Project for Creating Digital Elevation Model Enabling Disaster Resilience in Sri Lanka

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ABSTRACT: The Japan International Cooperation Agency (JICA) LiDAR project aimed to help the disaster risk reduction in the Democratic Socialist Republic of Sri Lanka (Sri Lanka). The Project provides the Digital Elevation Model (DEM) which becomes the source of creating topographic data in disaster prone areas in the Colombo, Gampaha, Nuwara Eliya, Kegalle, parts of Kandy, Budula, Kalutara districts and surrounding areas. The Project started in January 2015 and completed in December 2016. There are two areas depending on the density of LiDAR measurement points. The 1 x 1 meter mesh area has 2,400 km^2, and the 2 x 2 meter mesh area has 5,400 km^2. The 1 x 1 meter mesh areas and the low land areas are accurate of ±30 cm, and the 2 x 2 meter mesh areas have ±50 cm - 100 cm. Some part of the Nuwara Eliya was excluded from the LiDAR survey because of weak GPS signal reception. The data with high vertical accuracy are available for updating topographic maps and preparing disaster management plans for the districts and communities. The JICA Project Team accelerated processing the data and provided to the Survey Department; the data are already in use for analyzing the flood area along the Kelani River and the landslide in Aranayake caused by the tropical storm on May 15, 2016 in Sri Lanka.

1. INTRODUCTION

Sri Lanka is affected by the climate changes, and many natural disasters such as floods and landslides have affected lives and infrastructure. Floods are the major natural disasters that have caused tens of thousands of victims each year according to the records of the Disaster Management Center (DMC). In the central and southwestern areas of Sri Lanka are prone to landslides due to: topographic and geological characteristics; and development and cultivation activities in the mountainous areas. These disasters have affected human lives, destroyed houses and damaged arterial roads; they thus negatively impacted economic activities. Under these circumstances, the Government of Sri Lanka (GOSL) announced a policy on disaster management triggered by the earthquake of Sumatra and tsunami in 2004 to minimize damages proactively rather than reactively. GOSL has enacted "Sri Lanka Disaster Management Act" which became a fundamental framework for activities of mitigation, preparedness, response and recovery in May 2005. The Act created Ministry of Disaster Management and DMC to strengthen organizational structure on disaster prevention and countermeasures against calamities. GOSL has a plan to consolidate early warning arrangements by preparing hazard maps of floods and landslides. In the process of these hazard map preparation, accurate elevation data will be required. The LiDAR technology is the technology to acquire the data efficiently, but such technology is not available in Sri Lanka; therefore, conventional technologies are used unwillingly.

The stated situation has led for the Ministry of Land and Land Development to make an official request to the Government of Japan to transfer the LiDAR survey technology to create DEM that will be used for disaster prevention and related activities. Receiving the request, JICA dispatched a study team for detailed plan preparation from July to August 2014. The Survey Department of Sri Lanka (SDSL) and JICA came to agree on the contents of the project. The objectives of the project are: 1) Preparation of DEM Data; and 2) Technology Transfer on DEM preparation and thematic map preparation.

Figure 1-1 Flood (May 2016)

2. PROJECT AREAS AND SPECIFICATIONS

The major areas of the districts of Colombo and Gampaha, Nuwara Eliya, Kegalle, parts of Kandy, Badulla and the surrounding areas are covered as the project areas. The original project area map is shown below with classifications of DEM processing and accuracy.

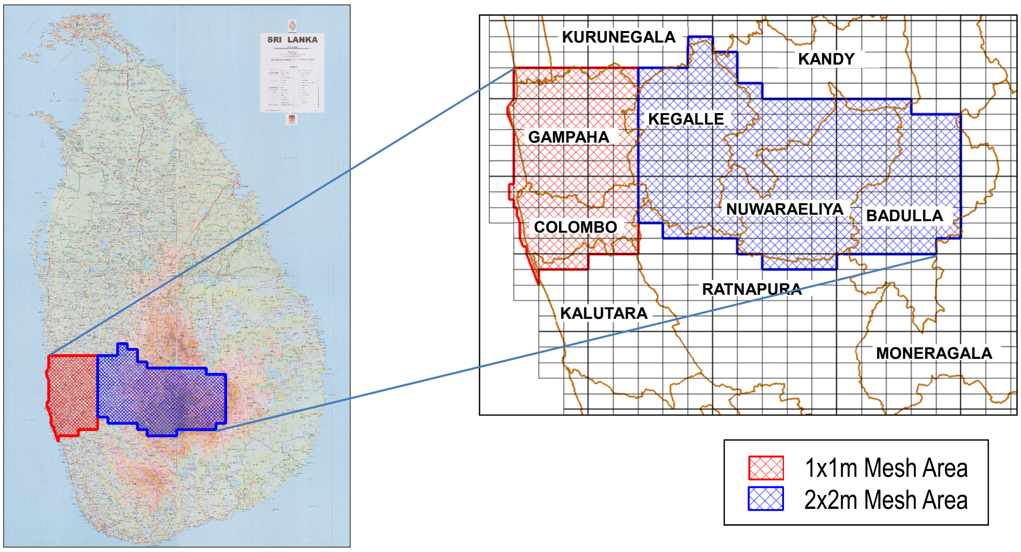

Figure 2-1 The Original Project Areas

On January 22, 2016, the aircraft pilot reported a problem of GNSS signal reception to the Project Team.
The report said that on January 15, 2016, when the LiDAR survey was conducted in the mountainous area in the middle of the survey area, the GPS receiver on board of aircraft was unable to receive the GNSS signals from the satellites in the area bounded with the red painted place on Figure 2-2. After the incident, the aircraft pilot reported that they could not receive the GNSS signals as shown in the flight line chart.

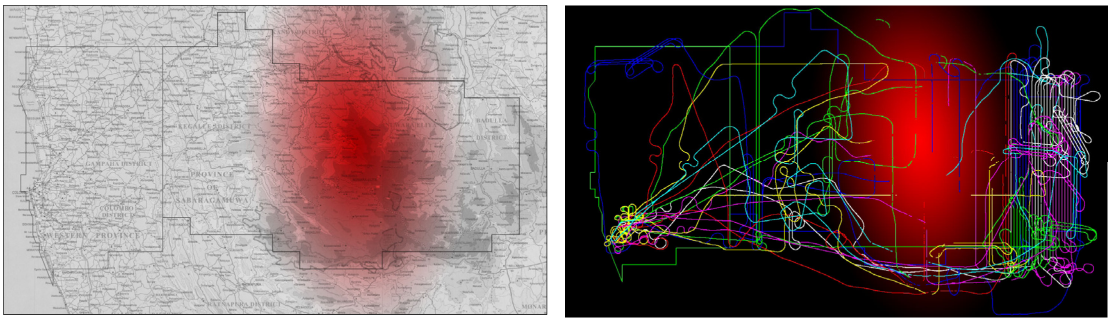

Figure 2-2 Jamming Area

SDSL has been investing the cause since February 12, 2016 as requesting related agencies, but SDSL reported to the Project Team that the cause had not been identified.
SDSL requested to change a part of the survey area to the Project Team on the February 24 and 25, 2016, since any solution has not been reached over the problem of GNSS signal reception. The 900 km^2 area where the LiDAR measurement cannot be conducted because of the jammed GNSS signals would be shifted to the mouth of the Kalu Ganga river and surrounding area and Ingiriya area in the north-eastern area in Kalutara District.
After the amendment of the areas, the total LiDAR Survey area is 7,800 km^2, and the total DEM processing areas is 3,200 km^2. The areas and accuracy corresponding to the areas are summarized in the following table.

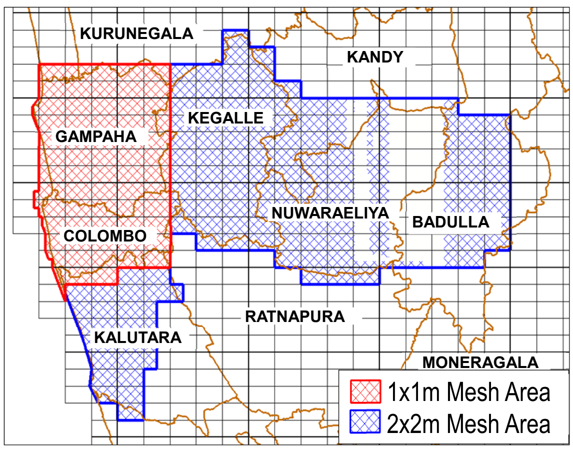

Figure 2-3 Amended LiDAR Survey Areas

Table 2-1 LiDAR Survey and DEM Processing Areas

Locality	DEM mesh size	LiDAR Survey Area	LiDAR Point Density	Vertical Accuracy	Ground Pixel Size on Ortho-photo image
Colombo and Gampaha districts	1 x 1 meter	2,400 km^2	1 point / 1 x 1 meter	±30 cm	30 cm
Other than above	2 x 2 meter	5,400 km^2	1 point / 2 x 2 meter	±50 cm-100 cm	50 cm

3. IMPLEMENTATION OF LiDAR SURVEY AND DEM DATA PREPARATION

3.1 LiDAR Survey

The aircraft and the equipment of the LiDAR survey are summarized in the following table and figure.

Table 3-1 Aircraft Parameters

Item	Parameter	Unit
Type	Piper PA23 Aztec	-
Registration	PH-KED	-
Wingspan	11	m
Length	9.51	m
Power	2 motors 250	HP
Speed	90 to 150	kts
Ceiling	4,200	m
Range	850	nm

Table 3-2 Sensors

Item	Manufacturer	Type
Laser Scanner	IGI	LiteMapper 6800i
Camera	IGI	DigiCam H60

Figure 3-1 Aircraft and Laser Scanner

Table 3-3 LiDAR Survey Parameters

Item	Parameters by area		Unit
	1m x 1m area	2m x 2m area	
Ground elevation	1,040	1,400	m
Ground speed	120	120	kt
Lateral overlap between swaths	40	40	%
Scan angle	60	60	degree
Pulse rate	200	70	kHz
Point density	1.9	0.5	pt/m^2
GSD of photogrammetry	17	23	cm

3.2 DEM Data Preparation

The raw point cloud have been prepared from the raw LiDAR measurement data. After noise removal, the unclassified point cloud were prepared. Automatic filtering processing and interactive-filtering processing were performed to the prepared unclassified point cloud, and the ground data was prepared. The results were visually verified by a data processing engineer. When an error is found, the engineer interactively edits the data to finalize the ground data preparation.

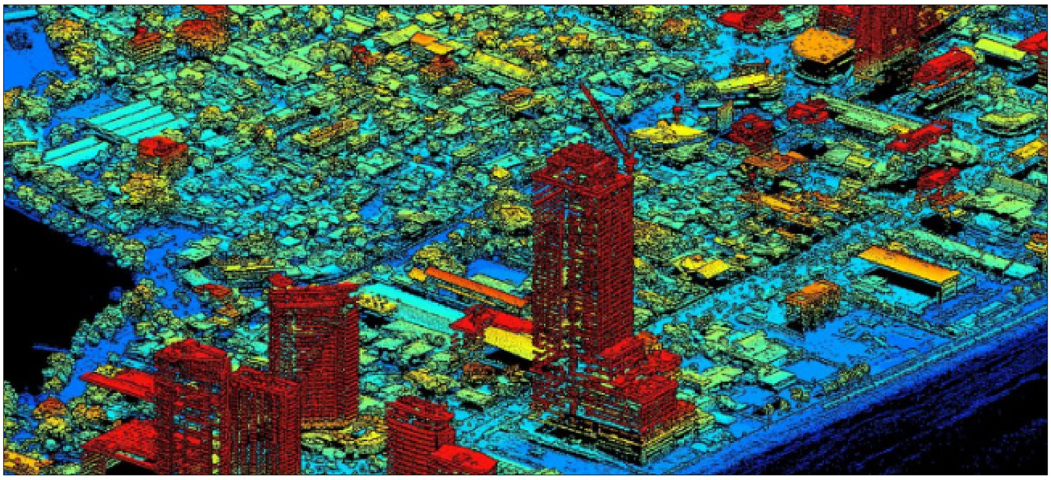

Figure 3-2 An Example of Unclassified point cloud (Bird's-eye view)

Using the ground data, the DEM data, the elevation data of a mesh, were prepared as utilizing the TIN interpolation method.

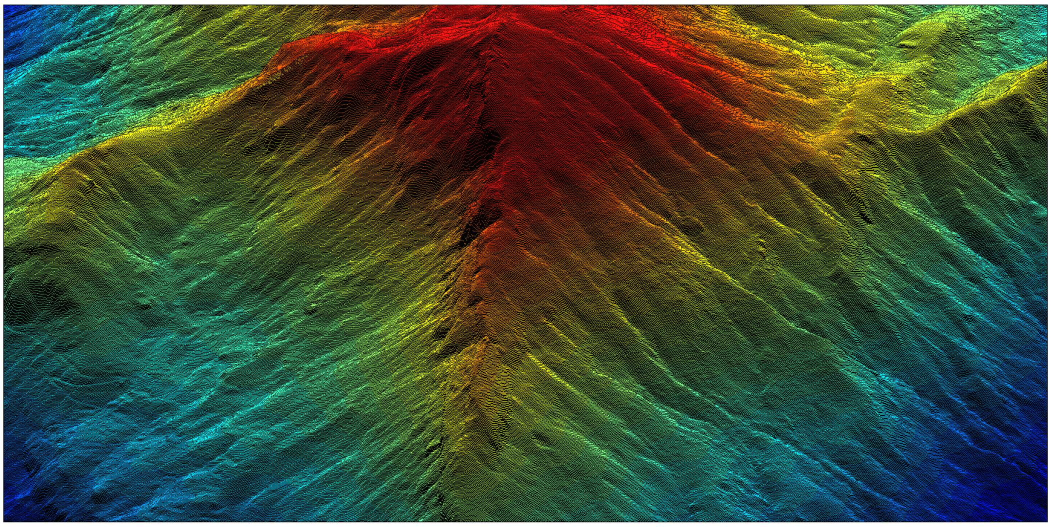

Figure 3-3 An Example of DEM Data (Bird's-eye view)

3.3 Verification of the DEM Data Precision by SDSL

The Project Team has submitted the DEM data of four areas in the 1 m x 1 m mesh area on March 21, 2016. SDSL examined the data as it compared with the leveling data at corresponding locations. SDSL reported that the DEM data satisfied the precision stated in the Specifications as submitting a verification report.

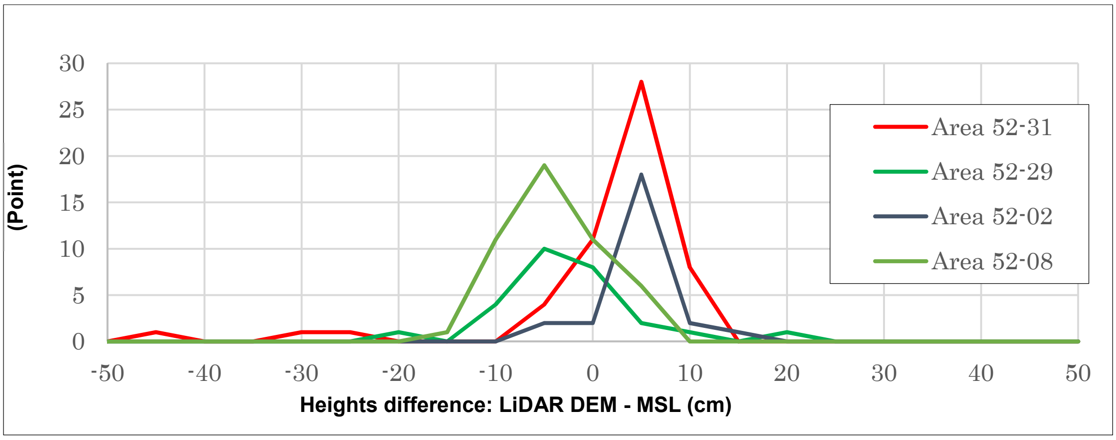

Figure 3-4 Results of Verification of the DEM Data Precision

Table 3-4 Results of Verification of the DEM Data Precision

DEM Data	Validation Point	Heights RMS error	Specifications
Area 52-31	54 points	0.09 m	0.30 m or less
Area 52-29	27 points	0.08 m	
Area 52-02	25 points	0.06 m	
Area 52-08	48 points	0.06 m	

3.4 Contour Line Data Preparation

Using the DEM data, contour line data are generated using a function of software.

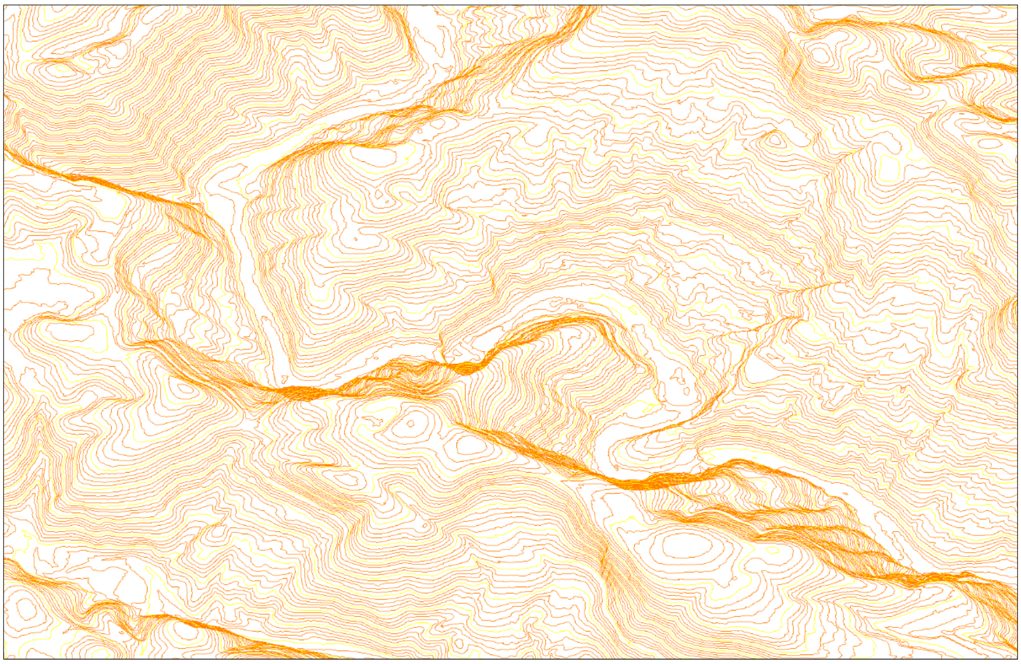

Figure 3-5 An Example of Contour Line Data (Bird's-eye view)

4. TECHNOLOGY TRANSFER

Technology transfer is one of the two objectives of the project. The training program covered all the processes necessary for processing the LiDAR data to produce DEM. SDSL allocated a training room for the Project, and the Project Team and JICA provided the equipment and software. Nine PC with the LiDAR processing software were setup with additional GIS software for thematic mapping. Nine LiDAR data processing engineers with experiences in computer assisted mapping were selected, and the training started in November 2015. Thirteen trainees were added to be trained by the original trainees already acquired the skills. The planning trainees were selected mainly from the Air photo Branch of SDSL. A thematic mapping course was made available to those from the GIS Section. Lecture and hands-on-session were the two major methods of training. In the lecture, the trainees answered questions to ensure the level of comprehension. For the hands-on-session, detailed operation manuals were provided so that they would be able to process the data even after the project. For the thematic mapping training, one trainee was trained to be a trainer. The JICA Project members developed LiDAR data processing manuals for each process of the work. A planning manual was also prepared for those who will be planning for a LiDAR project. All the scheduled training program was completed in May 2015. Additional contour line training was held in July and August 2016. Over 200 sessions were conducted including self-study sessions during the course of technology transfer by August 2016. All the trainees learned how to process the LiDAR data as they refer to the operation manuals. As they teach each other, and the leaders become lecturers and trainers, the LiDAR survey training has been established in SDSL Members from other natural disaster related agencies were invited to the training sessions which were provided by SDSL under the supervision of the JICA project members.

Fifteen members from SDSL practiced in Japan from April 10 to 23, 2016. The main task of the participants were to experience the LiDAR data processing operation in the facility of Nakanihon Air Service Corporation. They visited the hanger of the helicopter and aircraft with the equipment for LiDAR survey. They have also visited: Geospatial Information Authority of Japan (GSI), Japan Association of Surveyors (JAS), Disaster Prevention Research Institute (DPRI) Kyoto University, Asian Disaster Reduction Center (ADRC), Remote Sensing Technology Center of Japan (RESTEC), NTT DATA Corporation, and Japan Aerospace Exploration Agency (JAXA). A permanent GNSS station was another interest for the participants since they are currently in the process of establishing the permanent GNSS stations in Sri Lanka. The effort in Sri Lanka will enable efficient implementation of LiDAR surveys in the near future.

Figure 4-1 Technology transfer

5. RESPONSES TO THE DISASTER

On May 15, 2016 and May 24, 2017, Sri Lanka was hit by tropical storms. The storms caused floods and landslides submerging and destroying homes and facilities. The Colombo district was worst affected by the Kelani river overflow. SDSL soon started surveying the areas which were submerged using DEM data.

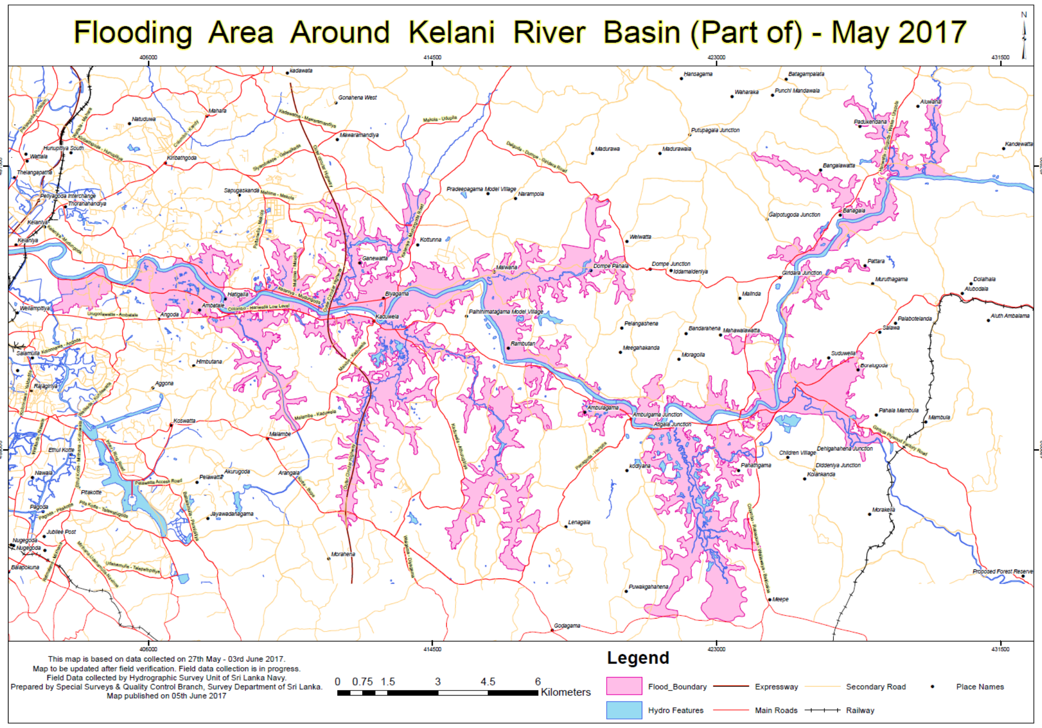

Figure 5-1 Flooding area map

(Source: SDSL, 2017)

In 2016, a landslide in Aranayake has devastated six Grama Niladhari. Over 100 people died and thousands of people were displaced. To study the landslide situation, the JICA experts of the Technical Cooperation for Landslide Mitigation Project has conducted an aerial survey using a helicopter provided by the Government of Sri Lanka. The experts have taken photos and processed the images to produce digital surface model (DSM) after the landslide. The JICA Project Team for the LiDAR survey cooperated with the JICA experts for the landslide mitigation project, and provided the LiDAR DEM data. The JICA experts used the newly acquired date to produce DSM and compared it with the DEM provided by the LiDAR project team. The comparison of data before and after identified amount of debris flow and affected areas. The analysis will facilitate delineation of landslide prone areas currently limited to steep slope areas and/or past landslide areas.

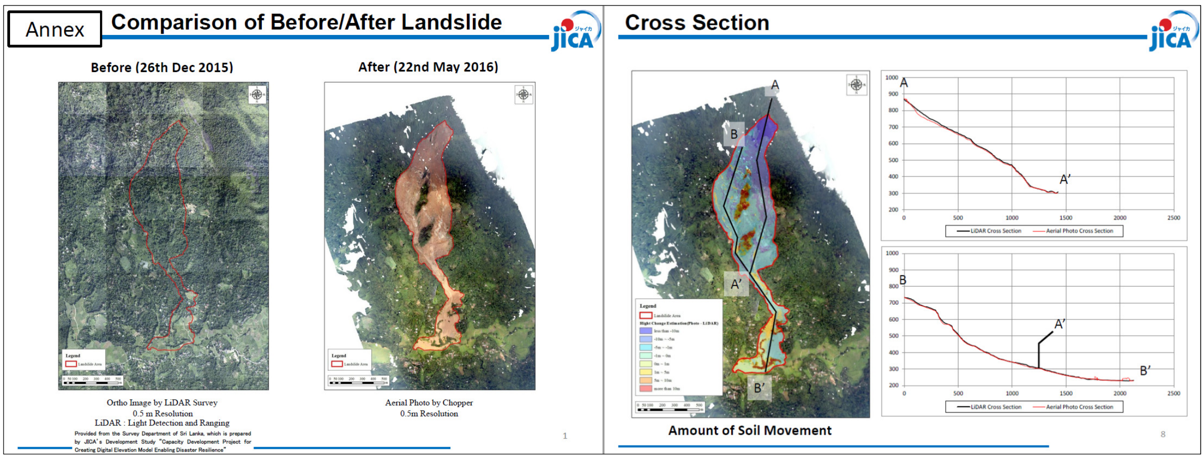

Figure 5-2 Landslide analysis

(Source: Technical Cooperation for Landslide Mitigation Project, JICA, 2016)

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REFERENCE

1. SDSL 2017. *Flooding Area Around Kelani River Basin (Part of) - 27th May - 3rd May 2017*, from http://www.survey.gov.lk/surveyweb/home%20english/kelani_river/Kelaniya_Flood_Map_2017.pdf
2. Technical Cooperation for Landslide Mitigation Project *et al.*, JICA 2016. *22nd May 2016, Aerial Survey report on inundation damages and sediment disasters / Annex*, from https://www.jica.go.jp/srilanka/english/office/topics/c8h0vm00006ufwhl-att/160615.pdf