagu, Uttara Kannada, Dakshina Kannada, Chikkamagaluru, Udupi, Shimoga, (Dakshina Kannada) and Hassana* districts. The ecological, social, economical costs of these landslides are really high. Hence, the recommendations made here have both short term and long term strategies. It calls for strengthening institutional mechanisms, integrating contemporary technical know-how in disaster forecast system, designing ecologically sensible development models which could prevent landslide possibilities, right mitigation measures etc. It has also recommended the need of streamlining and rationalizing compensation packages, so that all affected individuals, families, settlements and communities get adequate compensation and rehabilitation support wherever necessary. I wish the insights of this useful exercise get reflected in the state policies and programmes in coming days.

I take this opportunity to express my sincere gratitude towards Dr. B. S. Yeddyurappa for having constituted this committee on such a vital topic and given all necessary guidance and support throughout. I also thank the Chief Secretary of the Govt., Additional Chief Secretary of Dept of Forest, Environment & Ecology, Principal Chief Conservator of Forest (PCCF) & HoFF, all senior officers of Dept of Forest and other Govt Departments for their support given at various points of time. I am also grateful to all the official and non-official expert members, from whose contributions alone this report has come out. My special thanks to the non-official expert members, namely, Dr. G. S. Shrinivasa Reddy, Dr. Maruthi, Dr. C. V. Raman, Dr. T.V. Ramachandra and Dr. Keshava H. Korse for having written exclusive scientific write-ups for the purpose of this report. I sincerely acknowledge the contributions of Sri Brijesh Kumar, IFS, APCCF, Principal Secretary, Dept of Environment & Ecology (GoK) and the Member Secretary of this committee, for having steered its functions successfully. I express my sincere gratitude towards Member Secretary, members of governing body & staff members of KBB, for their active co-operation throughout. I thank all those who have contributed to this highly meaningful team effort.

I only wish the findings of this report may help in realizing the welfare of the people in the state, which could be achieved by adopting sustainable development modes emphasised here.

Bengaluru
14 January 2021

Sri Anant Hegde Ashisar
Chairman
Karnataka Biodiversity Board and
Chairman, High Power Committee on Studying Landslides in Karnataka

Introduction



Western Ghats and coastal regions of Karnataka have been witnessing frequent landslides in recent years, which are a matter of great concern. Recognising the magnitude of this issue, the Govt of Karnataka had constituted a high level committee to make comprehensive and pragmatic recommendations on preventing and mitigating these disasters in future (Govt. Order No: A.Pa.Ji.47.EPC2020, dated 17/04/2020). The committee was constituted under chairmanship of Sri Anant Hegde Ashisar, Hon. Chairman of Karnataka Biodiversity Board. It has both official and non-official expert members, representing various govt departments, research institutions, and expert domains. The committee has now completed its given task and the final report is being submitted.

The primary objectives of the committee have been comprehending the spatial and temporal patterns of the landslides that have occurred so far, the causes behind them and possible prevention & mitigations measures that can be taken up. All these questions were persuaded by the committee systematically by adopting a sound methodology. It conducted series of consultation meetings both in the Aranya Bhavana and the landslide affected districts. Several field visits were made, in almost all landslides affected districts. Wide consultations were held with all possible stakeholders including people's representatives, farmers, landless labours, tribals and victims. Several review meetings were held with govt. officials (both at higher policy level and local executive level). Information was gathered by interacting with various experts. Research papers, technical and media reports were referred. The non-official experts contributed exclusive technical reports based on their observations and assessments, focussing on their expertise domains. Thus, based on all these information gathered and insights generated, the committee deliberated in-depth on the recommendations to be made. This final report is the result of all these efforts.

Being the Member Secretary of this committee, I am privileged to work with all those who contributed to this cause. I express my sincere gratitude towards the Govt, ACS, Dept of Forest, Environment & Ecology, PCCF & HoFF, KFD and all senior officers for their constant support and guidance. And, I extend my heartily thanks to the Hon. Chairman and all members of this committee, both official land non-official experts, whose efforts are behind this highly relevant and important work. I am particularly thankful to expert members Dr. G. S. Shrinivasa Reddy, Dr. Maruthi, Dr. C. V. Raman, Dr. T.V. Ramachandra and Dr. Keshava H. Korse, as they have contributed exclusive technical reports for the purpose of this report. I acknowledge the service of Dr. Keshava H. Korse, an expert member of the committee and my office staff, which really helped me at great length in drafting this final report.

I wish the findings of this report help the cause of framing the policies and programmes aiming at prevention and mitigation of landslides in the state in future.

Bengaluru

14 January 2021

Sri Brijesh Kumar, IFS, APCCF
Principal Secretary to the Government of Karnataka
(Environment & Ecology) and
Member Secretary, High Power Committee on Studying Landslides in Karnataka

1. Executive Summary

This report comprises the following Key points.

- 1. Scope of the committee and its report:** It has a brief description about the significance of *Sahyadri* (Western Ghats) and Coastal regions of Karnataka. An account is also given on how the landslides are causing damage to the life, livelihood, ecology and economy of *Sahyadri* and Coastal region of Karnataka.
This chapter tells why this committee was constituted and what framework was adopted for the mode of functioning. The outcome of the works of this committee is presented in the form of final report.
- 2. The key objectives of the committee:** This short term high level committee has made an effort to find answers for the following key questions. Which are the highly landslide vulnerable regions in the state? What are the reasons for landslides? What could be the prevention & mitigation measures to be adopted?
- 3. Committee Structure:**
- 4. Final Recommendations:** The recommendations deal with the following aspects.
 - A.** Streamlining and strengthening ground level institutional framework
 - B.** Overview of technological models available
 - C.** Mode of integrating technology and information systems for developing a ‘Comprehensive Landslide Prevention & Mitigation Plan (CLPMP).
 - D.** Preventive measures to be taken up: It deals with the following components.
 - Protecting natural forest cover
 - Enhancing green cover
 - Keeping natural streams and rainwater channels intact
 - Drainage Management
 - Regulation of indiscriminate use of land digging and electric tree cutting machines (Power chain Saw) in landslide vulnerable zones
 - E.** Land Use Plan: It has the following components.
 - Land Use Planning and Mapping
 - Slope stability
 - Regulations of mining/ quarry
 - Establishment and maintenance of Linear Projects
 - Standard Operation Procedure (SOP) for terrain altering activities
 - Prevention of illegal roadside encroachment for commercial purpose
 - Restricting monoculture plantations
 - F.** Mitigation Measures
 - G.** Restoration of damaged landscape
 - Cost effective biological methods suggested for slope stabilization
 - Mechanical methods for top soil management
 - H.** Disaster management during the landslide calamities
 - I.** Need of a ‘Comprehensive Compensation Mechanisms’ (CCM)
 - J.** Suggestions for Policy Initiatives: It deals with following key aspects.
 - Recognizing landslide as a natural disaster
 - Extending ‘LANDSLIP’ project of GSI to Karnataka
 - Need of bringing amendments to certain Acts/ rules
 - Need of special financial packages
 - Practicing Sustainable Development Goals (SDGs)



2. Scope of the committee and its report.

2.1. Significance of *Sahyadri* (Western Ghats) and Coastal regions of Karnataka:

'*Sahyadri*', is a mountain range that covers an area of 160,000 square kilometres in a stretch of 1,600 kilometres parallel to the western coast of the Indian peninsula, traversing the states of Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat. It is commonly called **Western Ghats** or Great Escarpment of India. It is considered as a vital landscape ecologically as it supports wide diversity of flora and fauna, many of which are endemic. Therefore, it is recognised as one of the eight hot-spots of biological diversity in the world. The UNESCO has recognised this region as a World Heritage Site too. They influence Indian monsoon weather patterns by intercepting the rain-laden monsoon winds that sweep in from the south-west during late summer. The range runs north to south along the western edge of the Deccan Plateau, and separates the plateau from a narrow coastal plain, called Konkan, along the Arabian Sea.

Geologically the Western Ghats are older than the Himalayas. These are the mountainous faulted and eroded edge of the Deccan Plateau. Geologic evidence indicates that they were formed during the break-up of the supercontinent of *Gondwana* some 150 million years ago. Geophysical evidence indicates that the west coast of India came into being somewhere around 100 to 80 million years ago after it broke away from Madagascar. After the break-up, the western coast of India would have appeared as an abrupt cliff some 1,000 m in elevation. Basalt is the predominant rock found in the hills reaching a thickness of 3 km. Residual laterite and bauxite ores are also found in the southern hills. The northern portion of the narrow coastal plain between the Western Ghats and the Arabian Sea is known as the *Konkan*, the central portion is called Kanara and the southern portion is called *Malabar*. In Karnataka, the Western Ghats region is popularly called *Malenadu* and the coastal region *Karavali*. Coastal Karnataka constitutes an area of about 10,000 square kilometres and stretches from north to south for about 225 kilometres, with maximum width of about 64 kilometres in the south.

The districts in the western part of the state, namely, Chamarajanagara, Mysore, Kodagu, Hassan, Chikkamagalur, Shimoga, Uttara Kannada, Belagaum, Uttara Kannada, Udupi and Dakshina Kannada districts fall in these region either totally or partially. Millions of people live here and their livelihoods mainly come from the agriculture, horticulture, fishery and forest based enterprises. These sectors are found to be highly productive and making significant contributions to the state economy. That means ecology, economy, and people's livelihood security point of view; the region is highly significant landscape of the state.

2.2. The Landslides in *Sahyadri* and Coastal region of Karnataka:

Landslide is nothing but the movement of a mass of rock, debris, or earth down a slope. They are down-slope movement of soil and rock under the direct influence of gravity. It is a physical phenomenon when a part of rock, and/or debris/ soil fall due to the action of gravity. It may be caused by a set of terrain-specific geo-factors like slope, lithology, rock structure, land use patterns, land cover, geomorphology etc.

Usually slope movement is classified into Falls, Topples, Slides, Spreads, and Flows. These may be further subdivided based on the type of geologic material (bedrock, debris, or earth). Almost every landslide has multiple causes. Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength. Landslides can be initiated in slopes already on the verge of movement by the forces like rainfall, changes in water level, stream erosion, changes in ground water, disturbance by human activities, or any combination of these factors.

Numerous landslides are happening in the Western Ghats and coastal region of Karnataka during monsoon in recent years. Its frequency has increased in alarming rate since 2018. These landslides are causing huge loss to the life of people, death of livestock, widespread damage to public & private properties and natural ecosystems. They are making huge negative impacts on the livelihood of people, those who depend on agriculture. They have adversely affected almost all types land resources. Various govt agencies have been trying to prepare inventories of all these landslides and their impacts, by using both ground level information and remote sensing data.

Debris flows (also called ‘mudflows’ or ‘mudslides’) and rock falls are common types of landslides that have occurred in the state so far. For instance, the report of National Remote Sensing Centre (NRSC) of ISRO, GoI, made an in-depth study on the series of landslides that occurred in 2018 in the Western Ghats and coastal region of Karnataka. It made that analysis based on multi temporal high-resolution remote sensing images acquired before and after the rainfall event from Resourcesat-2, WorldView-2, GF-2, SPOT-6 and 7, Pleiades-1, Kompsat-3 and Sentinel-2 Earth observation satellites. It assessed total of 6970 landslides with a cumulative area of 22.6sq. km. As per this study more than 993 landslides events occurred in Karnataka during the monsoon period in 2018. They were mostly debris slide and debris flow type with entrainment along the channels. NRSC study indicates that most of the landslides (83.2%) are triggered by very high rainfall.

2.3. Mode of functioning:

This was the high level expert committee assigned with the task of understanding the reasons behind landslides taking place in Western Ghats and coastal region of the state in recent years and to recommend comprehensive prevention and mitigation methods. The committee having both official and non-official expert members unanimously adopted the following methodology for achieving the objectives. It functioned accordingly and the final report is being submitted now. The methodology adopted is briefly summarized below:

1. Conducted consultation meetings of the full committee periodically in Bengaluru. Some of the key meetings were one held at Aranya Bhavana (15 May 2020), Chikkamagalur (6 June 2020) and Aranya Bhavana (18 Sept 2020).
2. Reviewed all available literature/ data (published research papers, research reports, project reports, committee reports, internal administrative reports etc).
3. Field visit were made by the Committee along with district units of line departments, in the major landslide hit areas of Kodagu, Hassana, Chikkamagalur, Dakshina Kannada, Udupi, and Uttara Kannada districts. Either the Chairman or the full committee visited the following places as part of field investigation efforts. The full committee paid exclusive visits to Chikmagalur (6&7 June 2020), Kodagu (19 & 20 June 2020) and Sagara-Kargal area (17 & 18 August 2020). A detailed account on the places visited are given below.
 - Many villages in Somavarapete, Madikeri and Virajpete Taluks of Kodagu district.
 - Many villages like Charamady, Didupe, Malavantige and other villages in Belthangady taluk of Dakshina Kannada district.
 - Many villages in Kottigehara-Kalasa region of Mudigere Taluk of Chikkamagalur district.
 - Araligae, Nandodi, Arodi, Aralagodu villages in Aralagodu Grama Panchayat and Varadalli in Sagara Taluk of Shimoga district.
 - Male-Malleshwara Hill landslide in Keegadi and Hegalatti villages in Singnabidre Grama Panchayat of Theeetrhahlli Taluk of Shimoga district
 - Jajigudde and Tallageira villages in Vanalli Grama Panchayat in Sirsitaluk on Uttara Kannada district.
 - Talakebail, Dabguli, Vajralli, Ramanaguli, Konala, Heggara, Sunkanala, in Bedti River valley in Ankola-Yellapura Zone in Uttara Kannada district.
 - Divagi Tandrakuli near Mirjan in Kumata taluk in Uttara Kannada district.
 - Tarehalli in Kansuru Grama Panchayata in Siddapura taluk in Uttara Kannada district.
4. Review meetings at the district level in the presence of Deputy Commissioner and interaction with all district, Taluk & Grama Panchayat level officers & staff of various concerned govt departments to get their feedback.
5. Consultation with people’s representatives, farmers, villagers, tribal, labours, landslide affected families/ villagers, local experts, field staff and general public to get their feedback. It included People’s representatives (Ministers, MLA/MLCs., ZP, TP & Grama Panchayat Members), general public like farmers, landless labours, tribal and victims, Govt. Officials, experts & journalists.
6. Expert members were requested to come up with special articles based on their insights, expertise and experience after the field visits and consultations. Accordingly, five expert members gave their exclusive articles. They are given as separate chapters further in this report. Their insights and recommendations are incorporated in the ‘Final Recommendation’ section given further.

7. Final consultation meetings were organised in order to derive conclusions based on the all documents, insights and experience obtained through the modes mentioned above. Final recommendations were made unanimously, and the same are included in final report.

2.4. Outcome of the report: This short term high level committee has come out with following findings.

What are the reasons for landslides?

According to various evidences available in the form of scientific reports, *Western Ghats* is considered as one of the highly landslide prone regions in India. Landslides that occur here may include wide range of ground movements like rock falls, deep failure of slopes, shallow debris flows, etc. These ground movements are caused when the stability of a slope changes from a stable to an unstable condition. Such changes in the stability of a slope may be caused by different factors acting together. Those reasons could be the unstable or loose nature of soil structure, absence of vegetation cover, drastic changes in land use like slope cutting and so on. The vegetation loss that is happening in recent decades is almost anthropogenic, that is manmade. Landslides may be caused due to slope modification, natural drainage blockage and/or diversion, roadside cutting, seepage along weaker zone, mining, loading on slopes, deforestation, rapid drawdown (of floods), low permeability of the slope material, high slope gradient, erosion at the base of a slope by streams/waves, forest land conversion and increase in pore pressure due to rain. Most of the landslides that have occurred in the state are due to combinations of these potential triggers, which are of natural and/or man made.

After considering the all available scientific literature, outcome of the consultations with experts & all stakeholders and field visit investigations, the committee has come to conclusion that ‘Debris Flows’ (Mud flows or Mud slides) and ‘Rock Falls’ are the main types of landslides that are taking place here. Ultimately two main reasons are responsible for this vast devastation in *Western Ghats* and its foothill regions in the western districts of the state. They are, the slope modification by human interference and the increase in number of intense rain events (heavy rainfall in span of 2-4 days) since 2018. They are acting as final triggers for ultimate landslide events.

Which are the landslide vulnerable regions in the state?

The detailed scientific studies of NRSC of ISRO and Geological Survey of India (GoI) have identified certain regions in the state as landslide vulnerable zones. They fall in the Kodagu, Hasana, Chikkamagaluru, Shivmoga, Uttara Kannada, Belgaum, Udupi and Dakshina Kannada districts. It is based both on the detailed inventory of all landslide events took place over the years and simulation models developed based on various parameters. Based on these, Karnataka State Natural Disaster Monitoring Centre (KSNDMC) has further identified 23 Taluks in these districts as highly vulnerable zones. They are:

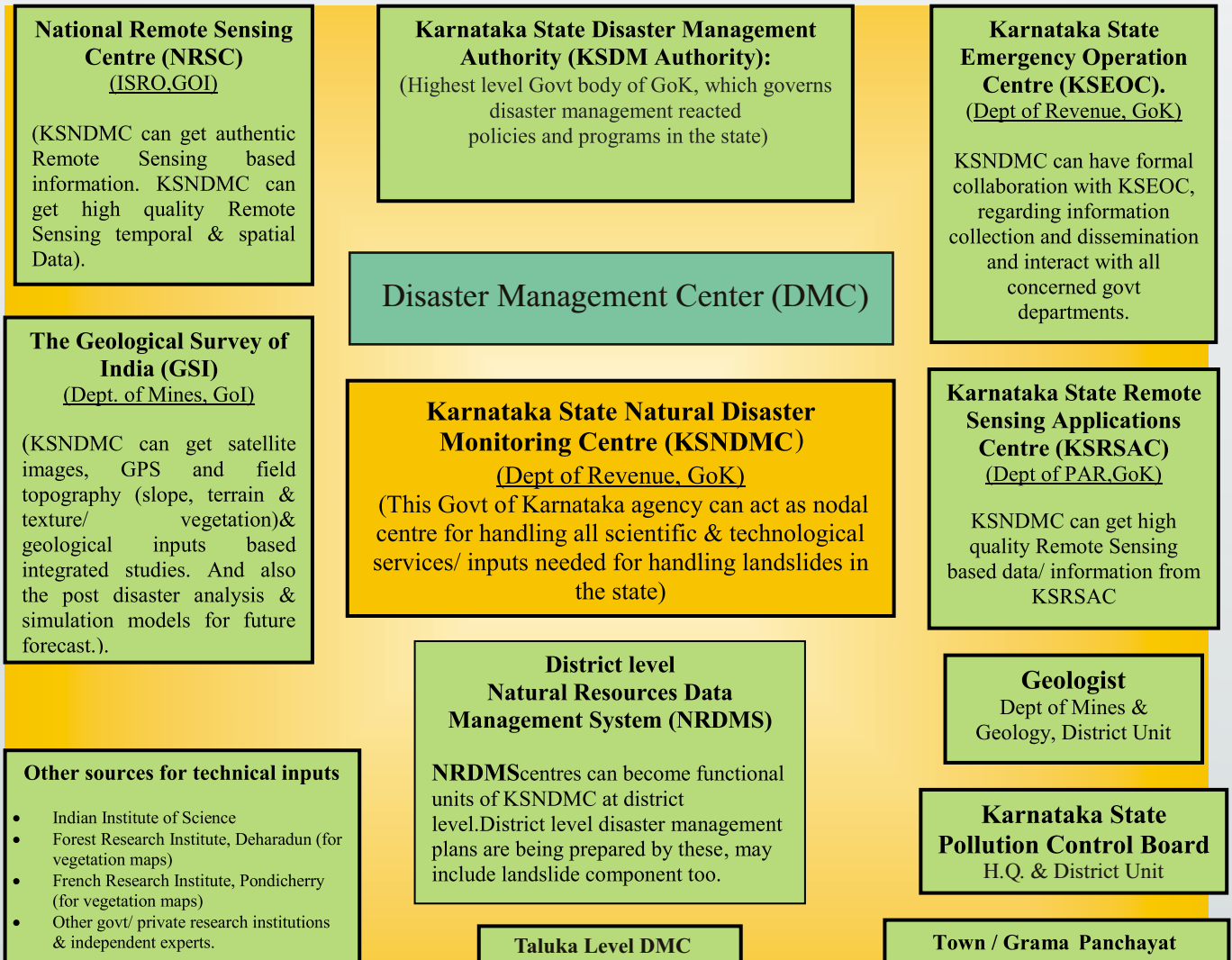
- Madikeri, Somwarpet and Virajpet in Kodagu disitric
- Sakleshpur in Hasana disitric.
- Koppa, Mudigere, Sringeri , Chikkamagalur in Chikkamagalur disitric
- Sagar in Shimoga district.
- Karwar, Ankola, Kumta , Honnavara, Siddapura, Sirsi, Yellapura, and Joida in Uttara Kannada disitric
- Karkala in Udupi district
- Beltangadi, Bantwal, Puttur, Sulya and Mangalore in Dakshina Kannada district

Along with these, the landslides have also occurred in many parts of Kundapura and Udupi Taluks (Udupi district), Hosanagara and Theerthahalli Taluks (Shimoga district) and Khanapura Taluk (Belagaum district) indicate that they could also be vulnerable. Therefore, all these identified zones need to be brought under sustainable land use regime in order to prevent the landslides and mitigate their impact in future. (The details are in the annexure). A detailed account on prevention and mitigation strategies to be adopted in the form of a **Comprehensive Landslide Prevention & Mitigation Plan (CLPMP)** in the state are being given as the Final Recommendations in the next chapter.



3. Final Recommendations

1. **Institutional framework:** An institutional framework needs be put in place for planning and executing a comprehensive landslide prevention and mitigation plan in the state. While **Karnataka State Disaster Management Authority (KSDMA)** established by Govt of Karnataka can become the highest decision taking body to in this regard, **Karnataka State Natural Disaster Monitoring Centre (KSNDMC)** can become the nodal agency to provide technical support for all functions. The overall institutional frameworks could be like this:



2. **Nodal agency:** **Disaster Management Centre (DMC)** which is already functioning under Dept of Revenue, GoK, can become the nodal agency for implementing a comprehensive landslide prevention and mitigation plan in the state.

3. **Streamlining and strengthening ground level institutional framework :**

As mentioned above, Karnataka State Disaster Management Authority (KSDMA) can frame and govern the policies. Disaster Management Centre (DMC) can become the nodal centre for implementing the same at the state level. It can have the following administrative mechanism at the district, taluk and village levels.

A. District level: A **Natural Disaster Monitoring Cell (NDMC)** can be established under District Disaster Management Committee (DDMC) which is already functioning under chairmanship of Deputy Commissioner. It may take the technical help of **Natural Resources Data Management System (NRDMS)**, which are functioning at every Zilla Panchayat now and governed by the Dept. of Science & Technology, GoK. In fact, these **NRDMS** centres can be made become functional units of KSNDMC at district level. District level disaster management plans are being prepared by these, must include landslide component too.

B. Taluka Level: A Natural Disaster Monitoring Cell (NDMC) can be formed and made functional under the chairmanship of Tahalshildar in every taluk in vulerbale zone. All Grama *Panchayats* must be its members and represented by Panchayat Development Officers (PDOs).

4. Technological models available: A brief overview is given here for the kind of technology and managerial know-how available now.

A. Landslide inventory: Any landslide has a specific spatial and temporal attributes. GIS is the only tool through which it's spatial, temporal and other attributes can be linked and be kept in a geo-referenced spatial database. Landslides are also of varied types, involving different types of material, different types of movement etc., Apart from the above, a lot of spatially-associated attributes about its causal geo-factors can also be observed which can be linked to a landslide incidence. All the above information in such a geo-referenced spatial database (e.g., GIS) can exhibit the landslide inventory of an area.

Examples:

- **Landslide Hazard inventory of NRSC (ISRO):** It is a geospatial database developed by NRSC, ISRO and hosted on online portal '**BHUVAN**' for visualisation and public use.
- **Landslide Hazard Information Management:** It is a web based landslide incidence inventory map service provided by Geological Survey of India (GSI). It is already having the database structure prepared with a provision of storing as many as 41 different attributes per landslide incidences, which is currently operational. They are available now at online portal '**BHUKOSH**'.
- **National Landslide Incidence Inventory:** It is web based database prepared by Geological Survey of India (GSI).

B. Landslide Susceptibility Mapping (LSM) for spatial prediction: This is scientific prediction of spatial locations where landslides may happen in future. These models are developed by using and analysing the huge data on all types of landslides that have occurred in given area.

Example: National Landslide Susceptibility Mapping (NLSM) is a major comprehensive database on the landslides that have occurred in India so far. It is done by Geological Survey of India (GSI) as part of a national programme of GoI on landslide susceptibility mapping of the country.

C. Landslide Hazard Analysis for spatial & temporal prediction: This is the set of techniques to predict landslide possibilities in future both spatially and temporally. Hence, this predictive analysis tells about where, when and how the future landslides may happen. This is basically developed on the basis of previous landslides that have occurred there.

Example: Landslide Hazard Zonation Maps of NRSC, ISRO.

D. Landslide Risk Analysis: This is a prediction model developed for estimation of losses to human lives as well as livelihood and property in case of any landslide hazard. This will help government to frame the suitable policies and programs to mitigate the impact of those calamities. The above analysis will be done on the available data on both spatial and temporal information of landslide occurrences.

5. Landslide Risk Management Plan: Govt. must formulate Landslide Risk Management Plan (LRMP), which is useful for the managing landslide calamities. It must comprise everything starting from identification of a landslide-related problem, knowing its susceptibility (predictions of spatial locations), hazard (combination of spatial, temporal and magnitude predictions) and estimation of risk (loss estimation), risk evaluation and process to implement ground-level actions towards reduction of the risk. All these can help for putting a well defined ‘**Preparedness Plan**’ in place. Some of the major modules available now are:

- 1) **National Database for Emergency Management (NDEM)** system of ISRO: It is an ISRO run Geo-Portal meant for assisting the governments on managing emergencies during calamities.
- 2) **Early Warning System of ISRO:** ISRO has developed Landslide Early Warning System models for rainfall triggered Landslides on experimental basis. That experience of ISRO would be helpful to the state

6. Integration of technology and information systems for developing a ‘Comprehensive Landslide Prevention & Mitigation Plan (CLPMP):

A Comprehensive Landslide Prevention and Mitigation Plan (CLPMP) can be brought out by KSNDMC under the guidance of KSDMA. It can be designed by integrating all available technological and managerial know-how. Necessary technical support for such a plan can be obtained by various agencies mentioned above. The findings & recommendations in Disaster Risk Reduction (DRR) plans prepared by Geological Survey of India (GSI) can help a lot in this direction. Such an elaborative plan must be clearly printed in local language and distributed among concerned villages through Revenue, Forest & Panchayat Raj departments. It must have clear guidelines on Prevention, Mitigation, Disaster Situation Management and comprehensive Compensation System to be adopted for the affected people, settlements, watershed and villages. Each one of these is dealt in detail further. It may have the following components.

7. Landslide Management Plans:

I. **Pre-Disaster Landslide Management Plan:** It can have the following two important information systems.

- 1) **Mapping Landslide Hazard and High Risk Zones:** The high altitude hilly and valley regions of Western Ghats and their foothill regions in *Sahyadri* and Coastal districts of the state are identified as highly landslide susceptible zones, as per the detailed assessment made by the Geological Survey of India, GoI. GSI has prepared a comprehensive database called ‘**National Programme on Landslide Susceptibility Mapping**’ (NLSM) through a national priority programme. It has landslide susceptibility mapping at macro scale (1:50,000). It is now available in BHUKOSH web portal. As per this precise mappings, high altitude hills with steep slopes and valleys in Kodagu, Hasana, Shimoga, Uttara Kannada, Belgaum, Dakshina Kannada and Udupi districts fall under those highly vulnerable regions.

Landslide hazard and risk zoning maps must be done at multiple scales for the above regions. While ‘Landslide Hazard Mapping’ are based on the geology and geography of the terrain, the ‘Landslide Risk Zoning’ depends on various elements like possible risks, exposure and vulnerability. Considering rainfall-intensity and changes in climate / hydrologic regimes (due to global warming) stochastic relationships must be explored to assess high-risk areas. It must be done for all the susceptible regions in the vulnerable districts of Karnataka as identified by GSI. Such maps with ‘**Hazard Zones**’ and ‘**Risk zones**’ should be made available for the **Cadastral Maps** with survey number for all types of land titles (forest, govt revenue land, community land and private land) in the landslide vulnerable regions.

- 2) **Landslide Monitoring & Early Warning System (LMEWS):** Landslides are mainly controlled by factors such as geomorphology, topography, lithology & geological structure, hydrology & climatic

condition, Land use, seismicity and anthropogenic activities. But, high rainfall may act as key trigger. Therefore, it is recommended to develop a “Landslide Early Warning System” (LEWS), based on rainfall threshold analysis. This will help in monitoring, forecasting and disseminating the vital information to all stakeholders in time.

II. Post-Disaster Landslide Management Plan: A robust information management system should be put in place for regular information collection and analysis, so that a sound database gets available for future reference. It may have two important aspects:

- 1) Cadastral Maps with Landslide Inventory.
- 2) Site-specific landslide monitoring and evacuation plan.

Example: National Database for Emergency Management (NDEM) System is a model project developed by ISRO. It is run on its geo-portal meant for assisting the governments on managing emergencies during calamities.

8. Preventive Measures:

- 1) **Protecting natural forest cover:** Priority must be given to protect natural forest cover, with special focus on high altitude forests, shola forests, grasslands and mountain peak vegetation, river valley forests etc. which falls under this high risk zones. Such highly sensitive ecosystems in the river valley systems of Kaveri, Kumaradhara, Netravati, Tunga, Bhadra, Chakra, Varahi, Sharavati, Aghanashini, Bedti and Kali must be recognised and protected. Cutting of forest and plantation trees must be restricted in this region.
- 2) **Enhancing green cover:** Green cover in the barren and degraded forest area in the landslide vulnerable zones must be enhanced. Most of this region can have natural re-growth of forest, if proper protection is given. In the case afforestation works are needed, local/ indigenous plant species must be planted in mixed plantation system. Unscientific digging and creation of ponds, trenches etc., must be stopped in this hill tops and slopes.
- 3) **Keeping natural streams and rainwater channels intact:** Care must be taken to keep all natural water channels, streams and rivers etc. intact and without causing any disturbance to natural flow of water. (In all types of terrain, namely: forest, common lands, grasslands and all forms of agriculture landscape).
- 4) **Drainage Management:** Proper drainage management, both for municipal waste and runoff water, especially during the rainy season is of paramount importance. It is observed that in most of the cases proper drainage facilities are absent or poorly maintained. The state infrastructure departments like PWD and local government agencies must coordinate in the proper maintenance of drainage facilities and cleaning of existing drainages before the onset of monsoon.
- 5) **Regulation of indiscriminate use of land digging and electric tree cutting machines (Power Chain Saw) in landslide vulnerable zones:** It is observed that the current free access to purchase and use of earth excavators, bore-well digging machines and electrical tree cutting machines (Power Chain Saw) have also been found responsible for the irreversible damage to landscape in many places in the steep hill area. Therefore, their sale and use must be properly regulated through a suitable competent authority in landslide vulnerable zones.
- 6) **Land Use Policy:** These districts need very clearly laid out Land Use Policy. Such a policy must have clearly spelt out guidelines for all landscape slope and vegetation cover reducing developmental works: The state government must frame clear guidelines / regulations for the land use in these landslide prone hilly terrains of *Western Ghats* and Coastal region of Karnataka. It must look into the following components:

A. Land Use Planning and Mapping: The landslide prone areas and buffer zones may be identified separately highlighting what kind of activities can be allowed in these zones. A suitable land use plan must be designed and put in place by local government, which would pave the way for sustainable development. Local government must follow clear guidelines in giving

permission to any kind of land use changes in unstable slopes, in the landslide vulnerable zones identified by Landslide Susceptible Maps (NLSM). prepared by GSI. Grama Panchayats, municipal authorities, district authorities and town planners- all these local bodies must have a master plan indicating suitable regions for all future constructions & developmental activities, so that landscape/landform integrity is totally respected in future. Certain degree of restrictions are needed on large scale developmental projects, which may de-stabilise the land-slope integrity in these areas, particularly in the ecologically fragile regions like steep river valleys, which are identified as landslide vulnerable zones.

- B. Slope stability:** Assessment of the cut slope stability in the hilly area should be carried out for predicting instability which will be helpful for town planning and developmental activities. For all future cuttings in slopes of this kind, guidance of geologists/ structural engineers may be sought. Vertical cut slopes should be avoided in future as it destabilizes the slope. Due care should be given to the cut slopes made for any purpose like construction of roads, buildings or expansion of plantations. The cut slopes may be provided with suitable retaining structures. The design of the retaining structure should be made as per standards, keeping in view the strength parameter of the rocks in the area. Weep holes are to be provided to retaining structures with suitable graded filters.
- C. Regulations of mining/ quarry:** It is observed that mining and quarrying for major and minor minerals and sand are taking place illegally in many landslide vulnerable zones. They must be restricted. The legal ones must be properly regulated so that they follow all the safety guidelines laid by the competent authorities. New quarry or mining should not be allowed in the regions designated as Landslide High Risk Zones by GSI.
- D. Establishment and maintenance of Linear Projects:** Studies have shown that rail lines (Konkan Railway and Subramanya- Hassana Railway line) and highway roads (Ankola-Hibli NH, Karwara-Mangalore NH, Sagara-Honnava NH, Hassana-Mangalore NH, Mudigere-Belthangady SH, Madikeri-Sulya SH etc) have been witnessing widespread and severe landslides in recent years, especially in Western Ghats zone. Therefore, clear guidelines to be laid down on the way the terrain must be treated while maintenance of such corridors. While implementing new Linear Projects or expanding the existing ones, like rural roads, district roads, State Highways, National Highways, Rail Lines, High Tension Power Lines, irrigation channels etc. slope management should be given utmost care. That must include aspects like maximum angle at which hills can be cut, keeping natural channels of water flow intact, top soil restoration after the completion of civil works involving opening up the land, methods of extracting sand and mud for the on-site and off-site construction works etc.) Project proponents must have a comprehensive hydrological audit while preparing Feasibility Report. In case of the approved project, Detailed Project Report (DPR) must have proper mitigation methods. The regulatory agencies and implementing agencies like Public Works Department (PWD), National Highway Authority (NHAI), Dept of Railway, Dept of Irrigation and others must be directed to adopt those principles, while implementing their projects in landslide vulnerable areas. Govt may consider giving additional budget in such cases, so that implementing agencies carry out those additional works to meet the safety objectives, without compromising the quality of the construction.
- E. Standard Operation Procedure (SOP) for terrain altering activities:** It is observed that indiscriminate and unauthorised digging of soil and cutting of hill slopes often act as triggers for landslips in many landslide vulnerable region. Therefore, local govt. bodies (*Grama Panchayats*, *Town Panchayats* & Municipal Commissions) must regulate the commercial scale extraction of earth resources in their jurisdiction. They must have clear guidelines on where and how earth resources like sand, mud, soil, rocks etc have to be extracted. There must be a cap on the maximum amount to be extracted in a place and a plan for its rejuvenation.
- F. Prevention of illegal roadside and forest encroachment for commercial purpose:** It is observed that encroachment of forest land, roadside land, govt land, private land etc., often

contribute to landslides, by blocking runoff water channels, opening up vegetation, causing erosion in slopes, damaging slope pitching etc. Therefore, such illegal occupying of land must be prevented.

G. Restricting Monoculture Plantations: Economic contributions of monoculture plantations like that of species belonging to *Eucalyptus*, *Acacia*, *Heavia*, *Pinus* etc., are well recognised. But, data and experience of last four decades are indicating that, their contribution is negative when it comes to the ecological stability of a region, especially in the sensitive ecosystems like Western Ghats. The very activities required during planting, managing and harvesting of those timber trees in the slopes of landslide vulnerable zones, are found to be disturbing soil stability. Hence, they must not be taken up in the high landslides risk zones of these *Western Ghats* and coastal districts. However, afforestation /re-forestation / gap-planting programs can certainly be taken up with indigenous species.

9. Mitigation Measures:

Mitigation measures or interventions are meant for reducing the impact in the case of landslide events. Landslide hazard mitigation can be achieved by adopting several types of slope stabilization method, with the goal of lessening the effect of landslides. Some of them are:

A. Restoration of damaged landscape: The region where severe landslides have already occurred, a comprehensive restoration programs must be taken up. It must have both immediate restoration measures, as well as long term control approaches. Priority must be given to eco-friendly on the field measures. The civil works meant for reducing soil erosion / slope sliding / mud falling etc must be achieved through technology. There is also need of taking up investigations on the suitability of human habitations in the landside vulnerable high risk zones. In such cases, special financial packages may be given by the govt to landslide hit Taluks / Grama Panchayats / villages/ hamlets.

B. Cost effective biological methods suggested for slope stabilization:

- Grasses like *Vetiver* grass Turfing
- Deep rooted plants may be planted on slopes wherever there are signs of instability
- Mixed plantations of indigenous species in the barren slopes for enhancing stability
- Gap planting with native species like Bamboo in degraded forest
- Watershed development works in streams and runoff water channels
- Agro-forestry techniques in farm fields

C. Mechanical methods for top soil management:

Maintenance of drainage of water must be always monitored, to avoid pore-pressure in the slopes. The hydro-geological methods like creating U- form ditches on the slopes can be taken up to drain off the heavy water content of the topsoil. While altering the hillsides, the geometry principles that govern the slope stability must be taken into consideration. The techniques like terracing, stone pitching, ground nailing, construction of retaining walls with weep-holes etc. must be adopted wherever needed.

10. Disaster management during the landslide calamities :

A. District Level Disaster Management Plans (DDMP) and execution: Disaster Management Centre (DMC) must come out with a clear guidelines and strategies for managing any types of landslides. They must be suitably adopted in every District Level Disaster Management Plans (DDMP). During such calamities, saving the life and protecting the life and property must be given utmost priority by the District Administration. The public and private entities must join hands with District Administration in such events. In order to achieve that, effective landslide resilience mechanisms must be built in the disaster management strategies.

- B. Building ‘Landslide Resilience:** Clearly assigned responsibility framework is needed for building a strong ‘Landslide Resilience’. It requires the involvement of multiple agencies at different levels from the local administrative bodies and communities to the State departments and agencies. Different agencies need to carry out not only their own responsibilities, but also work in a highly coordinated manner with other players. It is necessary to identify all those various stakeholders/agencies and clearly specify their roles and responsibilities. At all levels, from local to the State, the relevant authorities must have institutionalized programmes and activities at the department level, inter-ministerial and inter-agency coordination must also be enhanced.
- C. Evacuation plan:** Clearly spelt out evacuation plan must be laid down. The high risk regions must have proper evacuation facilities in nearby safe village centres. Proper guidance and information must be given to local people in advance, along with proper sign boards all along roads in vulnerable zones.

11. Capacity Building:

- **Awareness among public:** The people in high risk zone of the hilly region must be given clear awareness on causes for slope instability which may lead to landslides. It will help the individuals as well as communities to be more responsible. It will also help the people to get well prepared in the case of emergency.
- **Trainings for the govt staff:** Different govt departments at district land taluka levels need to be sensitized on the prevention, mitigation strategies to be adopted in the field. The NRDMS centres at the district level with the support of Dept. of Mines & Geology (DMG) can design the modules and implement such continuous programs.
- **Involving & empowering citizens/communities/ community organizations:** The local people and community organizations like Biodiversity Management Committees (BMCs), Village Forest Committees (VFCs), Co-operative societies, Self Help Groups (SHGs), Farmers’ Groups, Youth Forums, educational institutions must be sensitized on the principles of prevention and mitigation strategies, so that they take active role in collaboration with local *Grama Panchayats*.

12. Suggestions for Policy Initiatives:

1. **Landslide as a natural disaster:** Karnataka State Disaster Management Authority (KSDMA) must include the landslide as one of the natural disasters under its areas of functions. The designated amount available in **National Disaster Mitigation Fund (NDMF)** and **State Disaster Mitigation Fund (SDMF)** must be spent on taking up prevention and restoration works on priority in the landslide hit areas. National Disaster Relief Fund (NDRF) & State Disaster Relief Fund (SDRF) must be for compensation and rehabilitation works in the landslide affected area and families.
2. **Extending ‘LANDSLIP’ project of GSI to Karnataka:** Geological Survey of India (GSI) has currently taken up a project called ‘LANDSLIP’ in collaboration with the British Geological Survey (BGS), which aims to develop early warning system for landslides. Govt of Karnataka may formally submit a request to GSI of Government of India, to include high risk districts in Karnataka like Kodagu and Chikkamagalur in Western Ghats of Karnataka under this project.
3. **Need of bringing amendments to Acts & rules:** It is suggested that govt must look into the necessity of bringing in certain suitable amendments for ‘The Karnataka Land Grants Rules, 1969’ (regarding granting the lands for agricultural purposes in the landslide prone areas), ‘The Karnataka Town and Country planning Act, 1961 and Rules (regarding the planning of the developmental works in the landslide prone areas), ‘*The Karnataka Panchayat Raj Act, 1993*’ (regarding the way the permissions to be given for constructions of commercial buildings, resorts, home stay guest houses in the landslide prone areas). Agriculture land conversion must be restricted in landslide vulnerable areas. The commercial scale activities like private resort

projects must be restricted and regulated in these regions. Government must have high level further consultation in this regard.

4. **Need of special financial packages:** Government may consider giving special one time financial packages to the severely landslide hit villages in Kodagu, Chikkamagalur, Dakshina Kannada, Shimoga, Uttara Kannada districts, especially since 2018. It may be spent on giving adequate compensation and rehabilitation support for all the affected families and farmers.
5. **Adopting Sustainable Development Goals (SDGs):** Planning and execution of development works in landslide vulnerable districts must be synchronised with SDG principles, which are adopted by Government of Karnataka.
6. **Need of a 'Comprehensive Compensation Mechanisms' (CCM):** The Dept. of Revenue, GoK, is currently looks after all compensation and rehabilitation functions in the case of any natural disasters, including landslides. Many affected families are found to be not getting the adequate monetary compensation or rehabilitation (C&R) support, due to certain gaps that exist C & R rules. For example, the people who are partially injured, the houses or farm partially damaged, those who lost standing crops, must be also given compensation. Tribal, forest dwellers and agri labours who do not have land titles must be given adequate compensations. Hence, the C&R rules must be suitably amended, so that those needy people could able to receive the govt support. There is need of coming out with such a 'Comprehensive Compensation Mechanisms' (CCM) for all the landslide affected people.

