Mapping the Geometric Characteristics of a Landslide using Airborne Lidar Data

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Abstract *Nearly 20% of the land area in Sri Lanka is identified as landslide prone. The increasing population density and expansion of settlements over hilly areas in Badulla district have significantly increased the risk for landslides. As a result, the urban resilience in these regions has decreased raising substantial threats to livelihood. In this backdrop characterizing and mapping the existing landslide geometry, referring to their longitudinal and cross-sectional profiles and the rate of change of slopes is highly important. These characteristics are vital for land slide zonation mapping. Among the large range of methods and techniques developed for determining landslide zonation mapping most preferred method was the detail collection using ground surveys using methods such as RTK GNSS surveys and topographic surveys. These methods provide the most reliable information about landslide geometry, but they require heavy labour and time. LiDAR technology is capable of acquiring faster, denser and more precise information about land terrain surface, allowing the 3D geometrical modelling of the topography at different scales. LiDAR is mainly used for landslide investigation to create accurate and precise high-resolution digital elevation models (DEM) in raster grids or triangulated irregular networks (TINs), which are 3D point clouds with a high density of information. LiDAR sensor mounted in a drone can be effectively used for mapping these landslide prone areas. Execution of LiDAR surveys systematically to collect the most important details related to landslides is highly important. The main objective of the study is to survey and map the landslides in Badulla district. Two different urban and suburban landslide prone areas along with the Badulla Passara road were mapped using an airborne LiDAR sensor. The generated detailed DEM`s reveal the heavy deformation that exists in these land slides providing the possibility to detail out the land slide geometry. The study details the planning out of the airborne drone surveys and the detailed processing of point cloud data in order to map the landslides. The importance of the study for the first responder such as SLAF is highlighted in case of emergency to warn the population about the threats and evacuation.*

Keywords: *LiDAR, landslide susceptibility map, digital elevation model*

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Introduction

Heavy rainfall has been affecting most parts of Sri Lanka causing landslides and floods that resulted in damage to human lives and properties. Past studies have clearly portrayed that the hill country of Sri Lanka has been exposed to various types of landslide in various geographical settings. The highest impact can be seen in the districts of Badulla, Nuwara Eliya, Kandy and Rathnapura. Thus in this study Landslide-prone areas in the central highlands of Sri Lanka especially on Badulla Passara road have been identified.

There are many experts in the field, proposing various classifications from different perspectives. Those various classifications of landslide are coupled with precise mechanics of failure, properties and characteristics of slope failure (Highland and Bobrowsky, 2008).

Among the large range of methods and techniques developed for determining landslide zonation mapping most preferred method was the detail collection using ground surveys using methods such as RTK GNSS surveys and topographic surveys. These methods provide the most reliable information about landslide geometry, but they require heavy labour and time. LiDAR technology can acquire faster, denser and more precise information about land terrain surface, allowing the 3D geometrical modelling of the topography at different scales. LiDAR is mainly used for landslide investigation to create accurate and precise high-resolution digital elevation models (DEM) in raster grids or triangulated irregular networks (TINs), which are 3D point clouds with a high density of information.

1. Location and Accessibility

The study area is located along the Badulla Passara road and selected two different urban and suburban landslide prone areas Passara town and Meedumpitiya.

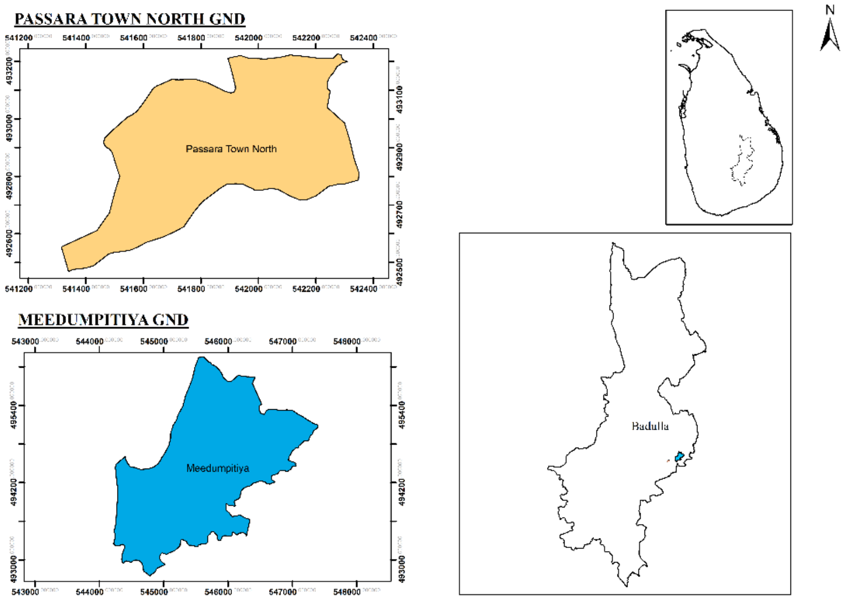

Figure 1: Map of Study Area

2. Material and Method

2.1. Data Acquisition

Light detection and ranging (LiDAR) is a remote sensing technology that emits intense, focused light beams. These laser beams travel at the speed of light and the time taken for the laser to return to the target's position can be determined accurately. It is similar to radar (radio detecting and ranging), except it is based on discrete pulses of laser light. However, accurate digital terrain models (DTM) are necessary for this study. DTM accuracies achieved by Shuttle Radar Topographic Mapping (SRTM; 30 m), and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER; 30 m) compared to LiDAR (±0. 5 m). High resolution DTM and high resolution of derivative maps enable high accuracy and visibility of main landslide features. The landslide body is clearly visible, including the main scarp as well as the zone of accumulation and zone of depletion on topographic derivatives, hill shades and slope maps

Standard LAS files from LiDAR were processed to create DEMs, slope maps, and hill shade DEMs. LAS files are binary files that contain the x, y, z data as well as the classifications of the multiple point returns (ground, trees, buildings, vehicles, power lines, and bridges).

The LiDAR data were acquired by using Zenmuse L1sensor attach to M300 drone. Flight height was maintained 100m to obtain orthomasiac images. To obtain LiDAR data it is required to fly the drone with a constant height above the ground surface. To achieve that Terrain, follow mode was used by using SRTM DEM. Moreover Field data was collected by using High-end GNSS device.

3. Result and Analysis

After capturing the raw LiDAR and RGB images from the site. The data was post processed in order to obtain the lidar points cloud and orthomoasaic. The DJI terra software was used to process the LiDAR data and images. Strip alignment and boresight calibration was carried out by the software during the processing stage

After the LiDAR points cloud was post processed using a post processing software. The z quality was checked using the control points data gathered at the site using the GNSS RTK receiver. Then the ground points classification was carried out. After successful ground points classification using the classified points TIN interpolation method was used to generate a digital elevation model using 0.25 m sampling interval.

Using the digital elevation model with GIS and CAD softwares, cross section analysis, slope analysis, hill shade analysis were carried out. From these deliverables the crown of the slope failures were identified.

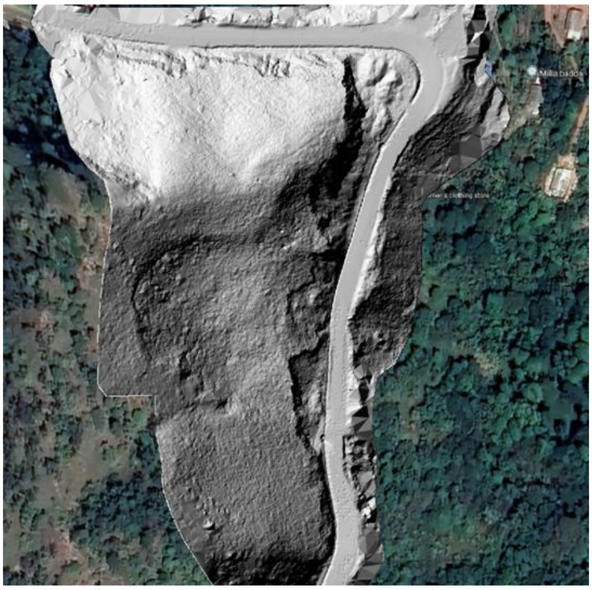

Figure 2: The Hill shade

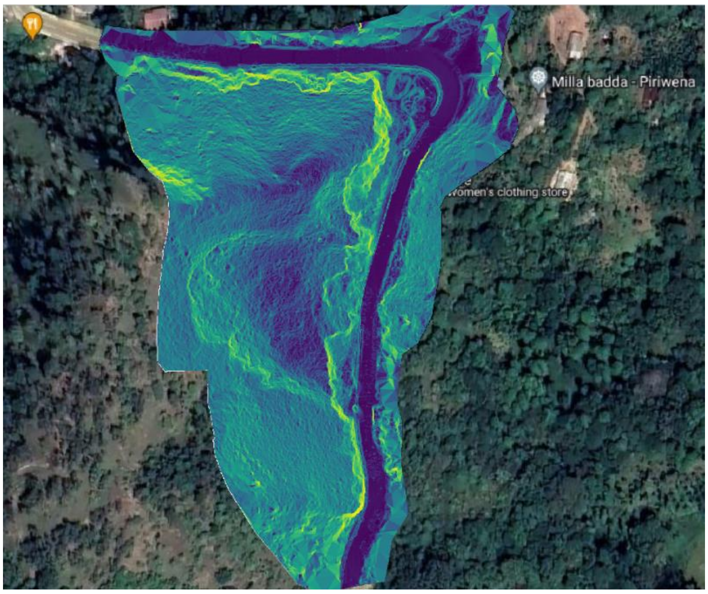

Figure 3: Slope Analysis

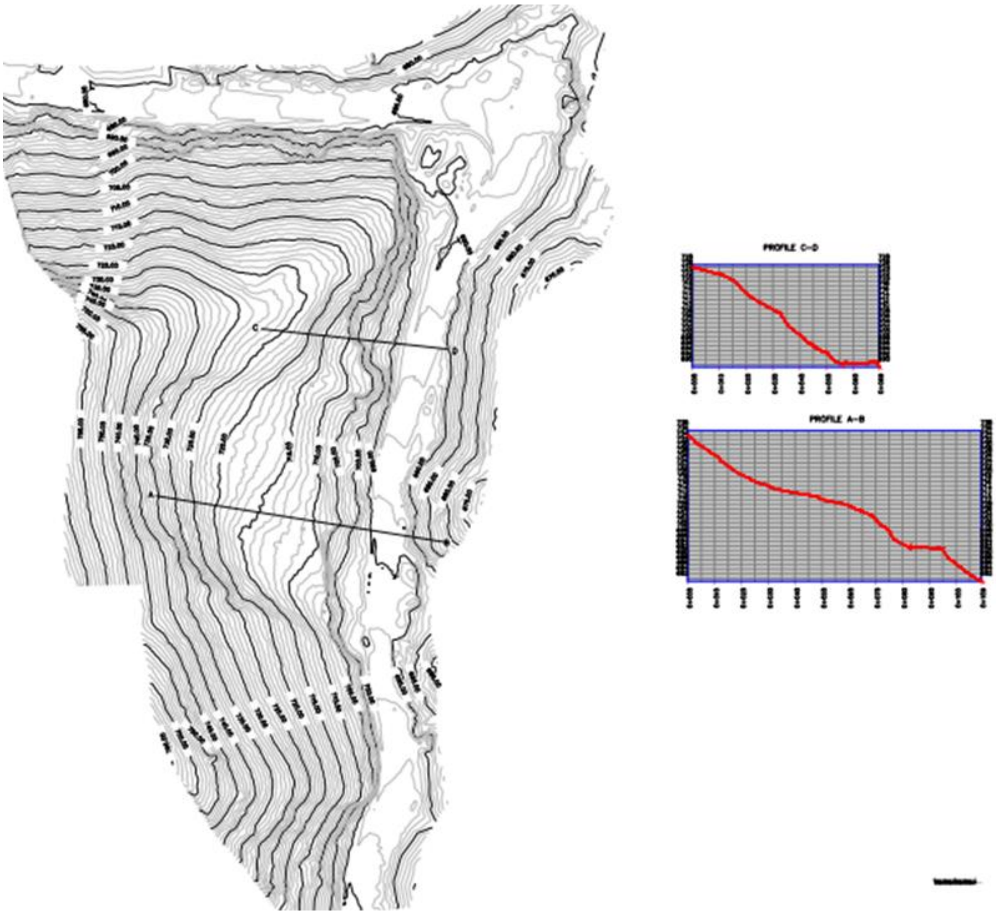

Figure 4: Cross section analysis

Table 1: Passara GNSS data and lidar data comparison

ID	Observed X	Observed Y	Known Z	Lidar Z	dz
1	541961.884	492767.794	874.382	772.7366	-101.645
2	541961.709	492765.018	874.501	772.9136	-101.587
3	541956.07	492769.72	874.911	733.285	-101.626
4	541961.205	492755.392	875.708	744.0783	-101.63
5	541926.681	492780.955	876.581	775.0053	-101.576
6	541945.984	492773.828	875.508	773.9723	-101.536
7	541984.648	492788.715	862.002	760.3883	-101.614
8	541990.024	492804.604	857.056	755.3445	-101.712
9	541987.234	492823.76	856.949	755.3082	-101.641
10	541977.187	492851.319	860.161	758.5184	-101.643
11	541973.911	492859.903	859.121	757.4927	101.628
12	541976.776	492822.578	862.089	760.4457	-101.643

Table 2: Meedumpitiya GNSS data and lidar data comparison

ID	Observed X	Observed Y	Known Z	Lidar Z	dz
1	546361.526	495661.652	796.877	695.464	-101.413
2	546362.729	495678.446	796.254	I694.822	-101.432
3	546364.010	495703.762	795.157	693.733	-101.424
4	546367.704	495719.726	794.455	693.001	-101.454
5	546375.017	495746.928	793.278	691.820	-101.458
6	546380.933	495766.481	792.505	691.061	-101.444
7	546375.034	495774.343	794.755	693.373	-101.382
8	546368.575	495773.670	799.357	697.981	-101.376
9	546380.806	495780.249	792.229	690.805	-101.424
10	546334.828	495693.657	812.201	710.789	-101.412
11	546334.973	495693.923	811.940	710.699	-101.241
12	546334.273	495684.217	812.143	710.840	-101.303
13	546338.912	495681.228	811.454	710.0913	-101.363

4. Discussion

LiDAR is a very cost effective and efficient method of gathering ground data from airborne platforms. From this study it was evident that a landslide formation can be identified using LiDAR technology. With proper workflows and data acquisition practice LiDAR can be instrumental in identifying potential landslide sites. The data that geologists need in order to study the failure can be gathered using LiDAR data. From the comparison of Ground points extracted from the LiDAR survey and the ground survey it is apparent that LiDAR is very accurate when proper data acquisition, differential corrections and post processing techniques are employed.