Date of Submission	1 Aug. 2024

IPL Project (IPL - 249) Annual Report Form 2024

1 January 2022 to 31 July 2024

Project Title: (2 lines maximum)

Development of early warning technology for rain-induced rapid and long-traveling landslides in Sri Lanka

1. Main Project Fields

(1) Technology Development

A. Monitoring and Early Warning, B. Hazard Mapping, Vulnerability and Risk Assessment

(2) Targeted Landslides: Mechanisms and Impacts

A. Catastrophic Landslides, B. Landslides Threatening Heritage Sites

(3) Capacity Building

A. Enhancing Human and Institutional Capacities

B. Collating and Disseminating Information/ Knowledge

(4) Mitigation, Preparedness, and Recovery

A. Preparedness, B. Mitigation, C. Recovery

2. Name of Project leader: Kazuo Konagai

Affiliation: (office and position). ICL Headquarters, Kyoto, Japan, Principal Researcher

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E-mail: Kazuo Konagai <kaz3776k@gmail.com>

Core members of the Project

Names/Affiliations: (4 individuals maximum)

Asiri Karunawardena / National Building Research Organization (NBRO), Columbo, Sri Lanka,

A A Virajh Dias / Central Engineering Consultancy Bureau (CECB), Columbo, Sri Lanka,

Kyoji Sasssa / ICL Headquarters, Kyoto, Japan,

Khang Dang / ICL Headquarters, Kyoto, Japan

3. Objectives: (5 lines maximum)

The early warning technology of rain-induced rapid and long-traveling landslides suitable for Sri Lanka is established by integrating newly developed technologies. They are:

(1) Time prediction of heavy rainfalls and pore water pressure buildup

(2) Site prediction of landslide initiations and motions

(3) Effective risk communication and public education

4. Study Area: (2 lines maximum; where will the project be conducted/applied?)

Two pilot study sites are 1) Aranayake in Kegalle District and 2) Athwelthota in Kalutara District, Sri Lanka.

5. Project Duration: (1 line maximum)

from 2019 to 2025

6. **Report**

1) Progress in the project: (30 lines maximum)

Our project was initiated in response to the increasing frequency of Rain-induced Rapid and Long-traveling Landslides (RRLLs) in Sri Lanka. These landslides, often exacerbated by global climate change and human interventions, have led to tragic consequences. Collaborating with ICL and NBRO, we aim to develop an early warning technology to mitigate these risks, leveraging our partners' collective expertise and resources.

The critical technologies to develop in Project RRLL include:

(1) 24-hours-in-advance prediction of heavy rainfalls in mountains
(2) Assessing groundwater pressure buildup, initiation of an RRLL, its flowing dynamics, and
(3) Effective risk communication and public education.

For the (1) 24-hour in-advance prediction of heavy rainfalls in the mountains, we use MSSG (Multi-Scale Simulator for the Geo-Environment) as our generic platform for the weather forecast. MSSG is a state-of-the-art tool that can consider the topographic effect and thus the boundary-layer turbulence that affects the cumulonimbus clouds development, particularly over slopes against the wind. It is, therefore, suitable for better one-day-ahead rainfall predictions, particularly in the mountains.

For (2) Assessing groundwater pressure buildup, researchers at the Disaster Prevention Research Institute (DPRI), Kyoto University, conduct geotechnical centrifuge tests. These tests are instrumental in scale modeling any large-scale nonlinear problem for which gravity is a primary driving force. The successful reproduction of pore pressure buildups in numerical simulations validates our model. To predict RRLL occurrence 24 hours in advance, we use an established numerical tool, LS-Rapid, to simulate initiation, downslope movement, and deposition of a landslide mass.

For (3) effective risk communication and public education, AR software has been developed to combine computer-generated rains and RRLLs with either 2D or 3D map images of the terrain as an augmented reality on screens of computers and smartphones, relaying the predicted events in the last mile. The expected rainfall pattern for the next 24 hours is updated every 3-hour interval. The software uses an interactive time slider, providing more control over viewing timestamps of the predicted information (Fig. 1, next page). Of particular note is that arbitrary layers can be laid over the terrain image.

2) Planned future activities or Statement of completion of the Project (15 lines maximum)

Though there is room for improving individual technologies for rain and RRLL predictions, the augmented reality (AR) viewing websites are ready, and the system runs smoothly. Given this achievement, relevant stakeholders (officers at the regional offices of the Disaster Management Center, Divisional Secretariats, and people at local communities (GNs)) can display their hazard maps as "layers" over the AR image to use the system better. The planned activities for the final year of the five-year project (questionnaire surveys, workshops, town-watching activities, and disaster education at primary and secondary schools and temples) are all for the goal of helping stakeholders develop their layers.

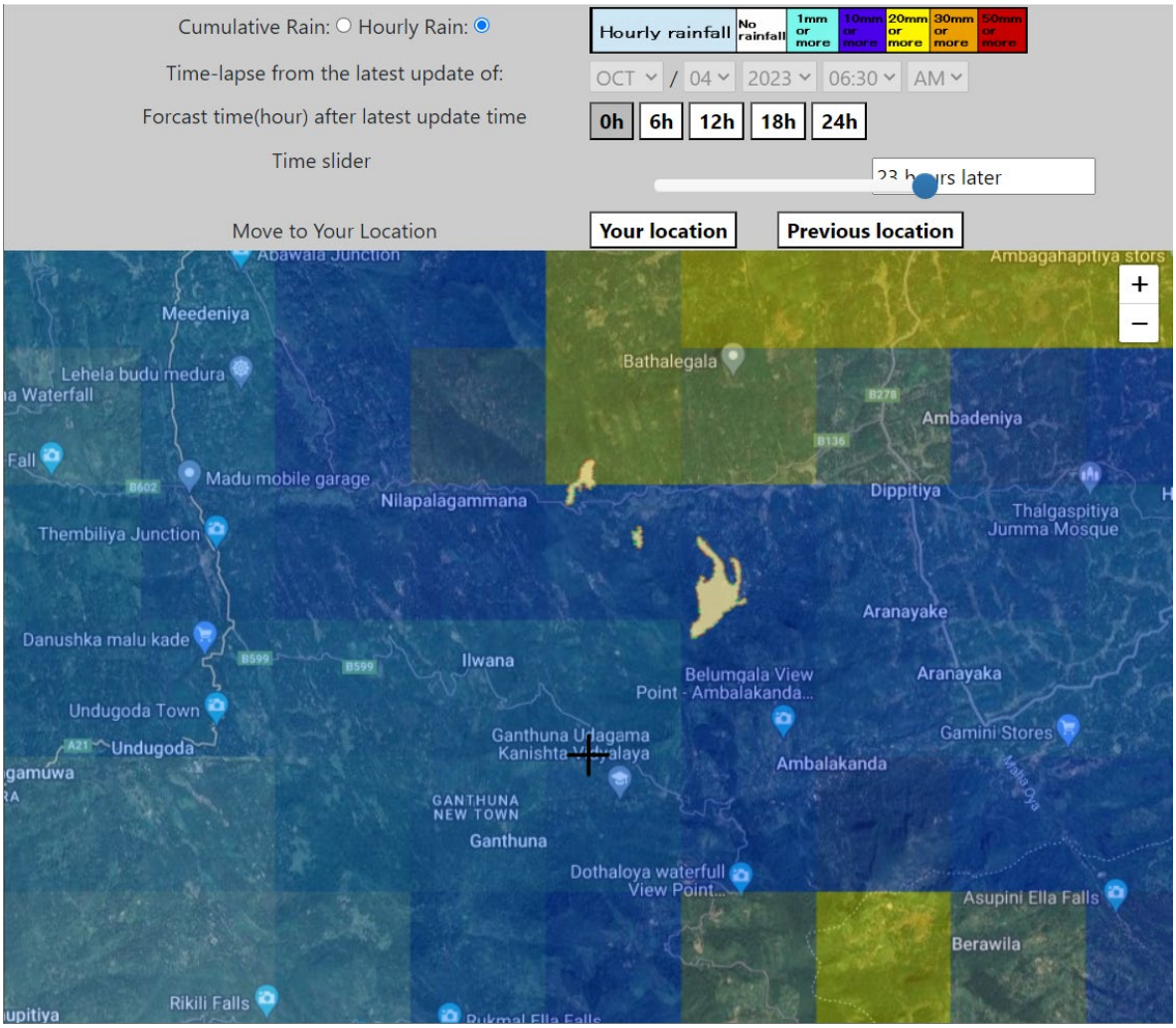

Fig. 1 AR view example for Aranayake area: The predicted rainfall pattern (500 m resolution) for the next 24 hours is updated every 3-hour interval. Polygons show the predicted landslides (Rapid and Rain-induced Long Traveling Landslides, RRLLs).

3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

Out of 25 administrative districts in Sri Lanka, 10 districts, approximately 30% of the island's total land area, are the most prone to landslides. These landslide-prone areas have become the primary areas of tea and cinnamon plantations; thus, about 35% of the population of Sri Lanka has gathered in these areas. So, the most direct beneficiaries are local people working for tea/ cinnamon plantations, those involved in tourism with six of the total eight world heritages in Sri Lanka, etc. In one of our pilot study sites (Aranayake), there are five communities (GN divisions) with a total population of about 5,000. The second pilot site, Athwelthota, has three GN divisions with about 3,000 inhabitants. Also, Beneficiaries include the National Building Organization (NBRO), the counterpart organizations of the project, the Disaster Management Center, the Department of Meteorology, the Department of Irrigation, and administrative agencies such as Districts, Divisional Secretaries, and Central Engineering Consultancy Bureau on the Sri Lankan side.

4) Results: (15 line maximum, e.g., publications)

Publications (see Annexure "Achievements-SATREPS_02.xlsx"):

The following articles have been published:

- Seven articles in "**Landslides"**
- 15 articles in the ICL Open-Access Book Series "**Progress in Landslide Research and Technology**"
- Eight articles in **Understanding and Reducing Landslide Disaster Risk** (https://doi.org/10.1007/978-3-030-60196-6)
- 18 articles in **other journals and books**

Links to the Augmented Reality (AR) views:

Category	Areas	URLs (as of July 22, 2024)
2D views	Aranayake	http://210.150.201.76/maptest/index400.php?AREA_NAME=Area1 (Rains shown in 500 m resolution)
	Athewelthota	http://210.150.201.76/maptest/index400.php?AREA_NAME=Area2 (Rains shown 500 m resolution)
	Central mountainous area	http://210.150.201.76/maptest/index400.php?AREA_NAME=Area1&MESH_SIZE=2000 (Rains shown in 2 km resolution)
3D views only for predicted RRLLs as polygons	Aranayake	http://210.150.201.76/3dtest/prot_test/3d_demo_main30.php?AREA_NAME=Area1
	Athewelthota	http://210.150.201.76/3dtest/prot_test/3d_demo_main30.php?AREA_NAME=Area2