EXTRACTING DIGITAL ELEVATION MODEL (DEM) FROM SENTINEL-1 SATELLITE IMAGERY: CASE STUDY A PART OF CAMERON HIGHLANDS, PAHANG, MALAYSIA

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Abstract - Because of simple structure and high applicability, Digital elevation model (DEM) plays a significant role in hazard studies. DEM is widely used as a basic source of data in many environmental fields. SENTINEL-1 is one of the most applicable tools for terrain data generation. Regarding online availability and its significance in interferometry studies, SENTINEL-1 satellite imagery in different areas is drawing scholar's attentions worldwide. Our purpose in this study is to create high resolution DEM from SENTINEL-1 satellite imagery for a part of Cameron Highlands, Pahang, Malaysia. However, we acquired a pair of SENTINEL-1 satellite images for the dates 25/02/2015 and 29/10/2016 through scihub.copernicus.eu website. Using Interferometry Synthetic Aperture Radar (InSAR) technique and Sentinel Application Platform (SNAP) software we generated DEM with 10*10 resolution. Results indicate that this method is highly effective for extracting high resolution DEM from SENTINEL-1 satellite products. Furthermore, using linear regression and standard errors of the estimate model using Statistical Package for the Social Sciences (SPSS) software the extracted DEM was validated. Moreover, this study can be a platform for those who want to generate high resolution DEM for their scope of the study.

Keywords - Digital Elevation Model, SENTINEL-1, Cameron Highlands, Malaysia

I. INTRODUCTION

Digital Elevation Models (DEMs), can be created using various ways, for instance interferometry, laser surveying, photogrammetry, Global Positioning System and many other techniques (Wang et al., 2018). DEM is one of spatial information source of data used in earth science, by which extraction of various layers is possible, such as aspect, elevation, slope and many other (Bhattacharya et al., 2012; Arun, 2013; Mokarrama&Hojati, 2016).

Regarding complicated creation process, acquisition of high-resolution DEM data is a quite challenging task (Reddy et al., 2017). Some online available DEMs, like ASTER, SRTM have 30 meters cell size and cannot be applicable for sensitive studies (Mukherjee et al., 2013). Therefore, creation of high resolution DEM is vital, especially where acquiring data is challenging.

RADAR imageries has been faceddramatic interest in a wide variety of fields during last decade. This interest is remarkably refer to the necessity to obtain information, where cloud coverage dominate for long time in the area (Kervyn, 2001). SENTINEL-1 image is one of the most important source of RADAR data among scholars worldwide and can be acquired online for free.

Many research have been concentrate on DEM generation using different methods worldwide, including Giles& Franklin (1996) extracted DEM from SPOT and evaluated derivative topographic surfaces with field measurements; Kucera (1999) obtained DEM using ERS SAR interferometry; Kervyn (2001) acquired DEM from interferometry by using ERS imagery; Lee et al. (2008) employed Digital aerial photography; Svobodová&Tuček (2009) used kriging method and elevation of the results; Rossi&Gernhardt (2013) generated DEM using TanDEM-X; Wang et al. (2018) employed merging ASTER GDEM and ICESat/GLAS data.The main objective of this work was to generate Digital Elevation Model (DEM) from SENTINEL-1 satellite imagery using Interferometry Synthetic Aperture Radar (InSAR) technique for a part of Cameron Highlands, Pahang, Malaysia.

II. DESCRIPTION OF THE STUDY AREA

A part of Cameron Highlands, Pahang, Malaysia was selected for this study. However, this scope located in the Longitudes 101˚ 20' 00"E to 101˚ 27' 10''E and Latitudes 4˚ 23' 30'' N to 4˚ 31' 10'' N. The study area covers 81.249 Km2 from entire Cameron Highlands (Fig. 1).

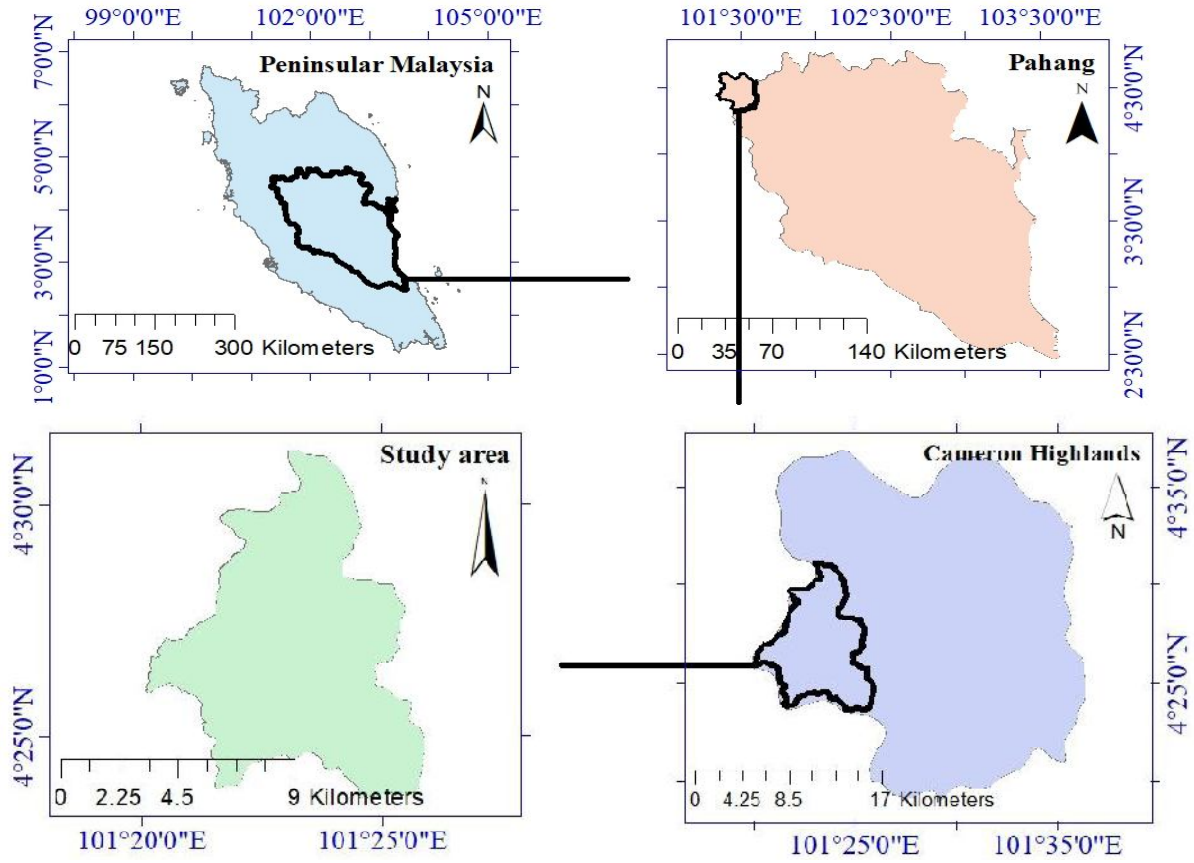

Fig. 1. Shows geographical location of the study area

III. MATERIAL AND METHODS

3.1. Database and data acquisition

The combination of two different images is needed for SAR interferometry (Massonnet&Feigl, 1998). Table 1 highlights the attributes of SENTINEL-1 data used in this study.

Table 1. Technical characteristics of SENTINEL-1 used in the study

Platform	S1A
Sensor mode	Interferometry Wide swath (IW)
Product type	Single Look Complex (SLC)
Date	25/02/2015 & 29/10/2016

In this study we have acquired SENTINEL-1 satellite imagery for generating Digital Elevation Model for a part of Cameron Highlands, Pahang, Malaysia. (Fig. 2).

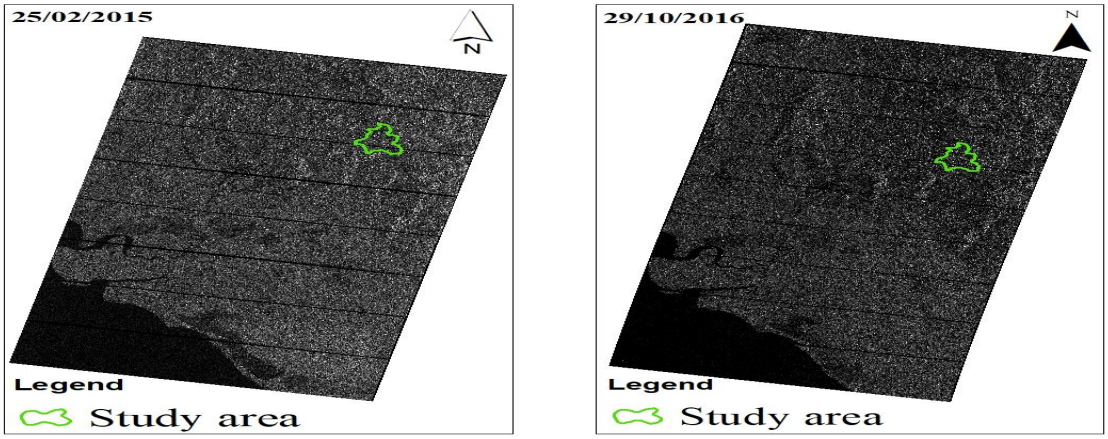

Fig. 2. Shows geographical location of the study area on SENTINEL-1 data

3.2. Data pre-processing and processing

Comparison of phase values for two different radar imageries is InSAR. The phase formation of two or more SAR imageries obtained over the same region can be combined based on the monochromatic nature of the scattered echoes (Bhattacharya et al., 2012). Fig. 3 represents methodology of applying pre-processing and processing steps of extracting DEM from SENTINEL-1 satellite imagery.

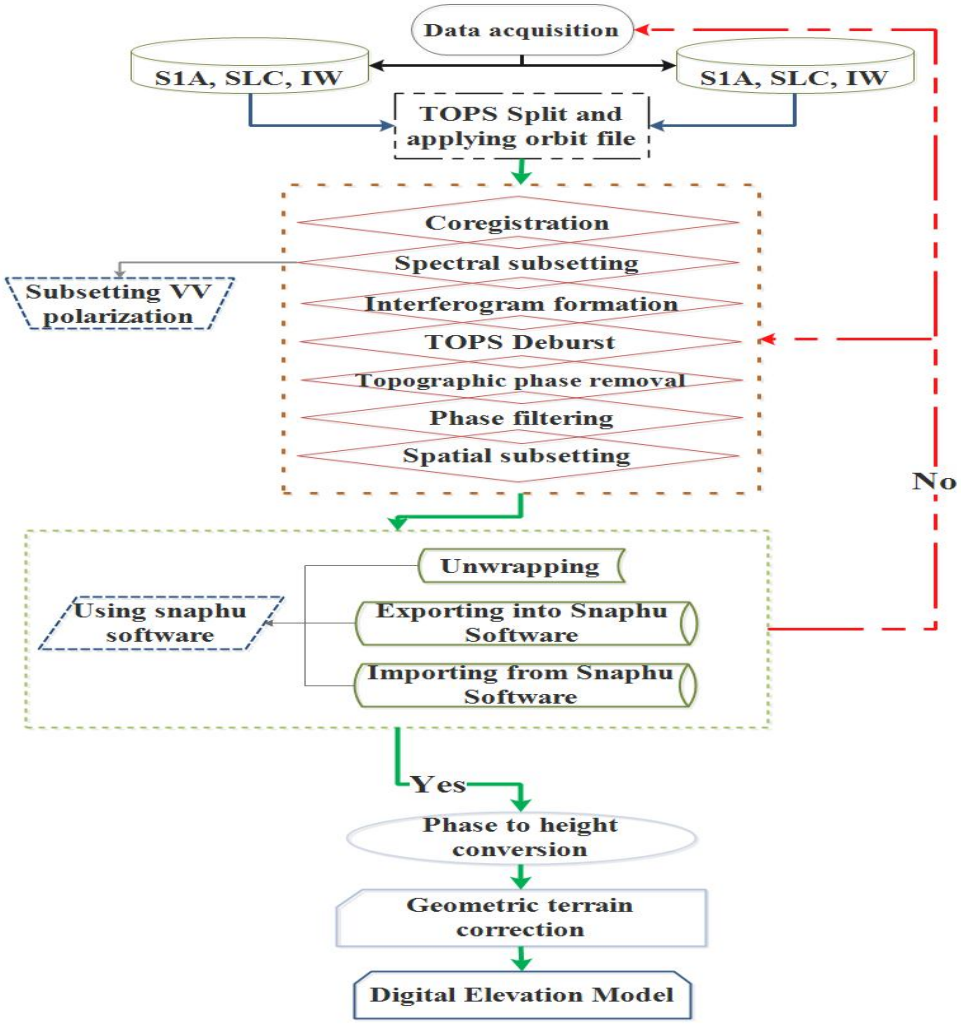

Fig. 3. Methodology of the study

3.2.1. TOPS split and applying orbit file

In Sentinel-1 IW SLC products, we can see 3 sub-swaths IW1, IW2, IW3, which each sub swath is for an adjacent acquisition by the TOPS mode (Fig. 4). Therefore, we must split one of the abovementioned sub-swaths through TOPS split command in SNAP Software.

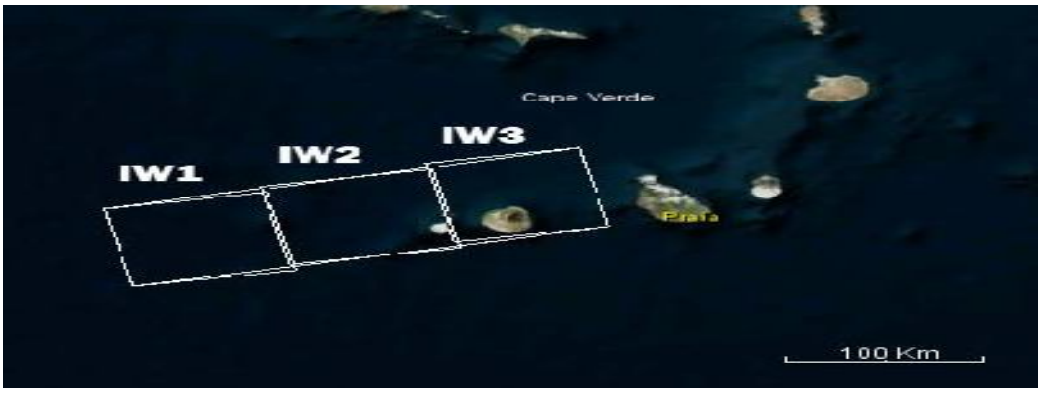

Fig. 4. Illustrates sub-swaths IW1, IW2, IW3 (Luis, 2015)

3.2.2 Co-registration and interferogram formation

Co-registration is done using the coherence between the two satellite images (Kervyn, 2001). The interferogram formation is computed through multiplying point by point value of each pixel of the master imagery and the conjugate complex number of the related pixel in the slave imagery (Fig. 5A) (Luis, 2015).

3.2.3. TOPS Deburst and topographic phase removal

TOPS data is acquired in bursts, which is separated by demarcation zones. However, any data within these zones can be considered invalid and must be deburst, otherwise the topographical phase cannot be removed (Fig. 5B).

3.2.4. Phase unwrapping

The phase unwrapping deals with the integration of the phase difference from point to point through adding the integer number of cycles, which minimises the phase difference (Fig. 5C) (Kervyn, 2001).

3.2.5. Phase to height conversion and terrain correction

Finally, after phase to height conversion step, which converts unwrapped phase band into height, the created DEM should be terrain corrected. Terrain correction converts an image from either slant range or ground range geometry into coordinate system (Fig. 5D).

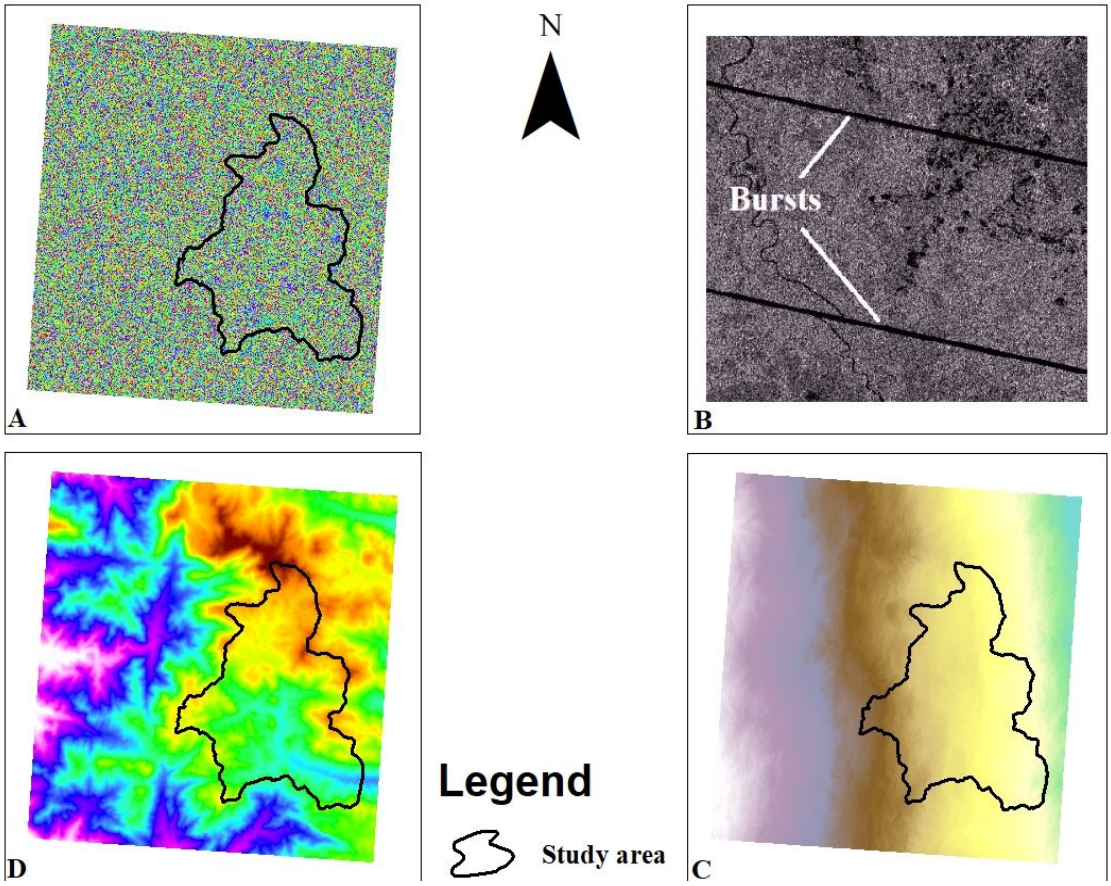

Fig. 5. (A) Interferogram formation output. (B) Bursts in SENTINEL-1 imagery. (C) Phase unwrapped using Snaphu Software. (D) Terrain corrected phase to height output

3.3. Validation using linear regression and standard errors of the estimate

Analysis of regression is associated with a collection of statistical techniques, which normally describes the behaviour of random dependent variables using independent variables. (Park, 2011).Correlation coefficient, which denoted by R has a value between +1 and −1, where 1 represents total positive linear correlation, 0 shows no linear correlation and −1 illustrates total negative linear correlation (Pearson, 1895).

The standard error of the estimate, demonstrates the accuracy of predictions. However, is defined as below equation (Darlington & Hayes, 2016):

$$\sigma_{est} = \sqrt{\frac{\sum(\hat{Y} - Y)^2}{N - 2}}$$

Where σest is the standard error of the estimate, $\hat{Y}$ is estimate variables, Y is an actual variables and here N is the number of ground control points (GCPs). It is worth mentioning that the numerator is squared differences between the actual variables and the

estimate once. However, the less the numerator the high the accuracy will be (Darlington & Hayes, 2016).

IV. RESULT AND DISCUSSION

A DEM with 10*10 cell size resolution was generated from SENTINEL-1 satellite imagery for the study area. The highest and the lowest altitude are 1944 and 953 meters, respectively (Fig. 6).

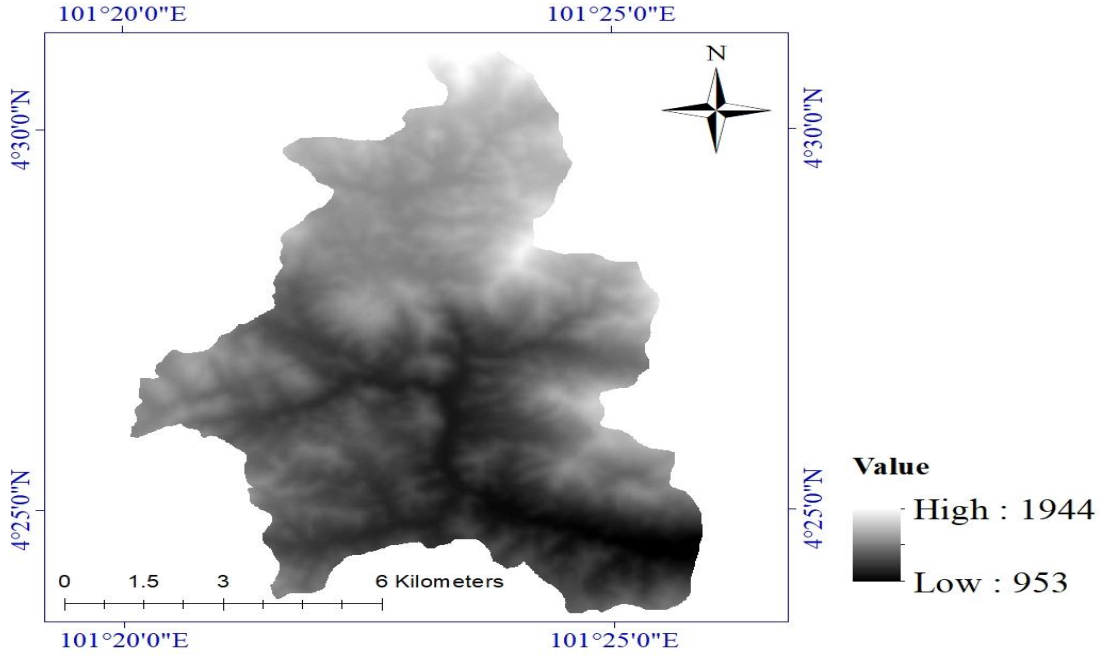

Fig. 6. Shows extracted DEM from SENTINEL-1 products

In general, accuracy assessment is essential process in approving the quality of information extracted from remotely sensed data (Alqurashi& Kumar, 2014). Hence, the extracted DEM from SENTINEL-1 satellite imagery was 10*10 cell size, then a 10*10 resolution DEM from AIRSAR data was selected for validation purpose. In this study we validated extracted DEM by using linear regression and standard errors of the estimate through Statistical Package for the Social Sciences (SPSS) software. Moreover, a 100 random points for scope of the study created and elevation values exported into them from both extracted DEM and AIRSAR one. Correlation coefficient (R) is 99.6% that confirm the variables are completely correlated. Std. Error of the Estimate is low, therefore extracted DEM has good accuracy (Table 2).

Table 2. Lists values of linear regression and standard errors of the estimate

Model	R	Std. Error of the Estimate	Sig.
1	.996[a]	1.99628	.001[b]

CONCLUSION

The main goal of this study was to extract Digital Elevation Model (DEM) for a part of Cameron Highlands, Pahang, Malaysia. Therefore, a pair of SENTINEL-1 satellite imagery for two different times and baseline was acquired online for free. An advanced remote sensing technique called Interferometry Synthetic Aperture Radar (InSAR) was used as a generally accepted method to generate the DEM by using Sentinel Application Platform (SNAP) software. A high resolution DEM (10*10 pixel size) from aforementioned technique was obtained.

Using SNAP software both data were stacked and phase band was created. Once bursts has been deleted from stacked imagery, it is then topographic phase removal process can be done. It is obvious that terrain coherence effect can remarkably affect the phase-unwrapping especially in vegetated or mountainous regions. Therefore, phase filtering was employed to minimize the decorrelation effect. By using SNAPHU Software the phase band was unwrapped. However, before terrain correcting process the unwrapped phase must be converted into height. Generated DEM was validated by standard errors of the estimate model using Statistical Package for the Social Sciences (SPSS) software.

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