Date of Submission	17 Dec. 2022

IPL Project (IPL - 249) Annual Report Form 2022

1 March 2020 to 31 December 2022

Project Title: (2 lines maximum)

Development of early warning technology of 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
   Contact: (postal address, fax, phone, email): 138-1 Tanaka-Asukai cho, Sakyo-ku, Kyoto 606-8226, Japan, FAX: +81(75) 950 0910, TEL: +81(75)723 0640,
   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 the following newly developed technologies. They are 1) time prediction of heavy rainfalls and pore water pressure build-up, 2) site prediction of landslide initiations and motions, and 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) Aranayaka in Kegalle District and 2) Athwelthota landslide 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, See Konagai et al., 2022)

Influenced by the effects of global climate change and, more seriously, by human-induced interventions in landslide-prone areas, the number of tragic Rain-induced Rapid and Long traveling Landslides (RRLLs) in Sri Lanka has been on a soaring trend in general. In this situation, ICL and NBRO started this project in 2020 after the preceding period of 2019.

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 hours 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 precise weather forecast. MSSG 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 (Fig. 1, Hiruma et al., 2022). The current challenge at the Tokyo Institute of Technology is to run the MSSG on an affordable workstation. To make it possible, a technique to construct rationally new data points from a low-resolution simulation on the workstation is being developed by applying machine learning technology.

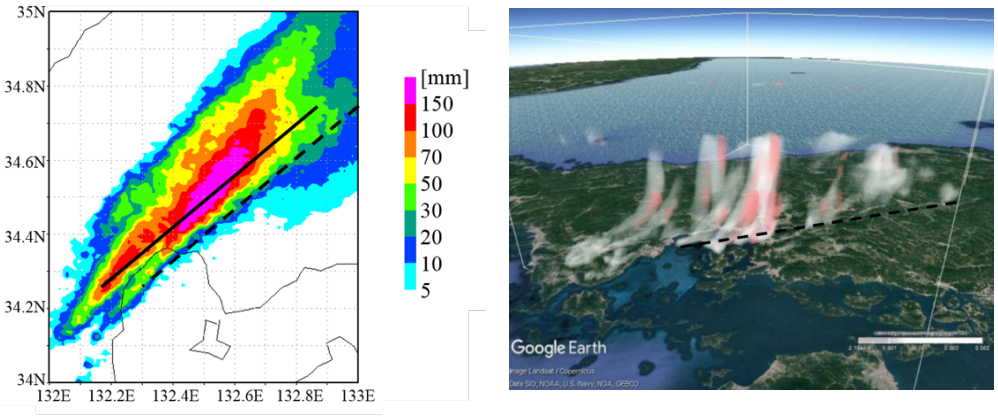

Fig. 1 Successful example of reproduction of a linear rainband developed over a mountainous region in Hiroshima Prefecture, Japan (Hiruma et al., 2022)

For (2) Assessing groundwater pressure buildup, researchers at the Disaster Prevention Research Institute (DPRI), Kyoto University, conduct geotechnical centrifuge tests (Fig. 2), which are helpful for scale modeling of any large-scale nonlinear problem for which gravity is a primary driving force. Of particular note is that the soils from mountain slopes in Sri Lanka are weathered fragments of Pre-Cambrian gneiss rock with fine contents ranging from 30 to 40%. Thus, well-graded sand with the inclusion of silt was used in the experiments. The pore pressure buildups at different soil mass locations were successfully reproduced in numerical simulations, thus validating the numerical model (Sanchitha et al., 2022).

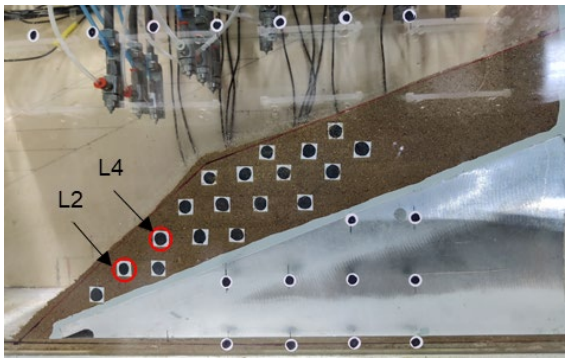

Fig. 2 Slope model prepared in a soil container of the centrifuge at DPRI, Kyoto University, with well-graded sand with the inclusion of silt

For (3) Effective risk communication, the communication tool we develop relays the prediction timely to the last mile as augmented reality dioramas of the potential rains and RRLLs with a terrain image displayed on tablets and PC screens. Developing this Augmented Reality software is underway. The developments of the above key technologies are well on track though it was not until March 2022 that some necessary activities, such as in-situ measurements, etc., that require joint in-person work and discussions, finally started.

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

As said above, under the COVID-19 crisis worldwide, developments of the crucial key technologies for the RRLL EW preceded the others; the others needed in-person meetings. It requires some more time for the RRLL EW system to show its effects because developing the AR software is currently underway. The AR software will show not only potential rains and RRLLs predicted one day in advance but also evacuation centers, routes, and important facilities on the screen of a table. These elements can be taken from the community landslide hazard maps. These maps have been made since 2016, given Official Development Assistance from JICA and having community people directly involved. So, even after the first version of the AR system is completed, it will have to be revised over and over, reflecting the change. For long-term strategic planning for sustainable social implementation, questionary surveys are scheduled for January 2023 and onward.

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

Out of 25 administrative districts in Sri Lanka, ten districts, approximately 30% of the total land area of the Island, are the most prone to landslides. These landslide-prone areas have become the primary area of tea and cinnamon plantations; thus, about 35% of the population of Sri Lanka has gathered in these areas. So, the majority of the 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 5 communities (GN divisions) with a total population of about 5,000. In the second pilot site, Athwelthota, there are 3 GN divisions with about 3,000 inhabitants as a whole. 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)

About Outline and progress:

Konagai K., Karunawardena A, Bandara K.N., Sassa K., Onishi R., Uzuoka R., Asano S., Sasahara K., Sanchitha J., Ariyarathna I. (2022) Early warning system against rainfall-induced landslide in Sri Lanka, *Progress in Landslide Research and Technology*, Volume 1 Issue 1, 2022, https://doi.org/10.1007/978-3-031-16898-7_16

About 24-hours-in-advance prediction of heavy rainfalls in mountains

Hiruma D., Onishi R., Takahashi K. and Fukagata K. (2022) Sensitivity Study on Storm Modulation through a Strategic Use of Consumer Air Conditioners, *Atmospheric Science Letters*, First published: 30 March 2022, https://doi.org/10.1002/asl.1091

About the infiltration process:

Jayakody, S.H.S., Uzuoka, R., Ueda, K. (2022) Centrifuge modelling of silty-sand slopes under intermittent rainfall conditions, *10th International Conference on Physical Modelling in Geotechnics*, September 2022, KAIST, Daejeon, Korea. (in print).

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