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The Utilization of Remotely Sensed Data to Analyze The Estimated Volume of Pyroclastic Deposits and Morphological Changes Caused By The 2010–2015 Eruption of Sinabung Volcano, North Sumatra, Indonesia

25 October 2018

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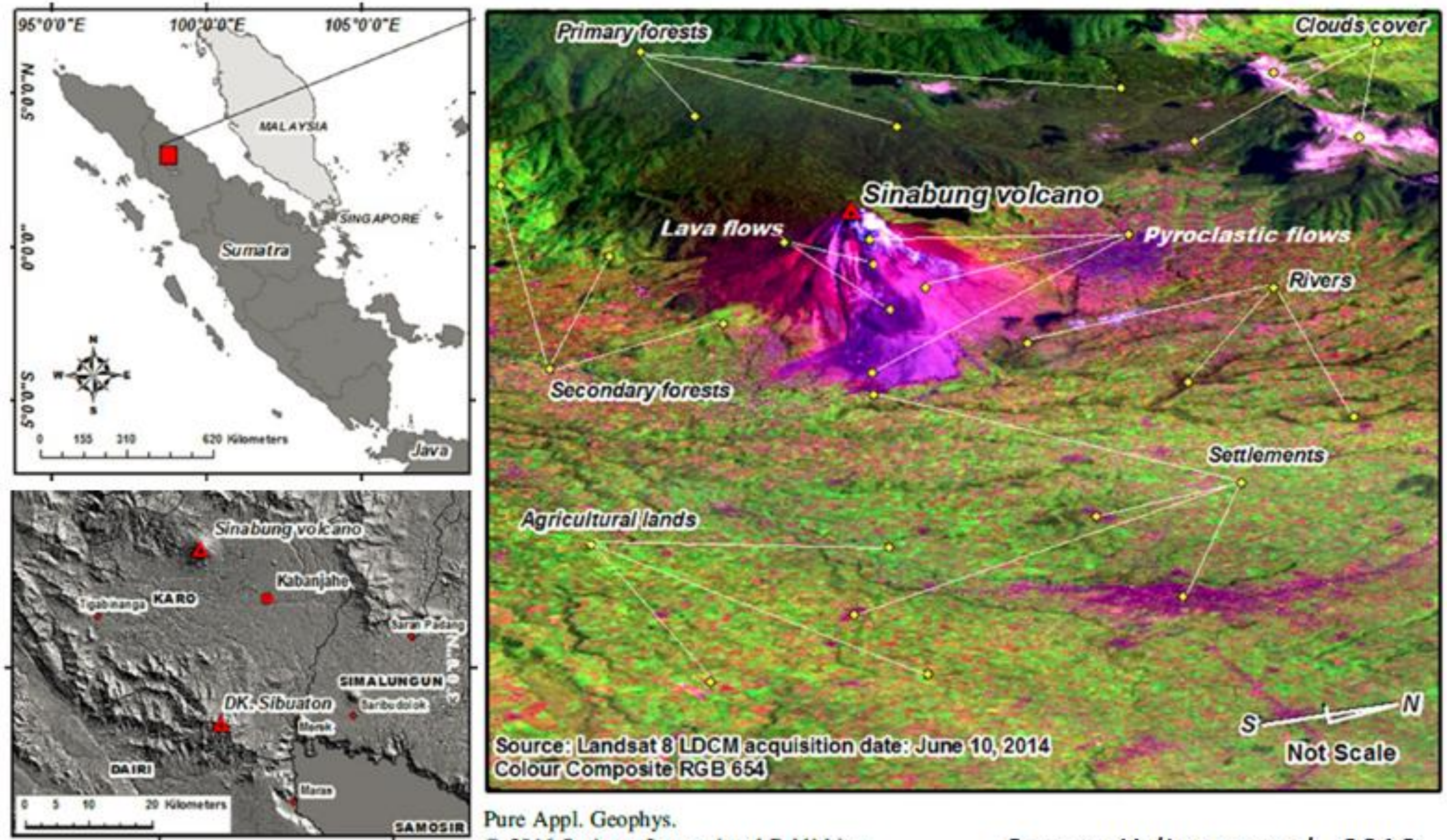
Research area at Sinabung volcano in North Sumatra, Indonesia



Pure Appl. Geophys.

DOI 10.1007/s00024-016-1342-8

Source: Yulianto et al., 2016

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INTRODUCTION (1)

- Among the developing countries, Indonesia is most vulnerable to natural hazards
- This vulnerability is caused by the location of the nation at the confluence of three active tectonic plates, namely: Pacific, Euro-Asia, and Indo-Australia
- The three plates slide past and collide with each other resulting in earthquakes, volcanic eruptions, landslides, floods and tsunami
- An important control on the occurrence of natural hazards is topography
- Topography has a dominant influence on the potential and direction of a hazard, such as volcanic eruptions, landslides, and floods

INTRODUCTION (2)

- The availability of topographic data and up-to-date information (including post-hazards topography) is needed to predict and prevent potential hazards in the future and minimize the risk of natural hazards.
- Limited availability of topographic data during the recent eruptions of Sinabung volcano has been an obstacle in analyzing morphologic change and in obtaining volumes of pyroclastic materials.
- To address this problem, we extracted a 2015 DEM from SPOT 6 stereo images, which have a spatial resolution of 6 m.
- By comparing our new DEM with pre eruption topographic maps we are able to estimate the volume of pyroclastic flow deposits and morphological changes for the period 2010–2015.

METHODOLOGY (1)

Data availability

- For our research we derived a pre-eruption DEM from ASTER GDEM version 1.0 (released 29 June 2009) and SPOT 6 stereo image data, which was acquired on 21 June 2015
- Additionally, topographic maps with a scale of 1:50,000 from the Indonesian Geospatial Information Agency (BIG) were used to combine with the ASTER GDEM and used as reference data to evaluate accuracy of the SPOT 6 DEM.

METHODOLOGY (2)

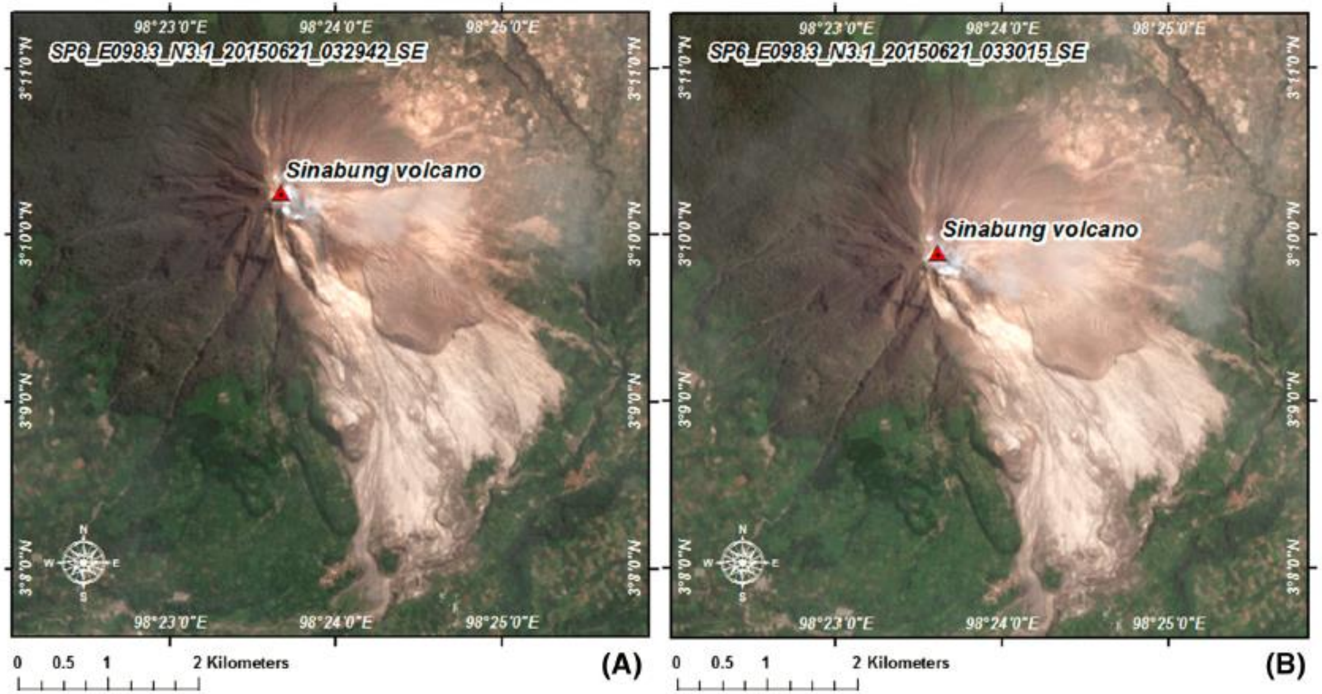


Figure 2

SPOT 6 stereo images at Sinabung volcano. **a** Dataset ID:SEN_SPOT6_ 20150621_032942900_000, *acquisition date* June 21, 2015, *time* 03:29:42.7, *orientation angle* +356.62°, *incidence angle* +18.45°, *sun azimuth* +52.42°, *sun elevation* +54.97° and **b** dataset ID: SEN_SPOT6_20150621_033015100_000, *acquisition date* June 21, 2015, *time* 03:30:15.0, *orientation angle* +263.96°, *incidence angle* +5.37°, *sun azimuth* +52.29°, *sun elevation* +55.08°. Source: LAPAN, 2015

METHODOLOGY (3)

The Estimated Volume of Pyroclastic Deposited

- As there has been on limited syn-eruption erosion, the approximate volume estimated of pyroclastic flows deposits from eruption of Sinabung volcano during the period 2010 to mid-2015 can be calculated by differencing the pre- and syn-eruption DEM data for this period.
- Thickness of pyroclastic flows is assumed to be equal to the difference values of elevation in the DEM pre- and syn-eruption data

- **ΔLTF = DEMt2** (syn-eruption) **- DEMt1** (pre-eruption data)

The Estimated Volume of Pyroclastic Deposited

- The volume of pyroclastic flow deposits can be formulated as shown

$$\mathrm{VolLF} = \sum_{l,l}^{m,n} xy\Delta\mathrm{LTF}_{i,j}$$

where ***VolLF*** is the volume pyroclastic flow deposited. ***x*** and ***y*** are the pixel dimensions. ***m*** and ***n*** are the array of elevation change columns and rows. ***ΔLTF*** is the pyroclastic flows thickness for each pixel position (***i*** and ***j***).

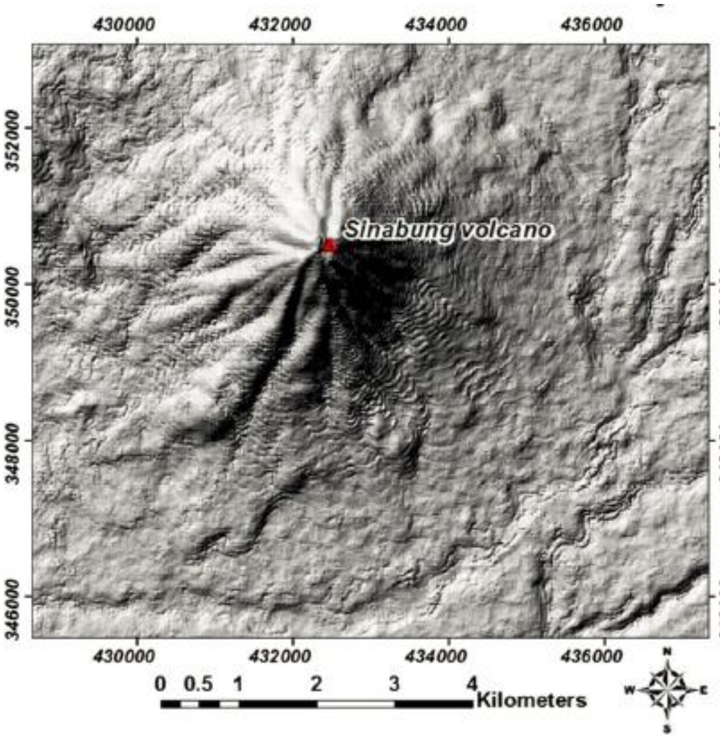
METHODOLOGY (5)

Morphological Change Detection Analysis

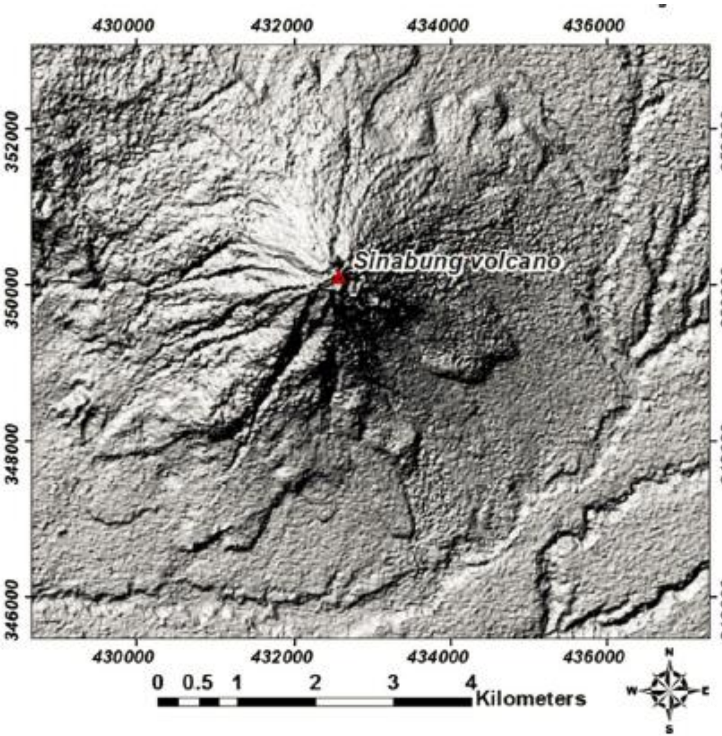
- Morphological change detection analysis can be done by comparing the locations expected to experience change in elevation on the condition pre- and syn- eruption.
- The analysis is done by creating a cross-section model at several location changes based on the DEM data pre- and syn eruption.

RESULTS (1)

(A) ASTER GDEM Year 2009

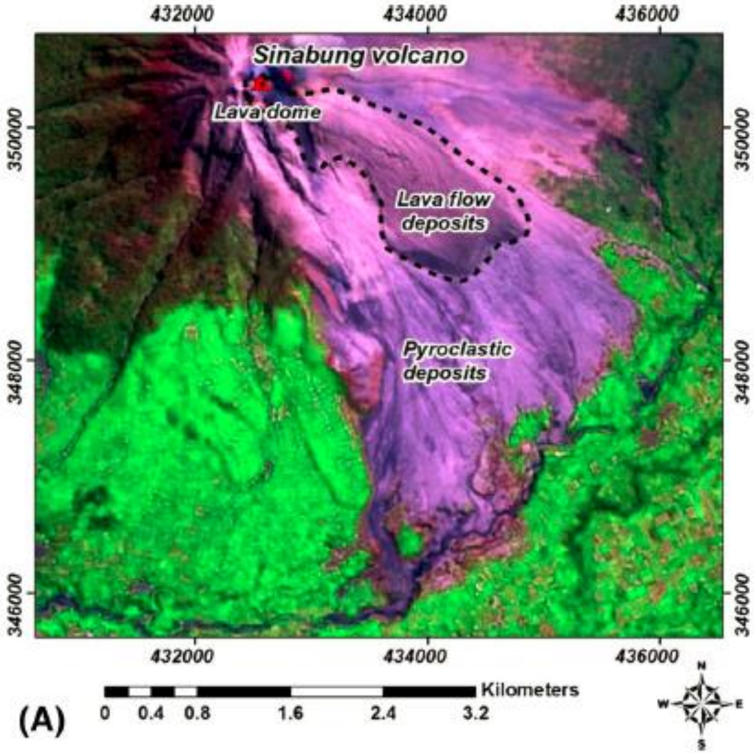


(B) DEM SPOT 6 Year 2015

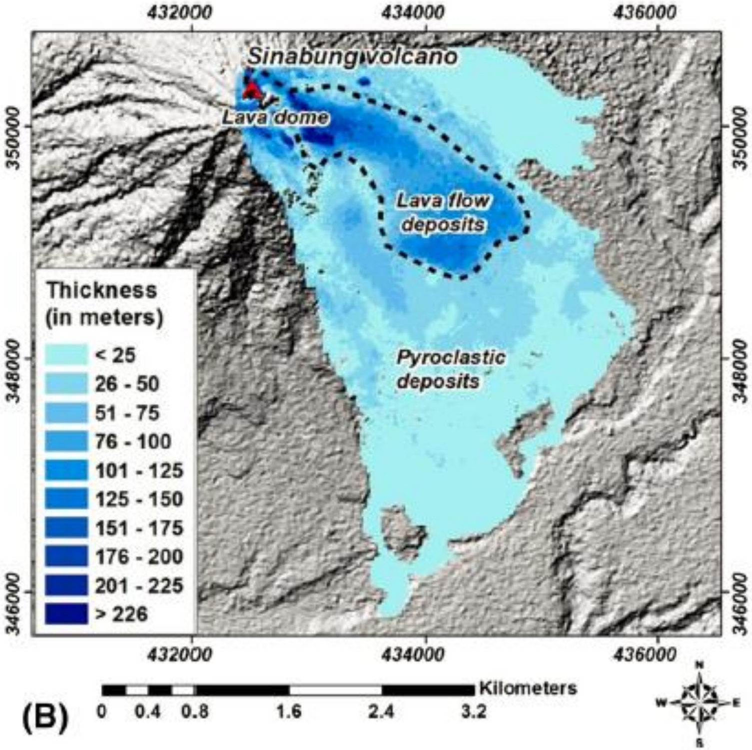


RESULTS (2)

(A) Landsat 8 Year 2015



(B) Thickness of pyroclastic and lava flow deposits year 2010 - 2015



RESULTS (3)

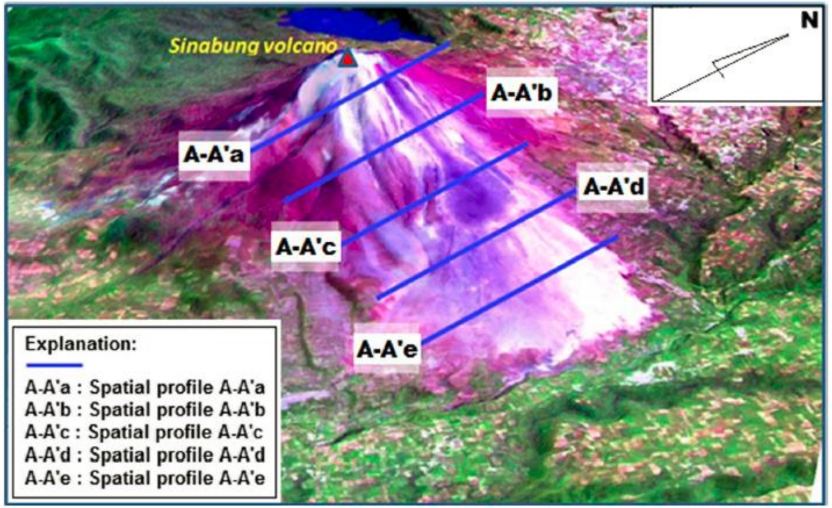
Estimated Volume of pyroclastic deposits year 2010 – 2015
= **~ 2.8 x 10^8 m^3**

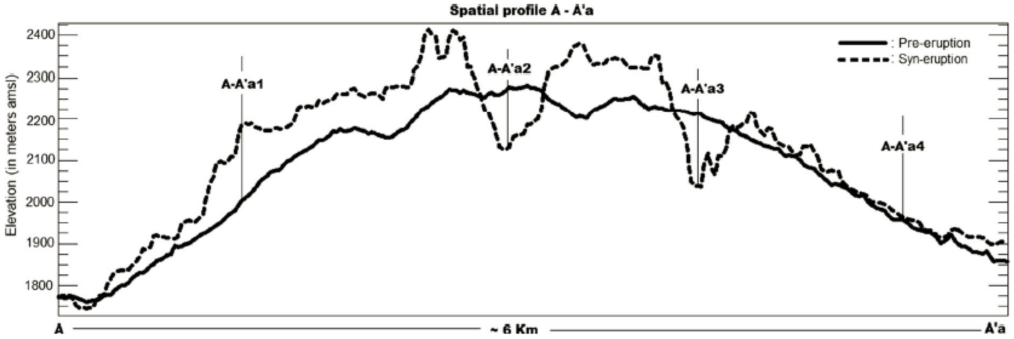
The results of the calculation of the estimated volume of pyroclastic flows deposits caused by the 2010–2015 eruption of Sinabung volcano

Class of thickness (m)	Number of pixels	Areas (m^2)	Approximate estimation volume (in $\times 10^8$ m^3)	Uncertainties vol_std$_1$ for most pessimistic value (in $\times 10^8$ m^3)	Uncertainties vol_std$_2$ for more optimistic value (in $\times 10^5$ m^3)
<25	49,256	1,773,216	0.252	0.188	0.260
26–50	46,491	1,673,676	0.615	0.178	0.253
51–75	19,433	699,588	0.428	0.074	0.163
76–100	14,075	506,700	0.447	0.054	0.139
101–125	12,183	438,588	0.491	0.047	0.129
126–150	4700	169,200	0.230	0.000	0.008
151–175	1838	66,168	0.107	0.007	0.050
176–200	1209	43,524	0.082	0.005	0.041
201–225	643	23,148	0.049	0.002	0.030
>226	1091	39,276	0.096	0.004	0.039
Total	150,919	5,433,084	2.797	0.576	0.456

Material Lava = ~ 0.9 x 10^8 m^3
Material Pyroclastics = ~1.9 x 10^8 m^3

RESULTS (4)

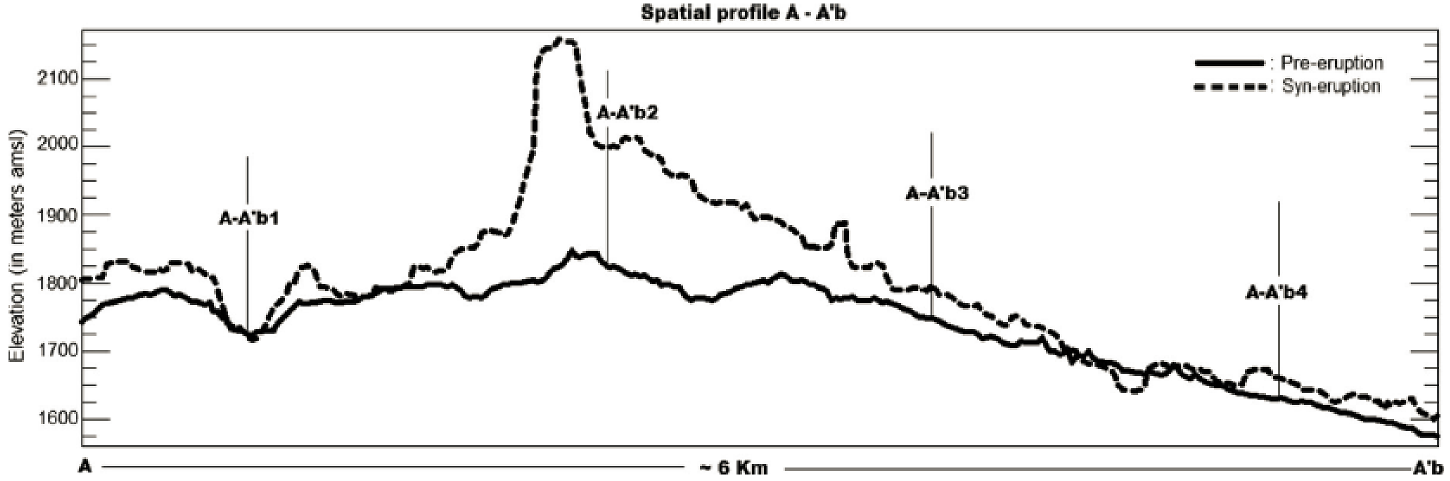




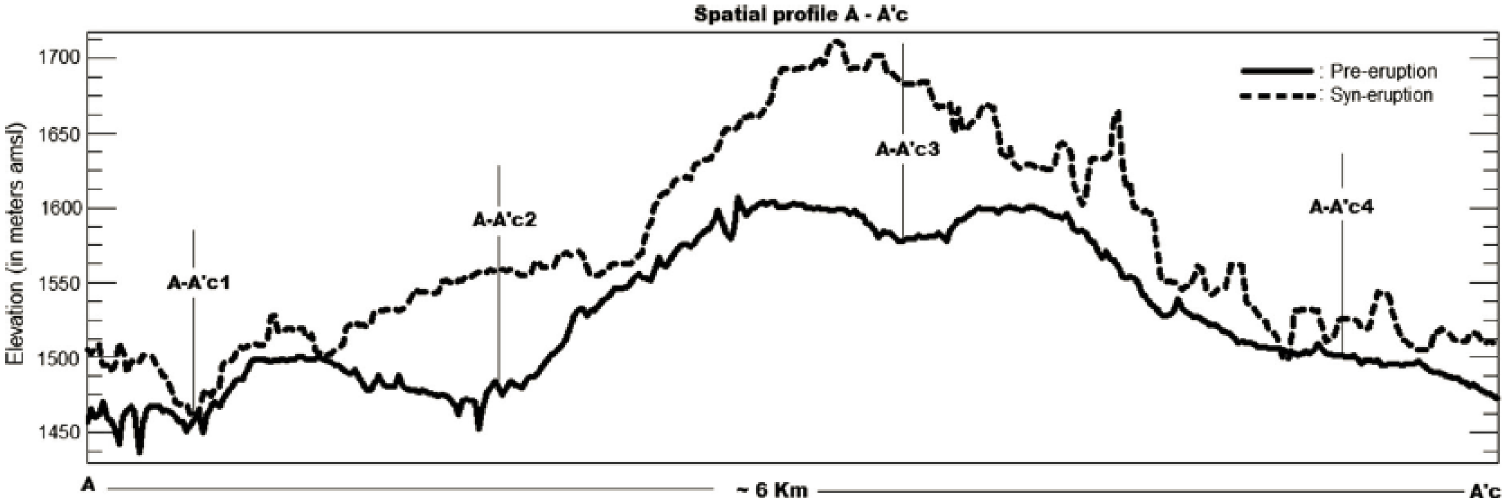
Analysis of morphological changes of the DEM pre- and syn- eruption in the period 2010 to mid-2015 in the research area

Spatial profile	Change of the DEM pre- and syn- eruption (in meters)			
	1	2	3	4
A-A'a	180 (+)	110 (−)	150 (−)	0
A-A'b	0	200 (+)	50 (+)	30 (+)
A-A'c	0	75 (+)	130 (+)	25 (+)
A-A'd	35 (+)	125 (+)	130 (+)	30 (+)
A-A'e	30 (+)	25 (+)	100 (+)	25 (+)

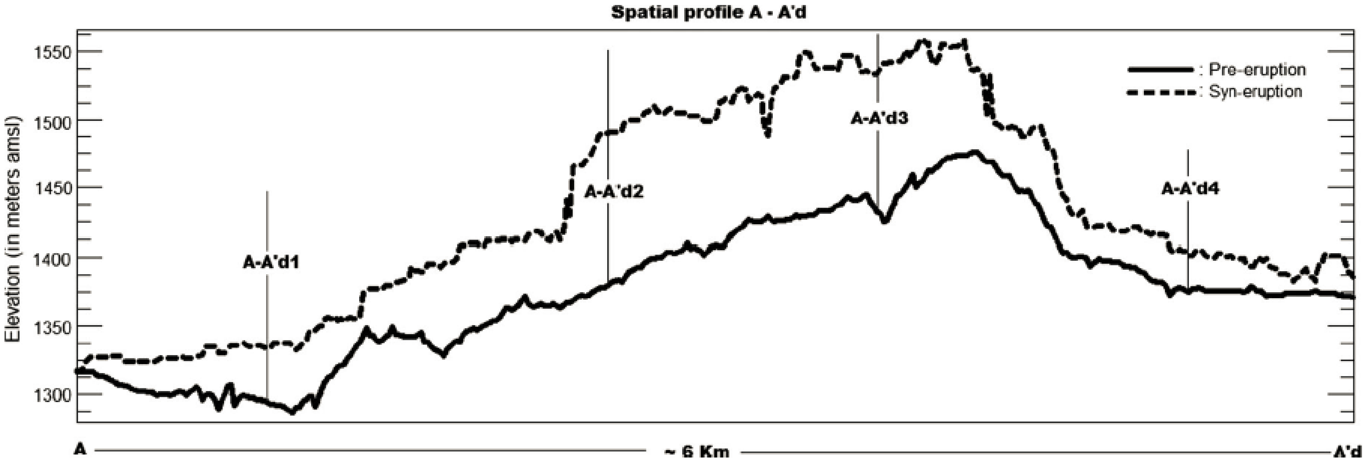
" +" sedimentation, "−" indication of the collapsed volcanic deposits with limited syn-eruption erosion, and "0" no change

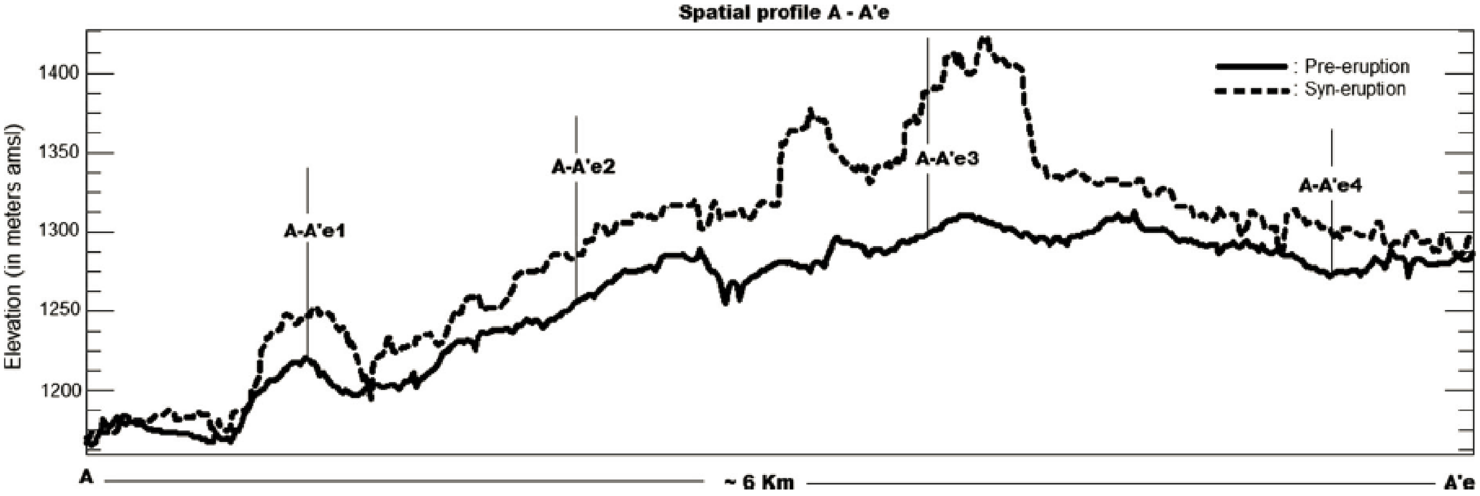


Spatial profile A - A'b
Pre-eruption
Syn-eruption
Elevation (in meters amsl)
2100
2000
1900
1800
1700
1600
A-A'b1
A-A'b2
A-A'b3
A-A'b4
A
~ 6 Km
A'b



Spatial profile A - A'c
Pre-eruption
Syn-eruption
Elevation (in meters amsl)
1700
1650
1600
1550
1500
1450
A-A'c1
A-A'c2
A-A'c3
A-A'c4
A
~ 6 Km
A'c


Spatial profile A - A'd
Elevation (in meters amsl)
1550
1500
1450
1400
1350
1300
A-A'd1
A-A'd2
A-A'd3
A-A'd4
: Pre-eruption
: Syn-eruption
A
~ 6 Km
A'd


Spatial profile A - A'e
Elevation (in meters amsl)
1400
1350
1300
1250
1200
A-A'e1
A-A'e2
A-A'e3
A-A'e4
: Pre-eruption
: Syn-eruption
A
~ 6 Km
A'e

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CONCLUSION

- The purpose of this research is to describe the use of remotely sensed data to estimate the volume of pyroclastic material deposited and to analyze morphological change as a result of the eruption of Sinabung volcano during the period 2010–2015.
- Approximate estimation of 2.8 x 10^8 m^3 for the total volume of eruptive products, comprising 0.9 x 10^8 m^3 of lava flow and dome deposits, and 1.9 x 10^8 m^3 of pyroclastic deposits.
- Related the Early warning, impact of this eruption volcano not only the primary hazard (Lava and Pyroclastics flow), but also the secondary hazard Lahars (mixed Pyroclastics deposits with rain fall water) can be a threat to the surrounding area.
- The output of this research can be used as input for modeling secondary hazard.

Detail Research Information

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DOI 10.1007/s00024-016-1342-8

Pure and Applied Geophysics

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Thank you for your attention

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