LANDSLIP KNOWLEDGE PRODUCT:
Institutional Roles

Introduction

LANDSLIP SHEAR

Darjeeling, West Bengal. Credit: © SaveTheHills.

ABOUT LANDSLIP

Between 2016–2021, the LANDSLIP (LANDSLIde multi-hazard risk assessment, Preparedness and early warning in South Asia: Integrating meteorology, landscape and society) project, consisting of nine partners from India, the UK and Italy, developed a prototype landslide forecasting and early warning system in two regions of India, the Nilgiris and Darjeeling.

Through LANDSLIP (www.landslip.org), experts on landslide processes, meteorological forecasting, social science, data and science-to-practice, came together and collaborated with Indian national and district authorities, and local NGOs, to help build resilience to hydrologically related landslides in vulnerable and hazard-prone areas in India.

A suite of Knowledge Products (KPs) has been developed to capture the knowledge and learning generated by LANDSLIP. The KPs have been designed to be accessible and support practitioners, policy makers and programme managers (amongst others) in the development of current and future landslide forecasting and early warning across and beyond South Asia.

CONTENTS OF KNOWLEDGE PRODUCT

This KP focuses on the various institutional roles and skills required in LANDSLIP to develop its prototype regional-scale landslide forecasting system:

- Introduction (this page).
- Part A: Nodal agency for landslides.
- Part B: Collaboration with national stakeholders.
- Part C: Downstream user.
- Part D: Skills required.
- Conclusion and recommendations.

INTRODUCTION TO THIS KNOWLEDGE PRODUCT

A regional-scale landslide forecasting system relies on defined institutional roles and remits, with clear collaboration between national and sub-national partners and stakeholders. Within India, LANDSLIP supported the establishment of a National Landslide Forecasting Centre (NLFC) that oversees and manages this institutional coordination. The NLFC is run by the GSI, which holds a mandate as the nodal agency for landslide investigation in India.

This KP sets out the role and responsibilities of a Geological Survey as the national nodal agency for landslide investigation. It highlights the roles and skills of other key organisations involved in the creation and delivery of an effective regional Landslide Early Warning System (LEWS).

WHY THIS TOPIC IS IMPORTANT

Early Warning Systems (EWS) are made up of four key components: Risk Knowledge, Monitoring and Warning, Dissemination and Communication, and Response Capability. An effective EWS requires multi-disciplinary and inter-institutional collaboration, ensuring the system is effective across all components. GSI and the NLFC holds a leading role in the system, enhancing risk knowledge, monitoring landslide risk and issuing landslide forecasts. Clear remits, roles and responsibilities are vital, both in terms of the roles and skillsets needed within the NLFC, and in terms of the partnerships required with national and sub-national stakeholders.

In the design of a regional landslide forecasting and EWS, a broad range of inter-disciplinary collaboration is required, bringing together a diverse range of physical scientists, social scientists, applied researchers, and practitioners. This multi-disciplinary team has been critical to the design and development of LANDSLIP's prototype landslide forecasting and EWS.

UKRI Natural Environment Research Council

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Foreign, Commonwealth & Development Office

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Examples of typical landslides found within the LANDSLIP study areas.

LANDSLIP KNOWLEDGE PRODUCT: Institutional Roles

Part A: Nodal agency for landslides

A1 OVERVIEW

The Geological Survey of India (GSI), in its capacity as the national nodal agency for landslide investigation, is integral to the development and operation of Landslide Early Warning Systems (LEWS) in India. This section provides an overview of GSI's role and remit within a LEWS. It describes key actions and outputs delivered by GSI including: (i) geological studies; (ii) a national landslide inventory; (iii) landslide susceptibility maps; and (iv) a portal for landslide data.

LANDSLIP researchers visit the Geological Survey of India offices in Kolkata, Nov 2019. Credit BGS © UKRI.

A2 GEOLOGICAL SURVEY OF INDIA: ROLE AS A NODAL AGENCY

Established in 1851, with the primary objective of locating mineral resources, the Geological Survey of India is an attached office of the Ministry of Mines, and remains the principal agency for geological mapping in India.

In 2004 the Government of India declared the Geological Survey of India (GSI) as the 'nodal' agency for landslide studies in India, noting the importance of this hazard in a country where 12 % of the land mass is prone to landslides.

In this capacity, GSI's responsibilities include:

- Conducting geological studies
- Preparing a landslide inventory, including monitoring landslides and avalanches.
- Developing landslide susceptibility maps and landslide hazard zonation maps at multiple scales.
- Developing Landslide Early Warning Systems (LEWS)

Geological studies

GSI is responsible for producing geological maps of India, including the development of a high-resolution geological map (1:50 k). Geological assessments provide information on slope formation materials and geological structures, and factors that can influence slope stability such as faults, lineaments, and regional thrusts and faults. This understanding of geological conditions and the processes of landsliding feeds into other GSI-led products, providing a foundation upon which other components of GSI's work are built.

Landslide inventory

GSI led the creation of a national scale repository of landslide information, a landslide inventory.

For data collection on landslide occurrence, GSI developed an information sheet that captures 42 different attributes of a specific landslide that can be filled in by a geoscientist in the field. These include the location of an event, relevant geological and hydrological factors, the type of landslide mechanism, and noted impacts.

An up-to-date landslide inventory can be accessed free of charge, by stakeholders and the public, through an online portal (the Bhukosh portal – see below).

The portal contains 52,146 landslide polygons (shape features), and 25,184 landslides as point features with detailed field-validated attributes. The inventory has to be updated regularly which requires the cooperation of a number of national and state agencies including those involved in road maintenance, forestry, armed forces, and public works.

The LANDSLIP project has contributed to the landslide inventory by developing tools that enable the public, government authorities, and civil society to actively collect landslide information and directly feed it back to GSI, to enhance the quality and completeness of the national landslide inventory.

National landslide susceptibility map

The creation of a National Landslide Susceptibility Map (NLSM) was an important priority to improve understanding of the distribution of landslides, enabling insight into the conditioning factors leading to landslides.

GSI drew upon different techniques, such as field surveys and remote sensing, to create each map depending on the availability of landslide inventory data in each location.

The NLSM provides useful information on landslide-susceptible zones at 1:50 K for all landslide prone areas in India. This information feeds into the LEWS bulletin (see 'LANDSLIP Knowledge Product: The landslide Forecast Bulletin') as well as informing pre-disaster planning and preparedness.

The production of these maps is greatly aided by the ability of GSI to draw on its national datasets and its extensive pool of expertise. During the LANDSLIP project, a suite of regional scale landslide susceptibility maps were created which identified areas affected by three different mechanisms of landsliding: falls, debris flows, and slides.

Bhukosh: the landslide data portal

Bhukosh, launched in 2016, is an online spatial data portal that provides a gateway to all geoscientific data held by GSI.

It is open to the public, and can be accessed at: https://bhukosh.gsi.gov.in/Bhukosh/Public.

This data portal ensures that the spatial geoscientific data managed by GSI can be accessed by a range of stakeholders including the wider geoscience community, stakeholders with specific information needs related to landslide risk (such as disaster risk managers and land use planners), and the wider public.

The portal provides access to the landslide inventory and national landslide susceptibility maps as well as geology maps at 1:50 k and 2 M scale. The data can be viewed and downloaded from the portal and provides a valuable resource of open data.

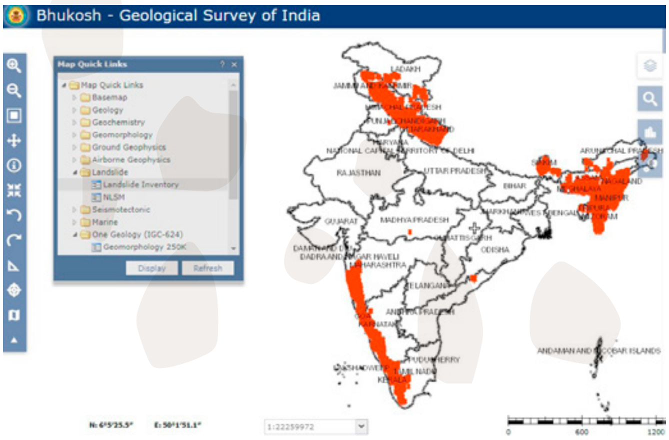

Figure A2 Image from Bhukosh depicting a landslide inventory map highlighting landslide-prone areas of India. Data in images © GSI.

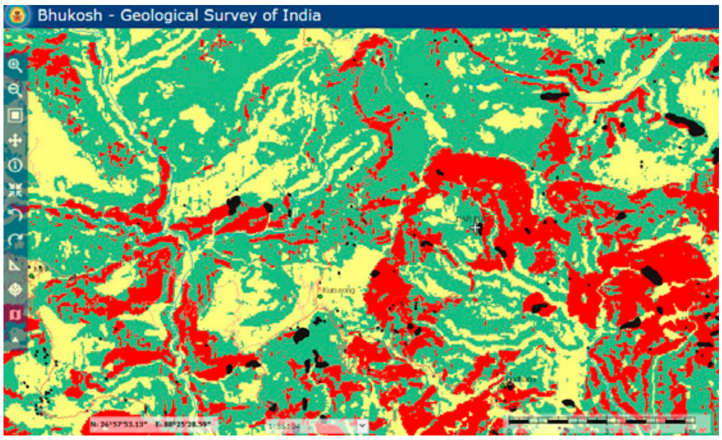

Figure A3 Image from Bhukosh depicting a Landslide susceptibility map showing distribution of high (Red), moderate (Green) and low (Yellow) areas of landslide susceptibility, alongside locations of landslide (Black). Data in images © GSI.

A3 IMPORTANCE OF THE NODAL AGENCY ROLE

The LANDSLIP project has reinforced the importance of having a nodal agency like GSI engaged in work on landslide forecasting and early warning. The nodal agency brings critical expertise and knowledge essential to the LEWS. At the same time, having GSI officially designated as the nodal agency gives GSI the remit to request other agencies' cooperation with the process, at times requesting collection of and access to data and records which would be difficult without such a designation. As nodal agency, GSI, with support from partners, has now united the different responsibilities and activities described above into a National Landslide Forecasting Centre (NLFC) as described in Part B of this series. The NLFC links together work on geological studies, landslide data collection, landslide susceptibility mapping, and landslide forecasting and early warning. These components and layers of data and knowledge form an essential foundation upon which LANDSLIP's prototype regional LEWS has been built. All of this data and knowledge resides with GSI, the national data custodian, making them an integral component of the LEWS.

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Part B: Collaboration with national stakeholders

B1 OVERVIEW

A National Landslide Forecasting Centre (NLFC) has been established for the first time in India, aiming to deliver a sustainable and robust landslide early warning system at a regional scale.

The NLFC is led by the Geological Survey of India (GSI), and draws upon expertise from a number of other national stakeholders integral to landslide forecasting.

Meteorological and landslide occurrence information is drawn from organisations such as the Department of Space (DOS), Indian Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), and National and State Disaster Management authorities (NDMA/SDMAs). These national stakeholders need to collaborate to enable the NLFC to produce a daily landslide bulletin (see 'LANDSLIP Knowledge Product: The landslide Forecast Bulletin' for further information on the bulletin). This section provides an outline of the roles of national stakeholders within the NLFC.

GSI meeting with IMD and NCMWF, Delhi, Feb 2020.
Credit: UK Met © UKRI.

B2 METEOROLOGICAL DATA

Landslide Early Warning Systems (LEWS) for rainfall-induced landslides require meteorological data inputs. Meteorological data for LEWS typically falls under two categories: (1) historical observation data, which can be used to support the development of rainfall thresholds to trigger warnings; and (2) forecast data, which can be used in forward modelling to forecast the potential occurrence of future landslides. Such datasets are typically managed and produced by national meteorological agencies. In India, the IMD operates and maintains the observational network across India for a range of atmospheric variables, consistent with procedures and standards defined by the World Meteorological Organization (WMO). These observations enable monitoring of current weather systems and are assimilated into numerical models which simulate meteorological scenarios to improve the skill of weather forecasts.

The development and enhancement of numerical weather prediction (NWP) systems is the principal mission of the NCMRWF. The NCMRWF collaborates with IMD who provide observation data for assimilation within NWP models. NCMRWF then develops and runs different NWP models to provide forecast information to IMD, where operational forecasters produce and issue information related to current and future weather, and disseminate weather warnings.

LANDSLIP has developed two forecast products to support the creation of the LEWS bulletin, which is being issued by GSI within the prototype system: a medium range forecast based on weather patterns developed by the UK Met Office and a threshold-based landslide forecast model developed by Consiglio Nazionale delle Ricerche (CNR), utilising short range weather forecast data. The key weather variable used within the LANDSLIP project is rainfall, although it is recognized that additional weather variables may be useful in some circumstances.

IMD provided daily rainfall accumulation observations from gauge stations across the pilot areas. This data was supplemented by rainfall observation data provided by Tea Garden estates. The use of both datasets improved the spatial density of rainfall observations across the two pilot areas. The IMD also provided a gridded product combining satellite and gauge data which provides a consistent and long-term record of observed rainfall across all of India. These data were used with historical landslide observations to analyse the relationships between the datasets and develop the medium and short-range forecast applications.

B3 MEDIUM-RANGE FORECAST APPLICATION

The medium-range forecasting application for landslides can be separated into two parts: (1) the high-level weather pattern forecasts, which provide the probability of a weather pattern occurring on each day out to 10-days ahead; and (2) the landslide application which uses an identified set of high-risk weather patterns specific to landslide occurrence to forecast period with a heightened likelihood for landslide occurrence, up to 10-days ahead.

As developers of NWP systems, the NCMRWF have a wealth of experience in running operational modelling systems, while GSI have the remit and expertise to issue information pertaining to landslides. NCMRWF will run and maintain the high-level weather pattern forecasts and GSI will run and maintain the landslide application specific to their needs. The NCMRWF will be responsible for running the global NWP ensemble model (NEPS-G) and calculating the probability of occurrence of each weather pattern. These outputs will be transferred to GSI on a daily basis and updated with each new model run. GSI will then be responsible for using this information to drive the medium-range landslide forecasting application, which can be used to support the creation of the LEWS bulletin. GSI will be able to make amendments to the design of the landslide forecast application (i.e. graphical design) and add new regions of interest, independent of the NCMRWF and in line with their own future needs.

B4 SHORT-RANGE FORECAST APPLICATION

The second forecast product utilized in the creation of the LEWS bulletin is the short-term landslide forecast based on a rainfall threshold developed for each pilot area. Rainfall data collected using rain gauges was used alongside the occurrence of known landslides to calculate the level of rainfall at which a landslide may be triggered. The landslide forecast model is able to estimate (once fully calibrated) the Non-Exceedance Probability (i.e. the likelihood that this level would not be reached) associated with a given cumulative rainfall-duration measured or forecasted in an area. The rainfall forecast inputs are vital for this short-range product and during the operational phase of the LEWS will be provided by the NCMRWF out to 72 hours ahead.

The NCMRWF are currently providing deterministic forecasts from two NWP models: global (12 km x 12 km) and regional (4 km x 4 km). NCRMWF share these global and regional rainfall forecasts with GSI who produce the landslide forecast model based on the thresholds previously developed.

Ensemble prediction systems enable an estimation of the uncertainty in a weather forecast, as well as the most likely outcome. Future developments may look to use NCMRWF's ensemble models to provide the rainfall inputs to the short-term forecast application. This will require updates to data feeds from NCMRWF and also potential adjustments to the landslide model which would need to be undertaken by GSI.

B5 NATIONAL REMOTE SENSING CENTRE: LANDSLIDE EVENTS

The National Remote Sensing Centre (NSRC) and GSI are committed to signing a MoU to develop a long-standing relationship for the sharing of landslide occurrence data. The NRSC is one of the primary centres of the Indian Space Research Organisation (ISRO), under the Department of Space (DOS), with a mandate which includes the generation of data products and the development of techniques for applying remote sensing data to tasks which include disaster management support. NRSC operates a Disaster Management Support Programme (DMSP) to monitor natural hazard-related disasters and produce data to aid decision making during events. The work of NRSC to create landslide inventories and hazard zonation is complementary to the work carried out by GSI and will be an integral data feed into the LEWS to aid the understanding of landslide occurrence related to meteorological events.

B6 BULLETINS AND WARNINGS

GSI is issuing an experimental, prototype daily landslide bulletin using the outputs from the medium- and short-range forecast applications. They are responsible for reviewing the forecast application outputs, synthesising the information and completing the pre-defined bulletin template daily. They then disseminate this bulletin to downstream users.

IMD issue daily weather bulletins for India, including weather warning information when appropriate, and have been doing so for many years. Future engagement between GSI and IMD around dissemination and alignment of forecast and warning products may be beneficial to ensure consistency and enable effective action by users, particularly in instances where stakeholders receive both bulletins.

Feedback from IMD and National and State Disaster Management Authorities will be critical to ensure the bulletin is useful and actionable. These agencies are also in a favorable position to provide information on landslide occurrences and their impacts, supplementing GSI's landslide mapping activities. Similarly, the IMD can provide continued access to rainfall observations. A routine approach and commitment by these agencies will provide valuable observational data that can be used to evaluate the accuracy of the bulletins and verify the skill of the underpinning landslide forecast applications.

LANDSLIP KNOWLEDGE PRODUCT:
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Part C: Downstream users

C1 OVERVIEW

An effective Early Warning System (EWS) comprises four main components: risk knowledge, monitoring and warning, dissemination and communication, and response capability (see **Fig. C1**). The National Landslide Forecasting Centre (NLFC) holds responsibility for two of these components: risk knowledge; and monitoring and warning. Downstream stakeholders hold responsibility for other critical components including wider dissemination and communication; response capability.

An effective EWS needs to carefully consider the roles, responsibilities and remits for all components of the system. Careful collaboration and planning are essential to ensure the forecasts produced by the NLFC are effectively transmitted to downstream actors in a manner that enables improved risk-informed early action. This section considers the roles of downstream users within the LANDSLIP's prototype Landslide Early Warning System (LEWS).

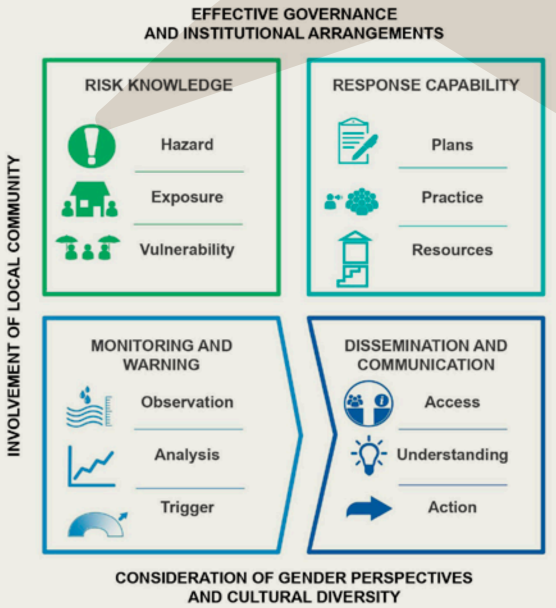

Figure C1 Elements of an Early Warning System. Figure provided by Practical Action 2021.

C2 ROLE OF DISTRICT AUTHORITIES IN THE PROTOTYPE LEWS

GSI, through the NLFC, will bring together forecast information, landslide susceptibility maps and geological expertise to create a Landslide Forecast Bulletin (see 'LANDSLIP Knowledge Product: The landslide Forecast Bulletin'). A prototype, experimental bulletin has been sent daily to the District Magistrate (DM) and the District and State Disaster Management Agencies (DDMA/SDMA) during the 2020 and 2021 monsoons as part of the LANDSLIP project (**Fig C2**). Once the system is operational, these downstream users will hold responsibilities for the remaining two LEWS components: dissemination and communication, and response capability.

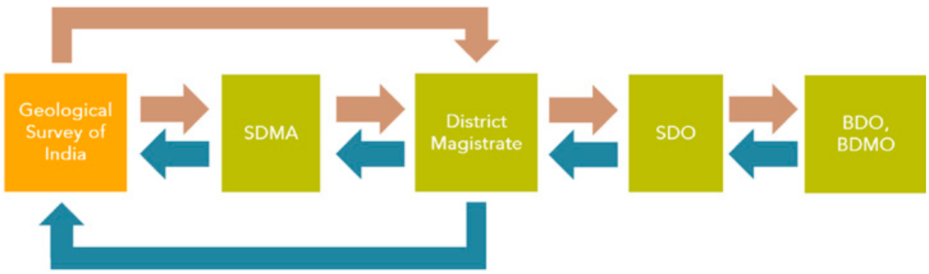

Figure C2 Role of district authorities in prototype Landslide Early Warning System (LEWS), showing dissemination of information (pink arrows) and feedback (blue arrows).

The District Disaster Management Authority (DDMA) holds responsibility for leading disaster management efforts at the district level, creating and managing a District Disaster Management Plan that is approved at state level by the SDMA. The DDMA holds the mandate for issuing and disseminating warnings at a district level and coordinating with Sub-Divisional Officers (SDO), Block Development Officers (BDO) and Block Disaster Management Officers (BDMO) within the District (**Fig. C2**).

Remit for dissemination of hazard warnings, and taking action in response to the Landslide Forecasting Centre's bulletin lies with the chair of the DDMA (the District Magistrate or District Collector (DM/DC)) along with the Chairman of the District Panchayat.

The DM and DDMA are responsible for deciding what to do with the information provided within the bulletin within each District. District level response to any hazard event is the responsibility of the DM/DC, and during an emergency situation the Police, Fire and Public Works departments are coordinated by the DM/DC.

The LANDSLIP project has focused on the production of a prototype, experimental Landslide Forecast Bulletin (see 'LANDSLIP Knowledge Product: The landslide Forecast Bulletin') and ensuring there are clear processes in place to effectively disseminate this bulletin to sub-national stakeholders with responsibilities for dissemination and communication, and taking forecast based early action. The downstream use of these forecasts, in terms of wider dissemination and communication, and integration into Standard Operating Procedures for Early Action, will continue to develop beyond the end of the project.

C3 FEEDBACK ON LANDSLIDE OCCURRENCE

An effective LEWS requires feedback on the accuracy of the landslide forecasts, cross-referencing landslide forecast with landslide occurrence. Effective communication and collaboration between those collecting landslide impact data and those producing landslide forecasts is critical to achieve this.

The DDMA collects loss and damage information for each disaster in the district as part of a Calamity Assessment Report, which can provide landslide data information to the NLFC. Complementing this, GSI developed a detailed form and guide to collect landslide occurrence data. This can enable sub-district level governmental stakeholders (Taluka/Block offices) to collect the landslide occurrence data and submit it to DDMA. DDMA can then combine this with rainfall data and feedback on the bulletin and then submit to GSI. Civil society can also play a role in highlighting or collecting data on landslide occurrence, data that will strengthen the accuracy of the landslide forecasts.

C4 COPRODUCTION OF THE BULLETIN

During the research phase of LANDSLIP, when the forecasts were being developed and refined, a series of meetings between the DM/DC and the LANDSLIP team were held to discuss the format of the bulletin to discuss how the DM/DC might interpret and act upon the information and to clarify the limitations of the current forecasts.

Pre- and Post-Monsoon workshops were also held with the DM/DC during the research phase, gaining important feedback on how the DM/DC understood and interpreted the prototype bulletins. This user feedback highlighted areas for refinement of the bulletin. These meetings contributed to the evolution of the bulletin, enhancing visual representation of information and clarifying the language used.

It is worth noting that this research phase did not include any plans for taking action in response to the information in the bulletins.

C5 ONGOING FEEDBACK MECHANISMS

Ongoing feedback between producers and users of forecast information is a critical aspect of any forecast and early warning system. The research phase facilitated two-way feedback between GSI and downstream organisations receiving the forecast bulletin.

The DM/DC sends a weekly update to GSI with information regarding any landslide occurrence data collected as well as any feedback on the bulletin content or understandability. DDMA/SDMA have a clear and designated channel to contact GSI whenever further information or clarification is required. End-of-Monsoon feedback sessions for users to feedback to forecast producers were arranged during the 2020 research phase and this will continue into the operational phase. Some examples of actions based on feedback from Post Monsoon workshops include:

- DDMA will endeavour to seek official orders from District Magistrate so that additional trained staff (including civil defense volunteers) can be engaged for systematic and accurate landslide documentation.
- Bulletins will be edited so that geographical boundaries (e.g. panchayat/ward level) are to be overlaid on the landslide susceptibility maps for better interpretation by District users.
- DDMA acknowledged that the quality and accuracy of the forecasts can be improved considerably, if the district manages to provide rainfall information from additional rain gauges, including from the Tea Estates.

C6 NEXT STEPS: DISSEMINATION AND COMMUNICATION AND RESPONSE CAPABILITY

The LANDSLIP project has facilitated the development of a prototype landslide forecast, as currently provided within the experimental landslide forecast bulletin. As this regional LEWS moves towards an operational phase, GSI and DDMA will need to prioritise a number of critical further actions to enable an effective operational early warning system. This will include: (i) the exploration of user needs (whether the bulletin is understandable and appropriate for key downstream stakeholders beyond the DM/DC); (ii) development of dissemination protocols (agreeing which sub-national stakeholders need to receive the bulletin and how); and (iii) testing of Standard Operating Procedures for Early Action (understanding which downstream stakeholders can take what early actions in response to Landslide Forecasts). It is worth noting that this Regional Scale Landslide Forecasting System is not designed to predict individual slope landslides, but to identify areas at risk of landslide occurrence. It is not intended to drive community evacuation, but to support decision-making for early action. As such, it may not be suited to the type of community-wide dissemination typically associated with flood early warning, and focusing on dissemination within institutional stakeholders may be more effective and appropriate.

LANDSLIP KNOWLEDGE PRODUCT: Institutional Roles

Part D: Skills required

D1 OVERVIEW

A diverse range of technical, scientific and inter-personal skills is required for the design, development and operationalisation of an effective landslide forecasting centre.

This section of the Knowledge Product (Part D) considers these two aspects:

- Skills required in the National Landslide Forecasting Centre (NLFC)
- The broader interdisciplinary skills that enabled the design and development of this prototype LEWS during the research stage

The diverse and interdisciplinary LANDSLIP team, Feb 2020, Delhi. Credit: KCL/BGS © UKRI

D2 SKILLS IN THE NATIONAL LANDSLIDE FORECASTING CENTRE

To manage an effective LEWS, including the production of an accurate and user-friendly landslide forecast bulletin, a diverse range of skills and technical expertise are required. Drawing on their various experiences, and through internal discussion, the LANDSLIP team have identified three technical skills categories that we believe are core to an effective National Landslide Forecasting Centre: Research and Development; Forecasting; and IT Skills.

Research and development

The Research and Development (R&D) team are responsible for the ongoing refinement and validation of the landslide forecasts and associated bulletins. Specific roles to be carried out by the R&D team include developing and maintaining the underlying models, evaluating the accuracy of the forecasts, and responding to feedback on the clarity and usefulness of the bulletin from downstream users. An understanding of process modelling and rainfall thresholds will be necessary alongside the skills to update susceptibility, vulnerability and exposure maps. The R&D team could also be involved in more detailed monitoring of highly landslide prone areas. R&D team members will need to have skills that span geology, geomorphology, geostatistics, GIS and remote sensing. Team members will also require relevant skills and understanding, such as scientific programming, to enable them to interact with the models and update them as new data is collected.

Forecasting

The forecasting unit is divided into sub-units based on the regional structure of GSI (North Eastern, Eastern, Northern, Southern, and Central). It has ten geoscientists responsible for the preparation and dissemination of the daily landslide forecast bulletin. Each unit will work on a short-range landslide forecast, a global and regional weather forecast, and a medium range forecast based on high-risk weather patterns.

In order to enhance these forecasts over time to reflect new data, the forecasting unit needs to be able to reassess which weather patterns are deemed high risk for landslide occurrence, determine new rainfall thresholds, and integrate these into the landslide forecast. The process of updating the thresholds and weather patterns will draw on a diverse range of skills from meteorology, programming, shell scripting and geostatisitcs through to GIS, quantitative data analysis,and database management.

IT skills

The role of IT service and support is a vital component for the successful and smooth operation of the National Landslide Forecasting Centre (NLFC). 24/7 operation requires uninterrupted internet connectivity and power supply. Vital IT services include IT architecture and design, app development, and the development and maintenance of a decision support dashboard, including software programming and support. In order to cover the breadth of requirements, the NLFC needs a separate dedicated unit of IT service and support, comprising five experienced IT professionals led by a Technical Head.

Levels of expertise

Different levels of expertise will be required depending on the task being undertaken. The tasks and the required skill levels have been captured for each step of the LEWS in a set of tables detailing the process, the skills needed and the level of expertise. Some of these tasks require intermediate level skills, such as developing visual representations of data for the bulletin, whilst making changes to the base model will require expert level skills.

D3 PARTNERSHIP AND COMMUNICATION

Partnership is a critical element of ensuring not just an effective landslide forecast, but ensuring the forecasts fit into an effective and operational LEWS that enables forecast based early action.

Partnership with a wide range of organisations (as detailed in section C and D of this series) is a fundamental part of a regional LEWS. The NLFC needs to develop and maintain a wide range of collaborative and trusted relationships with other key stakeholders in the LEWS. There will be a requirement to develop relationships with NGOs as well as the DDMA/SDMA to allow for ongoing cooperation, data collection, and validation and feedback.

Science communication skills are critical, including understanding how to communicate key scientific information in an accessible yet accurate way. For example, science communicators will need to work with downstream users on the phrasing of forecast bulletins, understanding how phrasing is interpreted and influences downstream users, and ensuring feedback informs adaptation of the bulletin.

Good science communication skills are also critical in ensuring the purpose, strengths and limitations of the forecast information are communicated to and understood by those receiving the bulletin.

D4 INTERDISCIPLINARITY

The LANDSLIP team developing the prototype regional LEWS brought together a wide and diverse team to design and develop this innovative system.

The team included a range of physical scientists, social scientists, computer and data scientists, and disaster risk management practitioners for an interdisciplinary approach, as outlined in **Fig. D1**.

In the context of landslides, disciplines which were found to be important include, but are not limited to:

- Meteorologists, including applied or operational meteorologists (i.e. people who deliver meteorological elements of national forecasting and EWS).
- Geologists, including applied or operational geologists (i.e. people who deliver geological elements of national forecasting and EWS).
- Social scientists with understanding of individual decision making and governance and political economy, with skills in institutional mapping, and stakeholder analysis.
- Disaster Risk Management practitioners with expertise in the design and operationalisation of EWSs.
- Computer and data scientists with landslide domain knowledge and skills to develop tools and data services to support the development of the forecasting service.

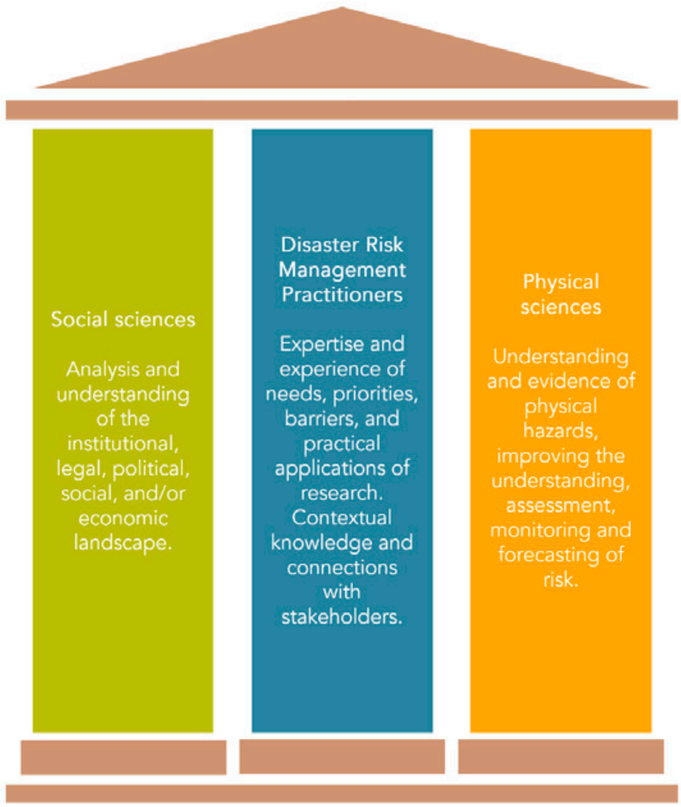

Figure D1 Pillars of interdisciplinary collaboration, source *Putting Science into Practice for Improved Disaster Resilience,* figure provided by SHEAR knowledge Broker.

Cutting across the above was a need for partnership, collaboration, and stakeholder engagement skills, building trusted partnerships with a wide range of actors outside of, but critical to, the project's success.

Science communication skills were also critical in external engagements, enabling the team to collaborate with stakeholders who were not experts in the specific topics. Internally, these skills were important in helping the interdisciplinary team to navigate different approaches, perspectives, assumptions, and terminology across the range of disciplines.

LANDSLIP KNOWLEDGE PRODUCT:
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Conclusion and recommendations

LANDSLIP SHEAR

SUMMARY

This Knowledge Product has outlined key institutional roles, responsibilities and skills in the development and delivery of Regional Scale Landslide Early Warning in India supported by the LANDSLIP project. It highlighted the roles and responsibilities of the national nodal agency (in this case the Geological Survey of India). It discussed the importance of partnership with national agencies and with user groups. Finally, it outlined the skillsets required, and the importance of interdisciplinarity, in the creation and delivery of a regional scale Landslide Early Warning Service (LEWS).

KEY LEARNINGS

- An effective LEWS requires the participation of a wide range of stakeholders across disciplines, including physical sciences, social sciences and disaster risk management.
- The different skills, knowledge, perspectives, and experience of this range of stakeholders is integral and includes technical expertise in forecasting, modelling, and communication, as well as skills in coordination and interdisciplinary working.

RECOMMENDATIONS

- The involvement of a mandated nodal agency brings required expertise as well as access to data, and the remit to engage other key agencies in the process.
- The development and implementation of feedback mechanisms and processes is critical to the development of accurate forecasts and useful forecast products which meet information needs.
- The development of relationships between stakeholders is vital for the effective design and delivery of the system which requires input and participation from a diverse range of actors.
- An understanding of existing relationships, mandates, and requirements, as well the leadership and skills to navigate complex institutional landscapes and build trust and alignment between partners is essential.

LIMITATIONS AND OUTSTANDING CHALLENGES

- The current prototype system is only being tested in two study sites in India. The forecasts and the system are still in an experimental testing phase.
- Significant time, resources and efforts will be needed to develop a robust forecasting and early warning system to cover the areas of India in need of LEWS.
- Moving from the prototype system into operational systems will require a period of testing, engagement, and upskilling of stakeholders.
- To develop regional LEWS to cover the whole country, the large spatial size of India will require training and resourcing of regional units within the NLFC as well as generation of new landslide observation data and development of regionally-specific forecast models.
- The NLFC will likely face a challenge in balancing the need to develop accurate forecast models and products, set up institutionally robust stakeholder systems with clear roles and responsibilities, whilst also experiencing continued pressure to supply actionable, accurate, and useful information as soon as possible as landslides continue to impact people on a regular basis in this highly landslide-prone environment.

FURTHER READING

- Ogra, A., Donovan, A., Adamson, G., Viswanathan, K. R. and Budimir, M. 2021. Exploring the gap between policy and action in Disaster Risk Reduction: A case study from India, *International Journal of Disaster Risk Reduction*. 63, 102428 https://doi.org/10.1016/j.ijdrr.2021.102428
- Sneddon, A. 2021. *Putting science into practice for improved disaster resilience*, SHEAR Knowledge Broker. https://www.preventionweb.net/publication/putting-science-practice-improved-disaster-resilience
- Budimir, M., Sneddon, A., Nelder, I., Brown, S., Donovan, A. and Speight, L. (in review). Development of forecast information for institutional decision makers: landslides for India and cyclones for Mozambique, *Geoscience Communication*.

CITATION

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