LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Introduction

Nilgiris, Tamil Nadu, India. Credit: BGS © UKRI.

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 landslide forecast bulletin and contains the following sections:

- Introduction (this page).
- Part A: Key components.
- Part B: The evolution of the bulletin.
- Part C: The LANDSLIP Decision Support Dashboard.
- Part D: SOPs for producing bulletins.
- Conclusion and recommendations.

INTRODUCTION TO THIS KNOWLEDGE PRODUCT

Within the context of a regional-scale landslide forecasting system, complex multidisciplinary data needs to come together to inform decision makers, in this case, sub-national government.

For the LANDSLIP project, the National Geological Entity (Geological Survey of India (GSI)), the nodal agency for landslides in India, aimed to produce a daily forecast that would be delivered to sub-national stakeholders in two study areas (Darjeeling, West Bengal; The Nilgiris, Tamil Nadu) in the form of a prototype daily landslide forecast bulletin.

This document provides an overview of this landslide forecast bulletin, highlighting its core content, the science underpinning the bulletin, its evolution, and related data management and decision support tools. It concludes with a summary of recommendations for others interested in landslide risk management, data management, decision-making and risk communication.

WHY THIS TOPIC IS IMPORTANT

As we attempt to tackle more complex risk management, including landslide forecasting, we need to consider how complex data sets can be brought together to inform decision making. A landslide forecast bulletin is intended to be a user-friendly way of communicating landslide risk information to enable more informed action on the ground.

The bulletin has become a central and critical area of focus in LANDSLIP. Roles and responsibilities have been agreed, with the Geological Survey of India tasked as the bulletin's custodian. GSI have produced experimental bulletins for limited distribution to sub-national government, on a daily basis, during the 2020 and 2021 monsoon seasons.

Natural Environment Research Council

Research funding from UK NERC and FCDO under the SHEAR programme grant LANDSLIP (Landslide multi-hazard risk assessment, preparedness and early warning in South Asia integrating meteorology, landscape and society). (Grant Numbers NE/P000681/1 NE/P000649/1).

Foreign, Commonwealth & Development Office

Examples of typical landslides found within the LANDSLIP study areas.

LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Part A: Key components

A1 OVERVIEW

A forecast bulletin helps to synthesise complex scientific information into easily digestible content to enable actions to be taken more effectively. LANDSLIP's prototype regional landslide forecast bulletin was produced daily throughout the monsoon season (June to November) for two pilot locations. This two-page bulletin contained the following key components:

1. The short-range landslide forecast map (section A2)
2. The short-range landslide forecast narrative (section A3)
3. The medium-range landslide forecast (section A4)
4. The landslide susceptibility map (section A5)
5. Important information section (section A6)


Nilgiris, Tamil Nadu, India. Credit: BGS © UKRI.

A2 THE SHORT-RANGE LANDSLIDE FORECAST MAP

Short-range forecast maps (for both 24 hr and 48 hr) are provided with geographical administrative zones (**Fig. A1**) coloured according to the landslide forecast level (likelihood of landslides, green through to red).

The date & time of the bulletin issuance and forecast validity period is clearly displayed to avoid confusion.

Forecast level	Description
Very high	**Very high possibility** of occurrences of landslides in **many locations (widespread)**.
High	**High possibility** of occurrences of landslides in **one or many locations (localised)**.
Moderate	**Moderate possibility** of occurrences of landslides
Low	**Low possibility** of occurrences of landslides, a **few small landslides may occur**

Figure A2 Forecast level and description.

Parts of the study area are flat, so would not be subject to landsliding and are consequently marked with parallel diagonal lines.

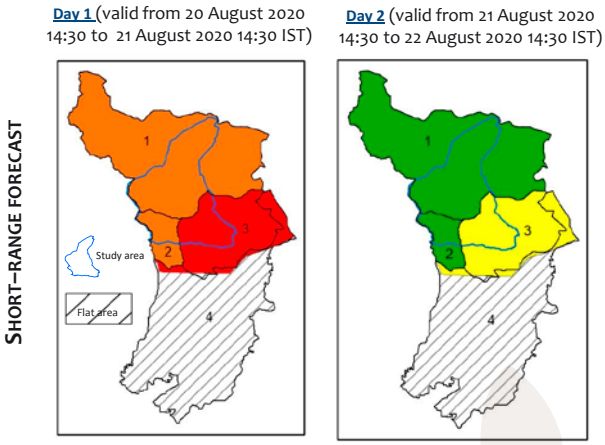


Figure A1 Example short-range forecast maps and forecast key.

The modelled forecasts (viewed by the landslide forecasting team) are translated to produce the bulletin using forecast index levels, determined through testing and evaluation during the pre-operational stages (or research mode) of the Landslide Early Warning System (LEWS). The criteria used to determine which index level to use is documented through a Standard Operating Procedure (SOP) to ensure a consistent approach across the forecasting team.

Evaluation needs to be repeated regularly and particularly during the early years as the LEWS is established. This evaluation requires robust data about landslide occurrence.

One landslide forecast level is assigned to each sub-district administrative area. These administrative areas are numbered on the map and linked to an index which is included in the bulletin (**Fig. A2**).

A3 THE SHORT-RANGE LANDSLIDE FORECAST NARRATIVE

Day 1: • **Very High possibility of landslide** occurrences in Kuresong and Siliguri (hilly areas) sub-divisions. Widespread/Multiple landslides may occur in the entire above two sub-divisions. • **High possibility of landslide** occurrences in Darjeeling-Sadar and Mirik sub-divisions. Multiple landslides may occur in entire two sub-divisions.

Day 2: : • **Moderate possibility of landslide** occurrences **in entire Kuresong and Siliguri (hilly areas) sub-division.**
• **Low possibility of landslide** occurrences in Darjeeling-Sadar and Mirik sub-divisions, however untreated modified slopes (road/settlement cuts) are prone to failure.

Figure A3 Detail about the confidence and accuracy of forecasts.

Under each forecast map, a descriptive interpretation is provided (**Fig. A3**). This narrative includes more nuanced, detailed descriptions of sub-district variations in landslide likelihood.

A4 THE MEDIUM-RANGE LANDSLIDE FORECAST

On the lower half of page 1 of the landslide bulletin, medium-range forecast information is provided in text format (**Fig. A4**).

This provides information on weather patterns associated with landslides that are likely to occur in the coming 15 days and any changes to those weather patterns.

MEDIUM–RANGE FORECAST

Valid from 22 August (14:30 IST) to 03 September 2020 (24:00IST)

On 22 August there is a low possibility of occurrence of a weather pattern that can be associated with landslide occurrence and after that the possibility will increases to **high** till **29th August 2020.**

The period from **30 August to 03 September 2020** there is a **moderate possibility** of occurrence of weather pattern that can be associated with landslide occurrence.

Figure A4 Example text from the experimental landslide forecast bulletin for the medium-range forecast.

A5 THE LANDSLIDE SUSCEPTIBILITY MAP

The landslide susceptibility map on the second page of the landslide bulletin is a static map (**Fig. A5**). This map shows where landslides are most likely to occur based on the underlying proclivity to shallow landslide occurrence as understood by a geological interpretation. The susceptibility map was created by analysing underlying existing factors known to increase the likelihood of landslides. Examples of factors include slopes, vegetation, slope forming material and geology. These factors are compared to known landslide occurrences in the past.

The map can be used to identify 'pockets' of significantly higher or lower spatial areas susceptible to landslides. Using these alongside the 24 hr and 48 hr landslide forecast maps can help to identify areas more or less prone to future landslide occurrences.

A larger version of the map has been distributed in paper form to the District authorities in the two study areas, who can use the map to further inform their decision-making following receipt of the daily forecast bulletin.

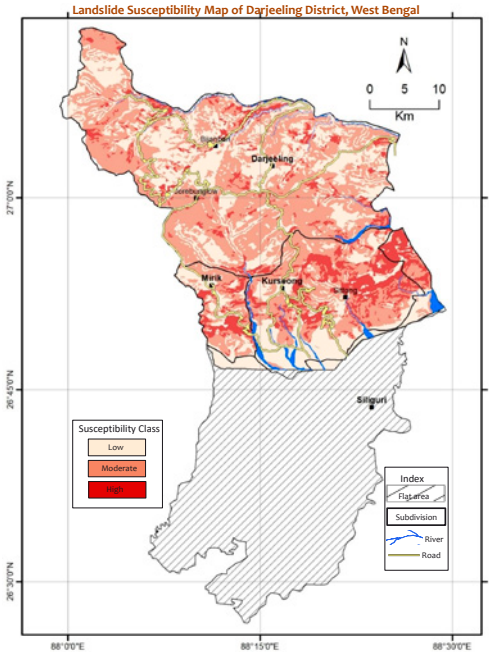


Figure A5 Detailed, static, landslide susceptibility map. Landslide susceptibility data © Geological Survey of India.

A6 IMPORTANT INFORMATION SECTION

Important Information

- There is a certain level of **uncertainty in the landslide forecast, rainfall forecast,** and **landslide susceptibility maps.**
- The landslide forecast information only covers **shallow landslides caused by rainfall.**
- **Landslides** caused or influenced **by earthquakes or human activity** are not covered in this forecast information.
- The **landslide susceptibility map** is **based on 2012 land use condition** and hence any changes in land use pattern, particularly modification of slope may locally increase or decrease the susceptibility.
- Landslides caused **by localised cloud burst rainfall events** are difficult to forecast and are unlikely to be represented in the forecast.

Even at low forecast levels, landslides may still occur

Figure A6 Detail about the confidence and accuracy of forecasts.

The bulletin contains an important information box (**Fig. A6**). The box contains text on how the bulletin should and should not be interpreted and some general limitations of use.

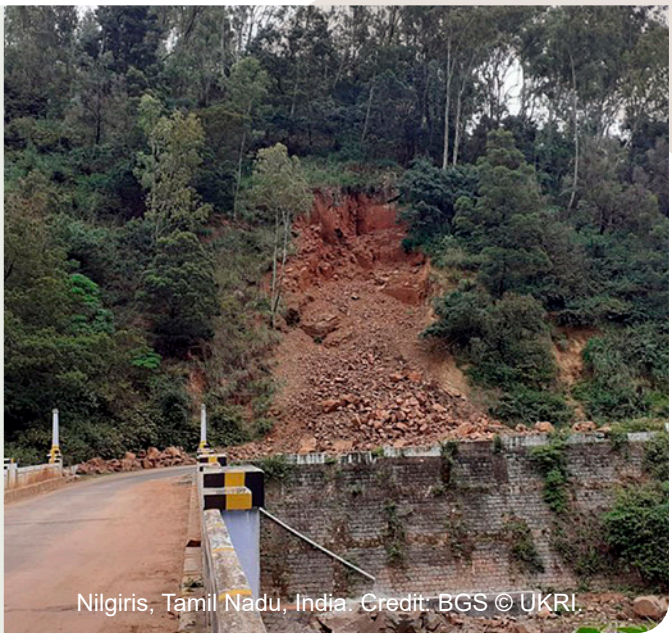
LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Part B: The evolution of the bulletin

B1 OVERVIEW

The structure, presentation and content included in the landslide forecast bulletin (providing prototype forecasts for two regions of India) shifted through a series of iterations. These iterations adapted the bulletins to enable effective decision making for early warning or early action. This section of the Knowledge Product (Part B) outlines five aspects of bulletin evolution:

1. Co-design through iterative development (section B2)
2. Bulletin visuals (section B3)
3. Information and language (section B4)
4. Information versus advice (section B5)
5. Multi-disciplinary team (section B6)



Nilgiris, Tamil Nadu, India. Credit: BGS © UKRI.

B2 CO-DESIGN THROUGH ITERATIVE DEVELOPMENT

Co-designing a forecast bulletin enables long term partnerships between scientists, local actors and practitioners to develop. Such relationships can lead to greater understanding (including limitations and uncertainties) of the forecast information, but also an increased awareness of recipients needs and requirements. Trust is developed.

The landslide bulletin evolved through several iterations. Decisions about whether to include, exclude or adapt certain types of content or information were taken in response to feedback.

Feedback was obtained through facilitated discussion between recipients (District Authorities) and producers (Geological Survey of India (GSI)) of the bulletin. Several meetings and workshops were held where stakeholders were invited to share thoughts or help identify potential areas within the bulletin where information was not valuable, not clear, or potentially dangerous or misleading.

Feedback from bulletin producers and bulletin users shaped the understanding of what information was understandable, relevant and useful for informing user action, with a shift away from technical jargon.

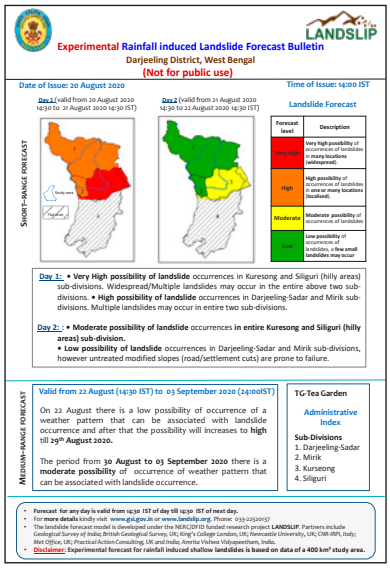
B3 BULLETIN VISUALS

Through this co-design, the supplementary weather forecast maps were removed from the bulletin. It focused instead on providing landslide forecast maps to avoid confusion between two different types of 'forecast' maps.

The landslide bulletins adopted the Indian Meteorological Department (IMD) traffic light colour scheme for their landslide forecast levels to align with user's familiarity (**Fig. B1**).

The static landslide susceptibility map was subsequently changed to a different colour scheme (greyscale, then switched to shades of red) to avoid confusion between forecast and susceptibility information.

Visualisations were accompanied by simple text explaining the maps and providing more detail to aid interpretation. Explanatory text was essential to enable users to understand the context and meaning of the bulletin's maps and colours.



Experimental Rainfall induced Landslide Forecast Bulletin
Darjeeling District, West Bengal
(Not for public use)

Date of Issue: 20 August 2020 — Time of Issue: 14:00 IST

Day 1 (valid from 20 August 2020 14:30 to 21 August 2020 14:30 IST) — Day 2 (valid from 21 August 2020 14:30 to 22 August 2020 14:30 IST) — Landslide Forecast

Forecast level	Description
Very High	Very high possibility of occurrences of landslides in many locations (widespread)
High	High possibility of occurrences of landslides in one or many locations (localised)
Moderate	Moderate possibility of occurrences of landslides
Low	Low possibility of occurrences of landslides, a few small landslides may occur

SHORT-RANGE FORECAST

Day 1: • Very High possibility of landslide occurrences in Kurseong and Siliguri (hilly areas) sub-divisions. Widespread/Multiple landslides may occur in the entire above two sub-divisions. • High possibility of landslide occurrences in Darjeeling-Sadar and Mirik sub-divisions. Multiple landslides may occur in entire two sub-divisions.

Day 2 : • Moderate possibility of landslide occurrences in entire Kurseong and Siliguri (hilly areas) sub-division.
• Low possibility of landslide occurrences in Darjeeling-Sadar and Mirik sub-divisions, however untreated modified slopes (road/settlement cuts) are prone to failure.

MEDIUM-RANGE FORECAST

Valid from 22 August (14:30 IST) to 03 September 2020 (24:00IST)

On 22 August there is a low possibility of occurrence of a weather pattern that can be associated with landslide occurrence and after that the possibility will increases to high till 29th August 2020.

The period from 30 August to 03 September 2020 there is a moderate possibility of occurrence of weather pattern that can be associated with landslide occurrence.

TG-Tea Garden

Administrative Index

Sub-Divisions
1. Darjeeling-Sadar
2. Mirik
3. Kurseong
4. Siliguri

- Forecast for any day is valid from 14:30 IST of day till 14:30 IST of next day.
- For more details kindly visit: www.gsi.gov.in or www.landslip.org. Phone: 033-22520157
- The landslide forecast model is developed under the NERC/DFID funded research project LANDSLIP. Partners include Geological Survey of India; British Geological Survey, UK; King's College London, UK; Newcastle University, UK; CNR-IRPI, Italy; Met Office, UK; Practical Action Consulting, UK and India; Amrita Vishwa Vidyapeetham, India.
- Disclaimer: Experimental forecast for rainfall induced shallow landslides is based on data of a 400 km² study area.

Figure B1 Page one of the Indian landslide forecast bulletin.

B4 INFORMATION AND LANGUAGE

Exposure and vulnerability information: One of the first and most significant changes to the LANDSLIP bulletin was not to include exposure and vulnerability information within the bulletin. LANDSLIP members and stakeholders noted challenges in assessing the exposure of assets and infrastructure to landslides and keeping exposure and vulnerability information up to date, especially at a national scale. There were also ethical concerns about providing information that could influence the allocation of resources in a way that could drive additional risk and vulnerability. It was agreed that local actors would have the greatest insight into specific vulnerabilities at any given time.

Landslide impact Information: Perspectives varied on whether information about the potential impact of landsliding (e.g. to people, infrastructure) should be included in the bulletin.

- Decision-makers at national and district level requested information about the impacts of the forecasted landslides; however, this could not be provided given the spatial resolution of the regional forecast data available.
- Those producing the bulletin highlighted the issues around including impact information that was either too general to be useful for making decisions or risked misinformed decisions due to the uncertainty of the information, especially regarding spatial and temporal resolution.
- An alternative perspective was discussed that included conveying example impact information as illustrations of potential damage caused by landslides as a useful preparedness tool for decision-makers.

LANDSLIP decided that the bulletin producers (GSI), would focus on conveying the likelihood of landslides, with the user (District Authorities) being better placed to understand the local exposure and vulnerability context to determine a suitable local response. Selected key locations and features were added to the maps so that users could interpret locations easier.

B5 INFORMATION VERSUS ADVICE

A critical discussion point was around whether advice or warnings should be provided in the bulletins. Discussions on the mandate to provide advice also took place. There was a tension between a desire to simplify complex risk information, and the need to avoid oversimplification, which could lead to decisions being made based on a flawed understanding of the risk and uncertainties.

The LANDSLIP project members reflected on the need to balance the expectations of users to provide advice with the uncertainty and the low-resolution scale of the available regional forecast, along with the capacity of users to take action. Given this, and the professional expertise of the bulletin producers, the consortium agreed to avoid terminology in the bulletin that provided warnings and advice to end users, but focus on communicating the landslide hazard forecast itself so that end-users could translate this to determine appropriate local action and/or advice.

B6 MULTI-DISCIPLINARY TEAM

A diverse range of expertise was key to supporting the development of a useful bulletin.

Team members brought expertise from different physical science fields, experience of operational forecasting, and skills in science communication. Physical and social scientific expertise informed and supported each other rather than working in isolation.

Critical skills included understanding forecasting models, their limitations and outputs; understanding the technical operational requirements for generating the information for the bulletin; and understanding how to communicate the information effectively.

East Sikkim, Sikkim, India. Credit: BGS © UKRI.

LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Part C: The LANDSLIP Decision Support Dashboard

C1 OVERVIEW

The different datasets underpinning the bulletin are managed within a prototype 'dashboard'.

This online decision support system brings together the model outputs and information that the landslide forecaster requires to produce the landslide forecast bulletin.

The dashboard has different interfaces which bring together the wealth of knowledge and data available to support forecasting decisions.

This section of the Knowledge Product (Part C) provides an overview of the key components (interfaces) of the dashboard and outlines some of the technologies and skills used in its development.

Reviewing the dashboard, Kolkata, India. Credit: BGS © UKRI.

C2 THE SPATIAL INTERFACE AND SHORT-RANGE LANDSLIDE FORECAST

The spatial interface (**Fig. C1**) brings together location-specific data into a web-enabled Geographical Information System (GIS). Where data is also temporal in nature (e.g. from weather forecasts), this is included in this interface.

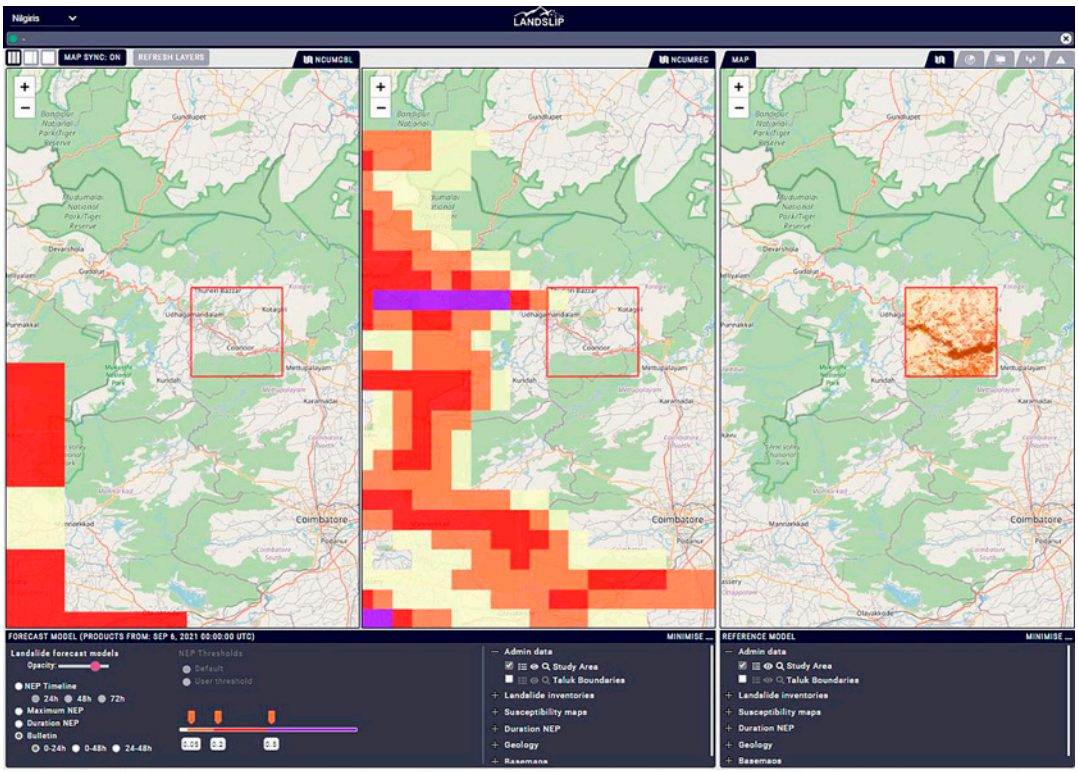


Figure C1 The Spatial Data Interface within the Prototype Decision Support System. Base map © OpenStreetMap.

The landslide forecaster can view up to three data windows side-by-side. The windows can be synchronised so that the data is shown in the same extent and scale. This interface enables the landslide forecaster to see temporal outputs from different short-range forecast models (e.g. data derived from global and regional weather models) alongside, as well as over the top of, more static information, such as landslide susceptibility maps.

The forecaster can amend the visualisation of the non-exceedance probability (NEP) thresholds for the short-range forecast data, and view the forecast models for the 24 hr, 48 hr and 72 hr timesteps.

C3 THE MEDIUM-RANGE LANDSLIDE FORECAST

The medium-range forecast helps the forecaster consider whether the forthcoming weather patterns during the next 15 days are likely to result in potential landslide events (**Fig. C2**).

Within the dashboard there are links to the medium-range landslide forecast tool (Landslide Decider Product) and associated guidance information (**Fig. C3**).

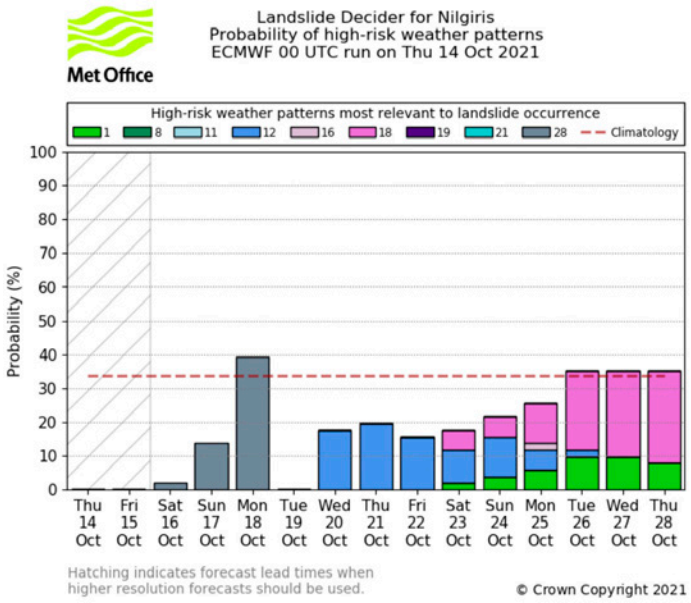


Figure C2 Landslide Decider information to support medium-range forecast.

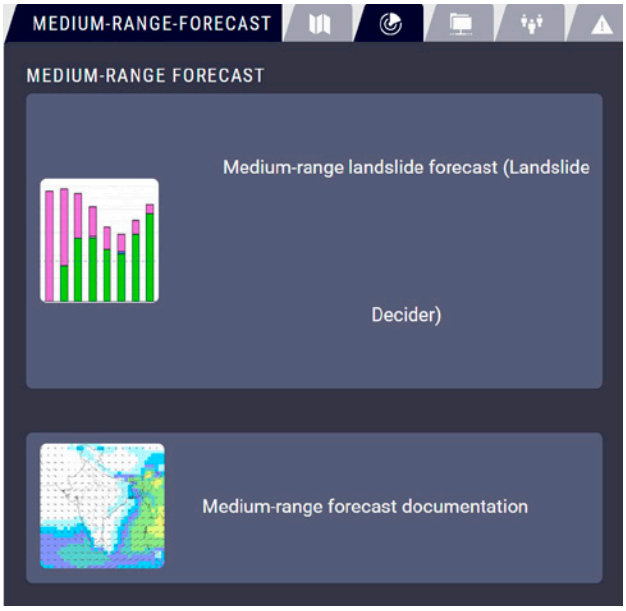


Figure C3 Medium-range forecast interface.

C4 NOTIFICATIONS INTERFACE

A notifications interface (**Fig. C4**) provides all users (forecasters) with essential information about system updates or outage of services that may impact bulletin production.

The notifications are also provided as a ribbon above the spatial interface.

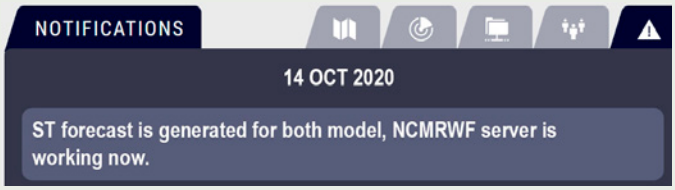


Figure C4 The notifications interface.

C5 DOCUMENTATION STORE AND SOCIAL MEDIA INTERFACE

There is provision within the prototype dashboard for a documentation store. This store enables users to access documents, such as Standard Operating Procedures (SOPs), from a file repository. A further interface has the potential to link to information retrieved from social media.

C6 TECHNOLOGIES USED

The prototype dashboard was built using open source technologies. This enables it to be shared and further developed without the need for partners to purchase proprietary software. Gitlab is used to store the code with continuous integration/deployment pipelines used to deploy Docker containers into a production environment.

GeoServer uses Docker containers to serve the spatial data, reverse proxy and frontend interface. A proficient understanding of the Angular.js framework is required, Unix and web programming languages for software development (e.g. JavaScript) are imperative to maintain the codebase.

LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Part D: SOPs for producing bulletins

D1 OVERVIEW

Interpreting forecast information and communicating effectively with decision makers is a complex process. A robust early warning or forecasting system requires Standard Operating Procedures (SOPs). SOPs for bulletin production ensures those producing bulletins follow:

- Clear steps in reviewing the complex datasets held within the Decision Support Dashboard.
- A consistent approach to transforming the underpinning data and modelling into the two-page daily bulletin.

This section of the Knowledge Product (Part D) outlines the components of LANDSLIP's SOPs for producing daily forecast landslide bulletins.

Darjeeling, West Bengal. © SaveTheHills.

D2 WHAT IS A STANDARD OPERATING PROCEDURE?

Standard Operation Procedures (SOPs) aim to provide consistent guidance and clearly written instructions that document a routine or repetitive activity (US EPA, 2007). SOPs are 'living' documents and need to be reviewed and refined over time to ensure they are fit for purpose and adapt to change.

A key component of any evaluation is learning from users' feedback and adapting to external environment changes. SOPs should be updated based on (i) feedback received from users, (ii) new research or advice on best practice for communicating forecast information, (iii) changes to communication or disaster risk management protocols. SOPs can be edited to include new information in the future. How feedback is to be gathered can also form part of the SOP.

In LANDSLIP, the SOPs for producing the landslide forecasting bulletin are reviewed and updated by the forecasting team at the Geological Survey of India (GSI) as the prototype forecasting system evolves and is evaluated.

D3 SOP FOR LANDSLIDE EARLY FORECASTING BULLETIN PRODUCTION

The process of interpreting forecast information and then communicating it effectively for decision makers to use is complex and nuanced. Regional Landslide Early Warning Systems (LEWS) typically require manual interpretation of the scientific forecasts into useful and usable information products for users. The SOP outlines this process and helps the forecasting team understand their roles and responsibilities and how they should best liaise and communicate with the bulletin recipients.

LANDSLIP's SOPs for producing the landslide forecast bulletin were prioritised to ensure the bulletin's legacy and sustainability beyond the project lifetime by capturing the processes involved. A key challenge for the GSI is the reassignment of staff. Therefore, the SOPs have been created to be usable for future team members who have not been involved in developing the forecasting system and bulletin production previously, in order to continue the process and maintain the quality and consistency of bulletin production.

The SOP outlines the process of how the forecasting team interpret and communicate information effectively for inclusion in a forecast bulletin. A standard template and library of phrases (and when/how to use them in the bulletin) were developed for all production team members to access, thus ensuring consistency is built into the system. Phrases, such as 'very likely', 'likely' and 'possible, may, could', relating to the uncertainty of the forecast were included into this library alongside a description of when to use such language.

SOPs are essential for ensuring consistency across the forecasting team but also from bulletin to bulletin during a given monsoon season.

D4 PREPAREDNESS AND PROTOCOLS

Developing preparedness, protocols, training, and templates in advance (i) ensures that the processes to generate and issue bulletins daily are streamlined, (ii) reduces decision time and potential errors, and (iii) ensures consistency and sustainability of producing forecast information. These resources promote effective communication, coordination and collaboration across different institutions, and guide a systematic way of working.

Once a forecasting system has proven reliable over several years, and moves from a prototype to an operational phase, recipients of the forecast bulletin (the District Authorities), will in turn, require their own SOPs or Early-Action Protocols (EAPs) to translate the forecast into actions on the ground.

D5 SOPs FOR DAILY LANDSLIDE FORECAST BULLETIN PRODUCTION

At the GSI, the landslide team assesses the landslide datasets and information daily during the monsoon season, using a decision support dashboard. The web-based 'dashboard' helps GSI access and interpret the range of model information available, in order to create daily bulletins of landslide forecasts for State and District Authorities. This daily routine is outlined through the following procedural steps:

1. Interpretation of the medium-range weather forecasts and short-range landslide forecasts.
2. Consideration of supportive information including: local context, landslide susceptibility information, nowcast information, new landslide events and previous landslide forecast.
3. Synthesis and discussion of all information.
4. Consensus of forecast levels, maps and text. This includes a procedure for translating the modelled forecasts, visible in the dashboard, into the forecast index level communicated by the bulletin.
5. Production and dissemination of daily bulletin to users.
6. Feedback from users.

Each outline step has detailed information on procedures to be followed for that step. The SOPs are used and followed every day during monsoon periods to produce the daily bulletin with consistent content and language previously co-developed and agreed with users.

D6 DEVELOPING LANDSLIDE FORECAST BULLETIN PRODUCTION SOPS

The landslide forecast bulletin SOP resides with the GSI's landslide forecasting team. The following set of procedural questions were used to help guide the creation of an initial landslide forecast bulletin and its associated SOP.

- What is the daily routine that needs to be followed by the forecasting team member? What models do they need to check and when? What information or data is available and where?
- How are the models interpreted and translated as information in the bulletin? How will the forecasted hazard be defined or delineated? What determines whether it is red, orange, yellow or green in the forecast bulletin?
- What time and how frequently is the bulletin issued? How long is it valid for?
- What internal 'sign off' procedures are required before the bulletin is disseminated?
- Who will issue the bulletin and to whom? How will the bulletin be issued (e.g. email, web page)?
- How do the recipients of the bulletin contact the forecasting team? How do they get further information?
- What communication procedures are in place for when a model is 'off line' and there is a lack of data to issue a bulletin?
- How and when will the SOP be reviewed and updated? How will feedback be collected to inform reviews?

With regular production of the prototype bulletin, the SOP is reviewed and revised to ensure it remains fit-for-purpose.

D7 REFERENCE

United States Environmental Protection Agency. 2007. Guidance for preparing Standard Operating Procedures (SOPs). Available at: https://www.epa.gov/sites/production/files/2015-06/documents/g6-final.pdf. Accessed 24/03/21.

LANDSLIP KNOWLEDGE PRODUCT: The Landslide Forecast Bulletin

Conclusion and recommendations

SUMMARY

This Knowledge Product has outlined the core elements of the prototype daily landslide forecast bulletin produced with the Geological Survey of India (GSI) through the LANDSLIP Project. The bulletin communicates complex information in a user-friendly manner to sub-national decision makers to enable appropriate and timely action on the ground.

KEY LEARNINGS

- Daily landslide forecast bulletins are an important tool for communicating complex landslide forecasts to decision makers (in this case sub-national government).
- The process of co-developing the bulletin in terms of content, layout and presentation was critical. It brought together experts in different data streams, alongside those with knowledge of risk communication and decision support.

RECOMMENDATIONS

- It is important to clarify roles and responsibilities, with one main custodian and producer of the daily landslide forecast bulletin.
- Co-producing a bulletin with those users who receive it, helps ensure a user friendly and usable product.
- Those responsible for producing the bulletin should engage in workshops with users, thus managing expectations of what the bulletin can and cannot do, but also enabling conversations around future improvements.

LIMITATIONS AND OUTSTANDING CHALLENGES

- The current prototype bulletin is shared with only a very limited set of stakeholders, with national stakeholders producing the bulletin and sub-national government receiving the bulletin. This is in order to be able to manage expectations during the experimental, prototype stage, before the model and system has been assessed and evaluated.
- The prototype landslide bulletin focuses on landslide susceptibility, not on landslide risk. As such, it provides limited information about likelihood or severity of impacts. Furthermore, as with any regional landslide forecasting system, the bulletin cannot be used to predict the exact location or timing of a landslide and as such is not suited to enabling site specific evaluation or mitigation.
- The prototype bulletin has been designed with space for future adaptations and innovations, for example, enabling greater integration of novel data sources such as social media generated data or information from future, more complex multi-hazard forecasting models.

FURTHER READING

- Alexander, S., Atsbeha, E., Negatu, S. et al. 2020. Development of an interdisciplinary, multi-method approach to seasonal climate forecast communication at the local scale. *Climatic Change* 162, 2021–2042. https://doi.org/10.1007/s10584-020-02845-9.
- Gill, J. C., Taylor, F. E., Duncan, M. J., Mohadjer, S., Budimir, M., Mdala, H. and Bukachi, V. 2021. Invited perspectives: Building sustainable and resilient communities–recommended actions for natural hazard scientists, *Nat. Hazards Earth Syst. Sci.,* 21, 187–202, https://doi.org/10.5194/nhess-21-187-2021.

CITATION

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