

IDENTIFICATION OF LANDSLIDES USING SYNTHETIC APERTURE RADAR (SAR) (APPLICATION TO MEERIYABEDDA LANDSLIDE IN BADULLA DISTRICT, SRI LANKA)

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KEY WORDS: landslide hazard, landslide occurrence inventory, interferometric processing, backscatter change detection

ABSTRACT

Synthetic aperture radar (SAR) is a radar imaging technology that is capable of producing high resolution images of the stationary surface targets and terrain. The main advantages of SAR are its ability to operate day and night and also in adverse weather conditions, hence overcoming limitations of both optical and infrared systems. Synthetic Aperture Radar (SAR) technology has provided terrain structural information to geologists for mineral exploration, oil spill boundaries on water to environmentalists, sea state and ice hazard maps to navigators, and reconnaissance and targeting information to military operations. There are many other applications for this technology.

In this study, we focus on applicability of SAR technology to identify the landslide hazard in the mountainous range in Badulla district, Sri Lanka in order to construct a proper landslide inventory map. The data used for this analysis were ALOS 2 images (Acquisition date: Master image – 01.10.2014, Slave image – 18.02.2015) and Sentinel 1 images (Acquisition date: Master image – 19.10.2014, Slave image – 06.12.2014). SNAP was used as the software for the analysis.

This paper discusses the feasibility and limitations of two well known SAR analysis techniques for Landslide Identification which are known as Interferometric Processing and Backscatter Change Detection. Role of Mountain Slope, Land Cover Type with respect to Microwave interaction is discussed in this papers considering famous Meeriyabedda landslide which happen in 2014, as an example. Additionally, successful case study using SAR data for landslides in Indonesia being used to justify these claims.

1 INTRODUCTION

Synthetic aperture radar (SAR) is a space based radar image acquiring technology which is able to produce high resolution images of stationary surface objects on ground. The ability of SAR to operate at night and in adverse weather conditions has overcome the limitations of both optical and infrared systems. It can be consider as the major advantage of this technology (Patel *et al.*, 2010, Ulaby *et al.*, 1981).

Synthetic Aperture Radar (SAR) technology is able to provide terrain information to researches for identifying minerals, boundary of oil spill on water surface, status of the sea surface and iceberg hazard maps, while it also provide useful information for field reconnaissance surveys and enemy target information for military operations. In addition, this technology can be used for many other uses. This study focused on applicability of SAR imagery technology for identifying landslide hazard in mountainous range in Badulla district at Uva province of Sri Lanka.

1.1 Principle of SAR

The rudimentary theory behind the SAR is that the radar moves along its path, it transmits pulses in microwave frequencies at a uniform pulse repetition interval. The reflected energy at any instant can be modeled as a convolution of the pulse waveform with the ground reflectivity function. Each received pulse is preprocessed and passed on to an image formation processor. The image formation processor produces an image that is a two-dimensional mapping of the illuminated scene. The formed two-dimensional image is interprets its dimensions of range and cross-range or azimuth. The range is the direction of signal propagation and the cross-range is the direction parallel to the flight path (Skolnik, 1970, Raney, 1998).

The range resolution of a SAR image is directly related to the bandwidth of the transmitted signal and the cross-range is inversely proportional to the length of the antenna aperture. Therefore, high range resolution is achieved by transmitting wide bandwidth waveforms, and high cross-range resolution is achieved by coherently processing returns transmitted from a variety of positions along a flight path to emulate a large aperture (Ferretti *et al.*,2007). SAR measures both the amplitude and the phase of the reflected waves which describe below,

- i. AMPLITUDE information; represents the proportion of microwave Back-scattered from the ground (the strength of microwave reflection)
 - a. Image interpretation
 - b. Difference of backscattering intensity
- ii. PHASE information; represents the position within one wave cycle
 - SAR Interferometry (InSAR) → DEM generation
 - Differential SAR Interferometry (DInSAR) → Displacement
 - Coherence analysis → Phase correlation

1.2 Importance of the Study

Landslide is the result of a geo-dynamic process which is a natural course that shapes up the geomorphology of the earth. However, there is a major concern when those unstable slopes influence on safety of people and their property. Normally landslides can be describes as an isolated process that individually may not significant in size but can happens with a high frequency and create considerable damage to life and property. In future it is expected that landslides will create more damage to properties than any other geological hazard (Varnes, 1984).

Landslides are among the natural disasters that are frequently experienced in Sri Lanka. Badulla, Nuwara Eliya, Ratnapura, Kegalle, Kandy, Matale, Kalutara districts are located in the central hills and Matara, Galle and Hambanthota districts in the southern hills are identified as landslide prone areas in Sri Lanka. Among those, approximately 20,000 sq. km (30.7%) of land area is highly susceptible to landslides (NBRO 1994). With the increasing demand for development and expansion of human settlements, landslides have become a major concern in the mountainous regions of the country.

When considering the Sri Lankan context, most of the landslides are small scale landslides which are ranging from 10-50m in width and length. Occasionally, the country has experienced large scale landslides such as occurred in Meeriyabedda - Koslanda. Use of remote sensory data is a problem due to the smaller scale of the frequently experienced landslide in Sri Lanka and also the images are disturbed by the overcast conditions. To acquire precise idea of landslides, it requires broad-area imaging at higher resolutions. SAR provides capabilities to acquire images at night or during inclement weather. SAR may take advantage of long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics to provide higher resolution images. The use of satellite image is highly advantageous to carry out landslide related studies in timely and effective manner.

1.3 Study Area

A severe landslide occurred in Meeriyabedda area, Koslanda estate in Kotabathma Grama Niladhari division in Haldumulla Divisional Secretariat Division in Badulla district, Uva province in Sri Lanka was selected as the location to perform the analysis of the study. The landslide was occurred in the morning on 29th October 2014. The impact of landslide affected around 330 people of 57 families in Amptikanda tea estate. Total numbers of buildings destroyed were 63 including Houses, Kovil, Community Center, Dairy collection Center, Boutiques, Telecommunication Center, and 3 Estate bungalows and massive social economic problems aroused in post disaster situation.

The area is covered by the geographical coordinates of longitude 81^o1'11.51" to 81^o1'26.99" Latitude 6^o45'19.40" to 6^o45'47.86". The topographic elevation of the area ranges from 840 m to 1060 m above mean sea level.

Geomorphology in the area is characterized by two distinguish patterns as terraced slope and corrugated hill slope. Additionally, steep valley areas are also prominent in the hilly terrain and river systems are aligned with these valleys.

The area is experiencing rain from both northeast and southwest monsoons. Most of the recorded landslides were linked to the high intensity rainfall during north east monsoon. The average annual rainfall in the district is around 2000 mm. During the Southwest monsoon season the district experiencing more sunshine. The average sunshine

duration exceeds 5 hours per day while average relative humidity of the area is 72.9% in day time and the average annual temperature of the area varies between 20° to 25° C.

The predominant lithology of the region is precambrian metamorphic rocks specifically, charnockite and charnokeitic gneiss of the highland series. This area consists of a number of antiforms and synforms steeply dissected by fault systems of the regional plate tectonism. Most of the land in the area is covered with patina (grassland), scrubland and estate settlements.

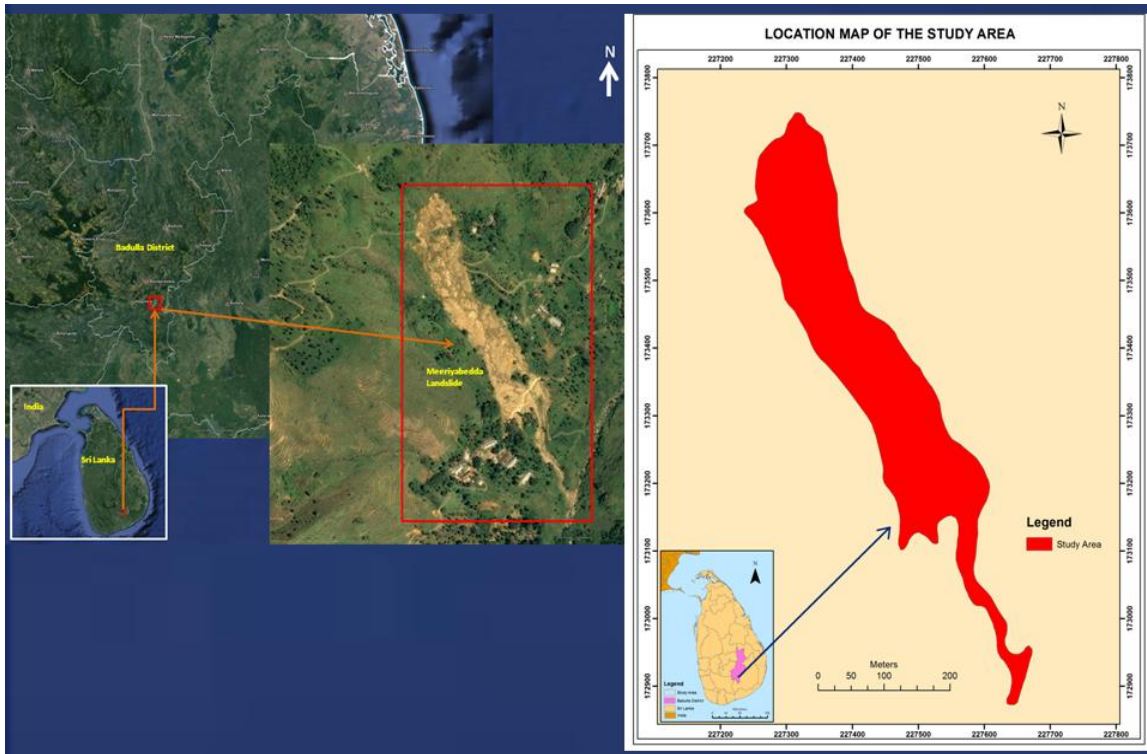


Figure 1: Location map of the study area

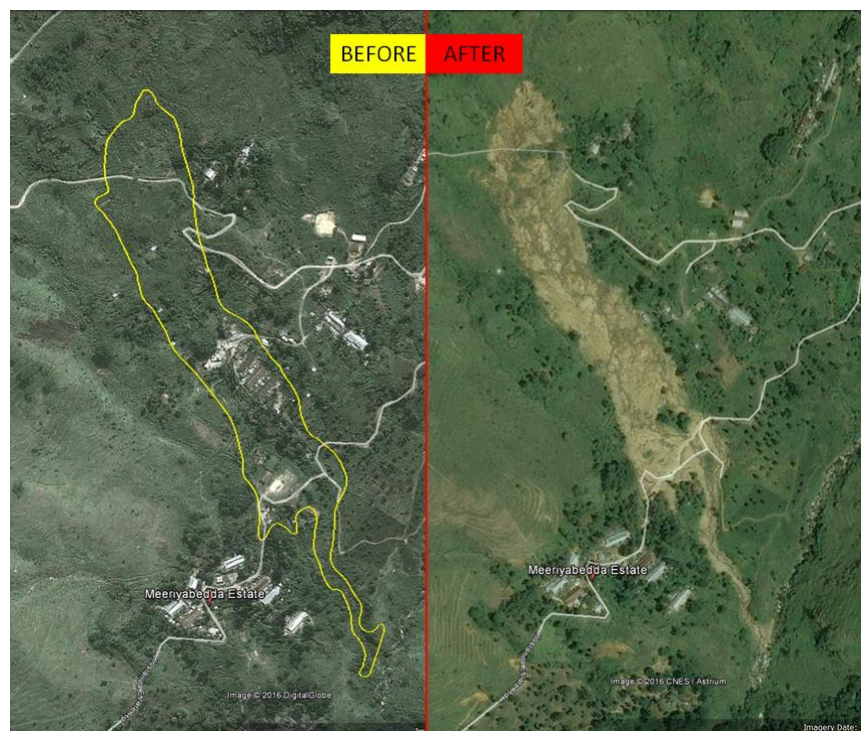


Figure 2: Map showing the condition of the study area before and after the landslide

2 METHODOLOGY

2.1 Data and Software Used

In this study two data sets of SAR from ALOS 2 and Sentinel 1 which acquired before and after the landslide were used to detect the landslide in Meeriyabedda estate. (ALOS 2: Acquisition date: Master image – 01.10.2014, Slave image – 18.02.2015 and Sentinel 1: Acquisition date: Master image – 19.10.2014, Slave image – 06.12.2014). SNAP analysis tool, which is an open source toolbox for reading, processing, analyzing and visualizing SAR data were used for the analysis of acquired data.

Table 1: Table showing the information of the SAR data

Property	ALOS 2		Sentinel 1	
	Master image	Slave image	Master image	Slave image
Date	01.10.2014	30.09.2015	19.10.2014	06.12.2014
Mode	FBD	FBD	IW	IW
Resolution	10*10 m	10*10 m	5*20 m	5*20 m
Orbit	162	162	19	19
Orbit Direction	Ascending	Ascending	Descending	Descending
Off-Nadir Angle	32.9 ⁰	32.9 ⁰	-	-
Polarization	HH, HV	HH, HV	VV	VV
Process Level	1.5	1.5	1.1	1.1

2.2 Data Processing

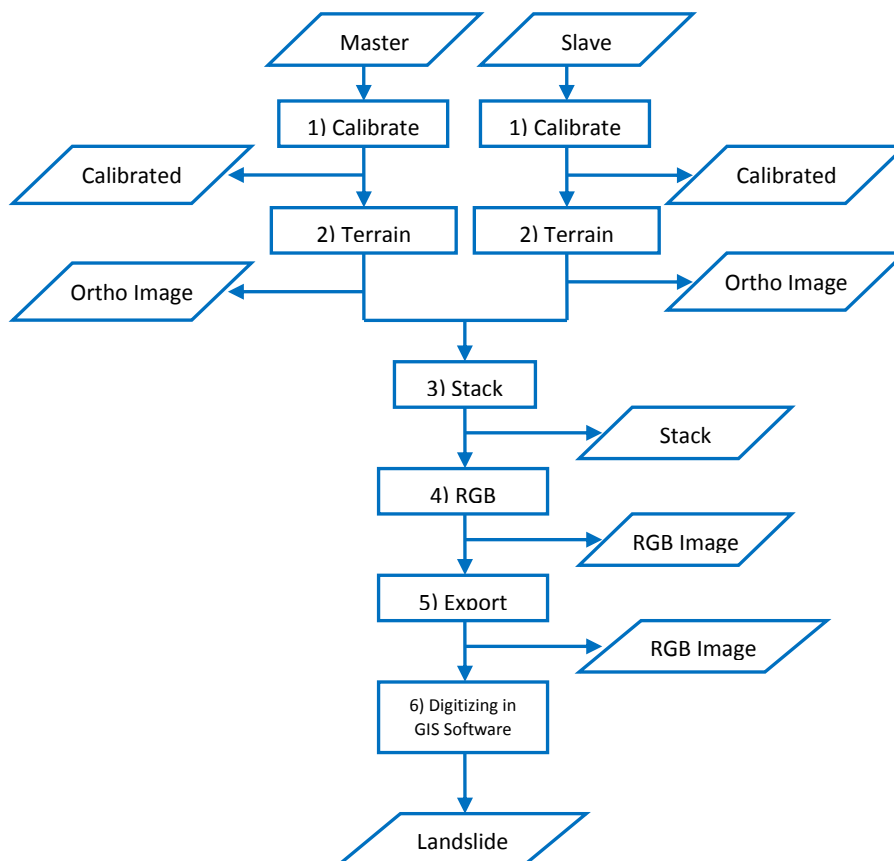


Figure 3: Chart showing the methodology of Backscatter Change Detection

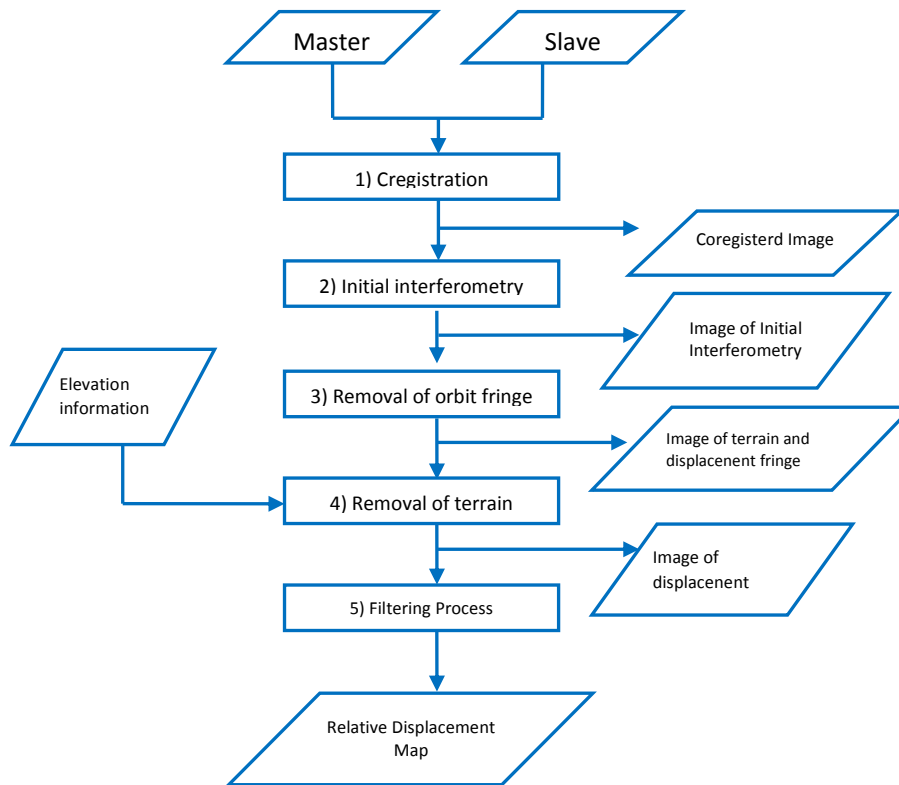


Figure 4: Chart showing the methodology of Interferometry Radar

For Backscatter Change Detection analysis for the interested area in the image was loaded by creating subset. Stacking image for false colour composite was constructed to determine the changes qualitatively between pre and post event SAR images. Increased backscattering intensity of landslide deposits allowed detecting the landslide in colour composite. However, terrain undulations may have influence on the geometric and radiometric quality of the SAR images. In quantitative analysis, terrain correction is more important to remove the effect. Using digital elevation model, the imaging geometry is reconstructed to correct the terrain induced distortion and resulting orthorectified image. In stack, changes were extracted though the set threshold of backscattering confident.

Two images were co-registered to fit the position of two images for interferometric analysis. Topographic phase removal was carried out to remove the fringes occurs due to elevation. Image was filtered to reduce the noise and improve the visibility of the interferogram. Orthorectified image was obtained though the terrain correction.

Concurrently, the similar procedure was performed to detect the landslide in Sampang vilage, Banjarnegara, Indonesia.

3 RESULTS AND DISCUSSION

Generally, Backscattering intensity increased after a landslide due to its deposits. In case of Meeriyabedda landslide, due to non-significant change of backscatter, it was almost impossible to identify landslide from surrounding area. This may be due to type of land cover in Meeriyabedda landslide area. This area is covered with small grasslands. After landslide, there were no significant textural (surface roughness) difference between pre disaster and post disaster surfaces and between landslide area and surrounding area which make it very hard to distinguish landslide area. Additionally, the selected area in this study is consisted of mountainous terrain, due to the slope angle of the location of the landslide, and viewing angle of the satellite observation may not be favorable to detect the variation of surface roughness.

In Indonesian study, it shows significant color change in RGB composite. The color is caused by the value of backscatter at image after disaster is more than the value of backscatter at image before the disaster, in other words, the value of backscatter is increased and clearly indicate the landslide area. At this case, landcover on landslide area before the disaster is covered by plantation (trees). After landslide occurred, there were so much debris that consist mud with logs, brach, part of house, and other materials. The debris make the surface more uneven than before disaster, this cause the value of backscatter increase. Simply, change of Land cover type of before and after disaster leads to change of backscatters which allow us to distinguish landslide from surrounding area.

Additionally, if significant change of surface roughness has been occurred due to a landslide Coherence of interferometric analysis can be used to identify the landslide which can be seen in Indonesian Banjarnegara landslide. In case of coherence, simply, it measures consistency of SAR backscatter pre and post images. So, it's good to identify changes of surface roughness using SAR backscatter.

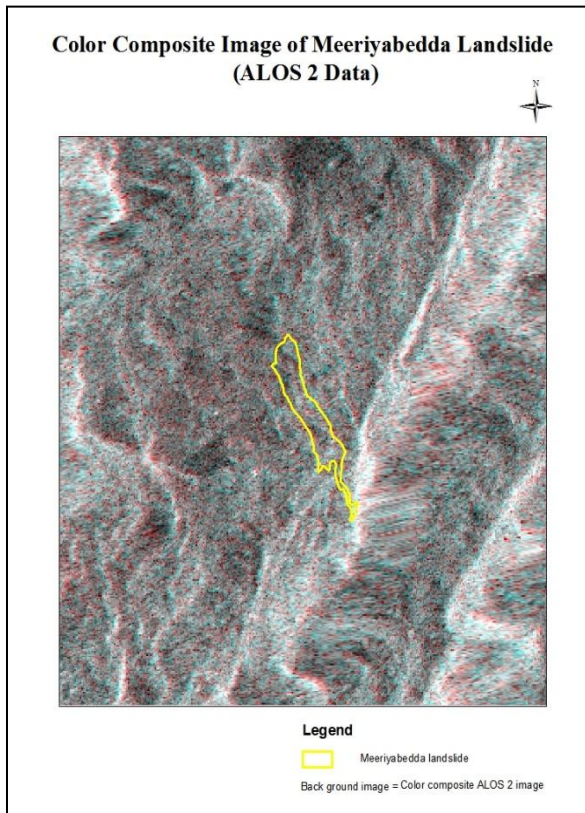


Figure 5: Map showing the output of ALOS 2 of Meeriyabedda Landslide area, Sri Lanka

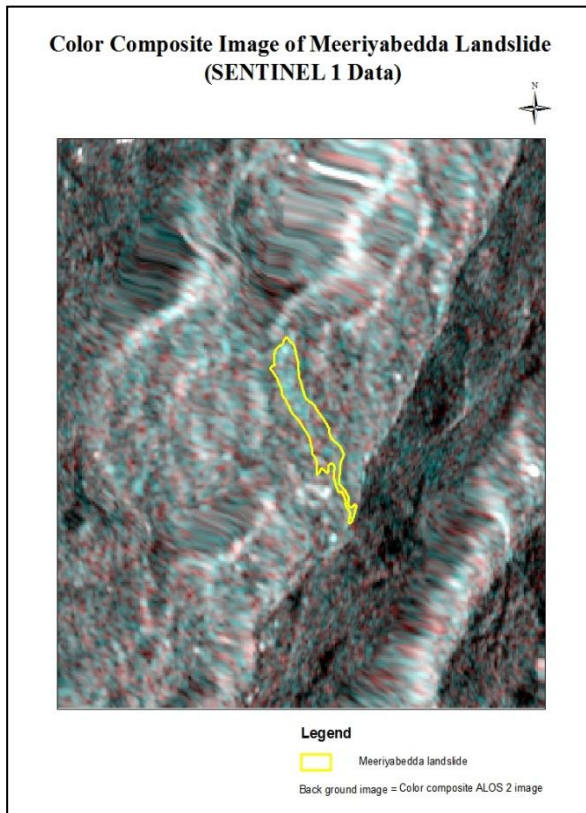


Figure 6: Map showing the output of Sentinel 1 of Meeriyabedda Landslide area, Sri Lanka

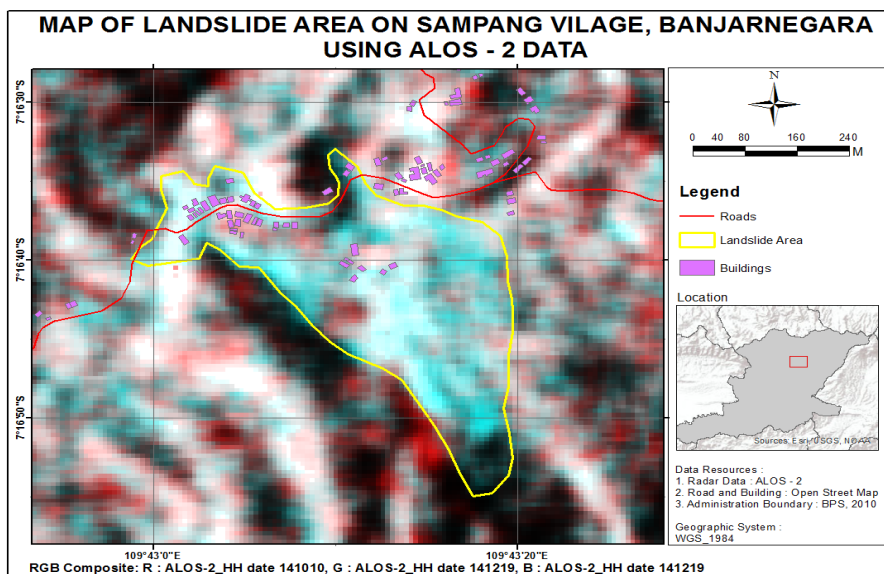


Figure 7: Map showing the output of ALOS 2 of Banjarnegara Landslide area, Indonesia

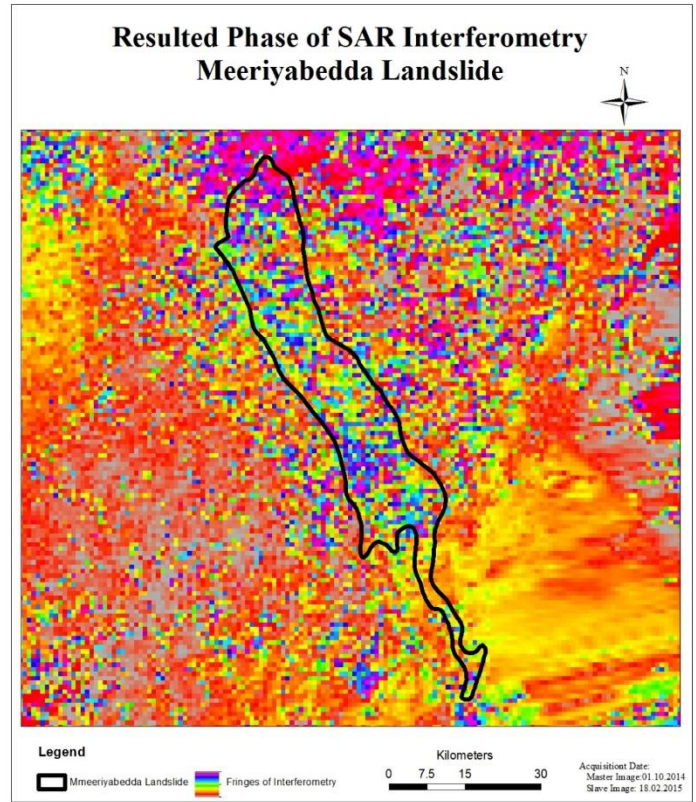


Figure 8: Map showing the resulted phase of SAR Interferometry of Meeriyabedda Landslide area, Sri Lanka

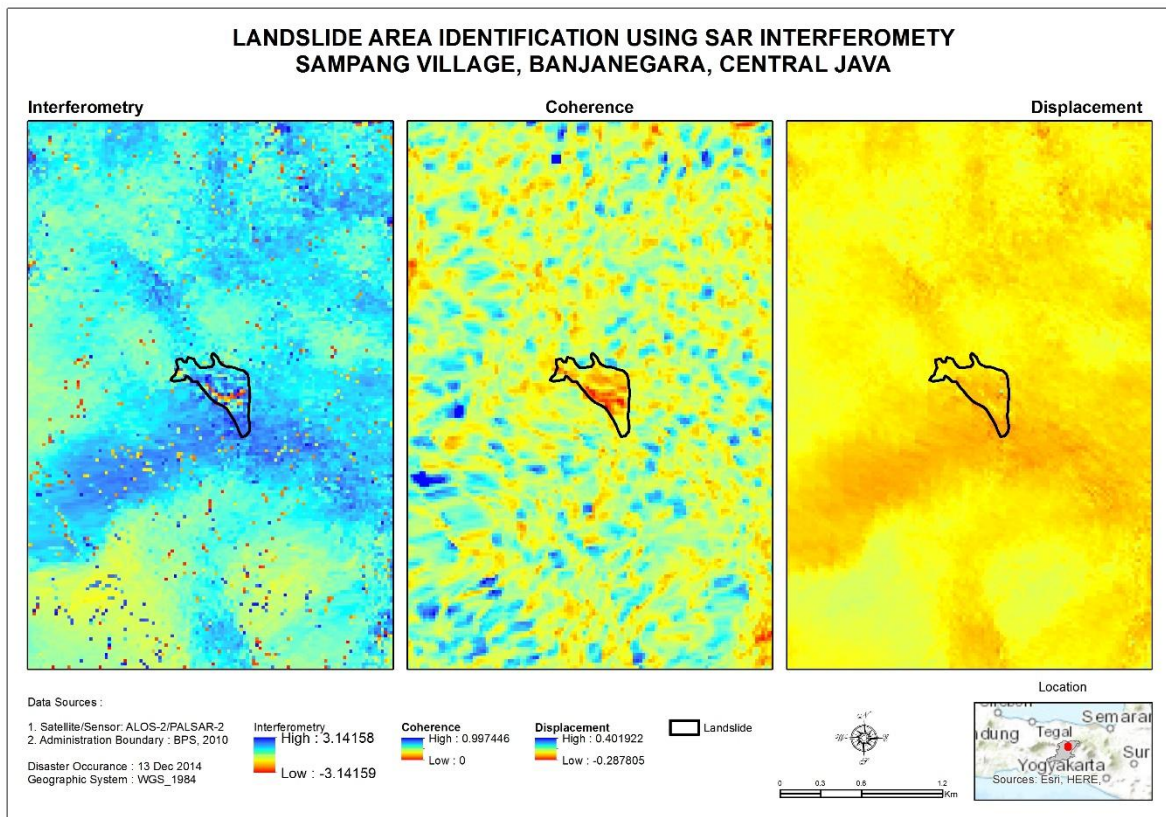


Figure 9: Map showing the resulted phase of SAR Interferometry of Banjarnegara Landslide area, Indonesia

4. CONCLUTIONS

SAR data can be used to identify landslide, but in the case of Sri Lanka, identification of landslides using backscatter change detection method which applies SNAP was not successful in this study and the result of SAR interferometry using SNAP was not significant to identify landslide area. If surface roughness has changed significantly due to landslide, false color composition of pre/post images and coherence analysis can be used to identify landslides.

ACKNOWLEDGEMENT

This study was performed in the framework of Sentinel Asia Mini Project 2015/2016. The authors would like to acknowledge the Japan Aerospace Exploration Agency (JAXA) for providing the SAR raw ALOS 2 and Sentinel1 data of the area of interest and very special thanks goes to all staff of Geo Informatics Centre, Asian Institute of Technology, Thailand, who helped in various capacities to finish this research work successfully.

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