THE USING OF GE-1 AND FORMOSAT-2 TO MAPPING LANDUSE CONDITION AFTER KELUD VOLCANO ERUPTION IN 2014

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ABSTRACT Kelud eruption in February 13rd 2014 has a huge impact for the environment. The ashfall spread out around Java island and make several airports need to close their flight schedule for a week. It's become obstruction for the movement of the economics, people and also goods. In the other side, about 4 days after the eruption event, Lahar coming down in the northern flank of volcano and then destruct a paddy field, settlement and killing a victims. Until now, the debris of pyroclastic materials still covered the area surrounding Kelud and it needs to be mapping out to help the inventory of damage and losses assessment done well. We will test both of high spatial resolution data to do this work. The imageries are GeoEye-1 and FORMOSAT-2. GeoEye-1 provide the condition before the eruptions happen while FORMOSAT-2 has an after event imagery, so that by these data we will evaluate the impact of eruption to the environment of Kelud Volcano especially for land-use. The OBIA techniques was implemented to the GeoEye-1, this step works out to reach the information of land-use that exist in the research area. FORMOSAT-2 with 8 meters in multispectral help us to delineate the pyroclastic materials around the volcano. Then we try to overlay both of map and analyse the results. From the results we can understand that the eruption has a huge power. The vegetation, crater lake and another artificial object as a tourism site in the summit area has swept out by that event. While the conditions of another land-use in the other parts of volcano could classified into three classes, i.e. collapse, medium collapse, and no collapse. From this point, we can also notice that the advantages of remote sensing data to assist the unreachable area in the volcanic ring.

KEY WORDS: Very high resolution satellite, Volcano, Pyroclastic, Land-use

1. INTRODUCTION

1.1 Historical Eruptions in Kelud

Kelud is one of the most dangerous volcano in Indonesia and especially in East java. Kelud is one of active volcano in Indonesia which has recorded with explosive eruption. This volcano is part of middle zone of Java Island as a result of Java subduction zone. It is located in the East of Wilis volcano and West of Butak-Kawi-Laksono-Anjasmoro volcanic range. Actually, this volcano has small size compared to other volcano in its surrounding.

Kelud has horse-shoe shape scar which have formed from two landslide (sector collapse) in the southeastern and western flanks (Thouret, et.al, 1998). Based on historical record, Kelud volcano have been erupted 31 times from 1334 until 2014 (Kusumadinata, 1979; Thouret, et.al, 1998; De Bélizal, et.al, 2012). The repose time of the eruption in Kelud is approximately 9-75 years with VEI 3-5 in average (Siebert et al. 2011). Historical eruption noted that more than 15.000 people killed by its eruption (Kusumadinata, 1979). The big eruption have been happened in 1586 and caused 10000 people killed in that eruption (Thouret, et.al, 1998). In 1919, Kelud noted its own history with lahar spreading up to 131 km^2 (Rodolfo, 1999) and more than 5160 was killed (Thouret, et.al, 1998).

1.2 The 2014 Eruptions

On 13 February 2014 after 1,5 hour of the danger level of volcanic activity announced by government, at 22:50 (local time) the Plinian eruption took place. Ash fell in the region in all direction of the vent. The 2014 eruption was made high of eruption column that reach until 25 km and distributed almost in a half of Java Island. Due to this processes, the volcanic material especially ash were dispersed and affected 7 airport (Juanda (Surabaya); Adi Sumarmo (Solo); Adi Sucipto (Yogyakarta); Tunggul Wulung (Cilacap); Ahmad Yani (Semarang); Abdul Rahman Saleh (Malang); Hussain Sastranegara (Bandung) in the Java Island.

1.3 The Using of High Resolution Imagery To Monitoring Volcano

Satellite remote sensing provide large of datasets of volcanic terrain and eruptive impacts. Nowadays, the availability of high-resolution imagery (such as GeoEye-1 and/or WorldView-2 with 50 cm spatial resolution and Formosat-2 with 2,5 m spatial resolution, in panchromatic). Remote sensing data from different sensors including SPOT, ERS, Radarsat, ASTER, AQUA/TERRA-MODIS, ENVISAT-MERIS and Worldview-2 were used to study different range of research like volcanic eruptive phenomena and volcanic impacts (Kerle, et.al. 2003; Joyce et al., 2009).

1.4 Research Problems

However, there is limited research that use high resolution remote sensing to analyst the volcanic phenomena (Joyce et al., 2009). Based on the recent trend of remote sensing application in volcano monitoring, we used data extracted from GeoEye-1 and Formosat-2 imagery to estimate the impacts of the eruption to land use.

1.5 Research Aims

This paper illustrates the capabilities of satellite remote sensing to examine understanding of using high resolution imagery by analyzing of landuse before and after the eruption.

2. METHOD

2.1 Study Area

Kelud volcano located in the eastern part of Java island, Indonesia. Highest point of this volcano is about 1731 m asl with the coordinate is 7° 56’ S and 112° 18,5’ E. Kelud surrounded with 3 different regency, they are Kediri, Blitar and Malang.

2.2 GeoEye-1

GeoEye-1 has three different level of processing; Geo, GeoProfessional and GeoStereo. Geo is a level of 2A processing which has correction for radiometric and geometric. By this level, the imagery are rectified into a datum and map projection system. GeoProfessional is one level ahead of Geo. GeoProfessional are ortho-rectified so that the user could have one of precisely data especially for terrain. GeoStereo provide a strong platform of three-dimensional feature recognition, this imagery can be used for DEM, height extraction and so on (GeoEye Product Guide, 2010).

On this paper, we are only using the 2A level of GeoEye and its enough to reach our study aims. The imagery can show us what is the land cover/land-use that exist on the body of Kelud before the 2014 eruptions. We process this imagery by Object Based Image Analysis (OBIA) technique. Due to this reason, we assume that we do not need to do further step in the radiometric correction such as at aperture spectral radiance, absolute radiometric correction or even planetary reflectance. Radiometric correction has no impact on image classification such as supervised and/or unsupervised classification.

2.3 Object Based Image Analysis (OBIA)

To do an OBIA technique, one needs to make a land-use classification clearly first on each level of segmentation. To deal with this step, we are using the classification scheme that was made by Danoedoro (2009). This is versatile land-use classification system for Indonesia that has complex problem of land-use and/or land cover. The Versatile Land Use Information System (VLUIS) has six perspectives to broken down the information of land-use, they are Spectral, Spatial, Temporal, Ecological, Socio-economic and Political. Only political that could not extracted from remote sensing satellite. From those perspective, we only choose Spatial dimensions to be implemented on this research due to it easiness to relate the object on the scheme with another spatial characteristic such as site, pattern, structure, and etc. List of our detail land use that we use stated in table 2 below.

Table 2. Land-use classes

Level 1		**Level 2**	
S2	Vegetation structure and composition	**S21**	Block coverage
		S23	Vegetation mosaic
S3	Barren land/open soils	**S33**	Volcanic barren land
S4	Buit up/paved surface	**S43**	Built up features with linear shapes
		S44	Built up features with moveable units

Level 3		**Level 4**	
S211	Specifically shaped, homogeneous	**S2112**	Specifically shaped, homogeneous, regularly spaced
S212	Specifically shaped, heterogeneous	**S2122**	Specifically shaped, homogeneous, irregularly spaced
S213	Non-specifically shaped, homogeneous, irregularly spaced		
S214	Non-specifically shaped, heterogeneous, irregularly spaced		
S231	Mosaic of mixed vegetation and non-vegetation	**S2311**	Mosaic of mixed vegetation and barren land
		S2312	Mosaic of mixed vegetation and built up features

S232	Mosaic of trees and herbaceous vegetation	**S2321**	Mosaic of trees and grass
		S2322	Mosaic of trees and shrub
S431	Built up features with network pattern	**S4313**	Small road and other road with unclear boundary
S441	Built up area with cars		

The algorithm for our segmentation is multiresolution. This method has a region growing basis. Its carry on the segmentation by five parameter such as scale, color, shape, smoothness and compactness. We can define our own desire number on each parameter and found the best segmentation that we need. There is no strict rule that can determine which value is better than another one. The only way to know the segmentation is suit for our research is by evaluate it using our visual. On this research, we only change the value of scale to make several pixel on a group and let the another parameter as a default of software. The evaluation of the results was done by visual interpretation in the vector format.

2.4 FORMOSAT-2

Processing level of our FORMOSAT-2 data is 2A, which means this imagery has been through the radiometric and geometric correction with WGS84 projection as default. We need to keep in mind that the radiometric correction that has implemented here is only remove any distortions due to variations in sensitivity of elementary detectors of imaging. To convert Digital Number (DN) into the value that we need, further procedure of radiometric correction must be applied. According to Tsai *et al* (2010), Chen and Cheng (2012), the DN needs to be converted into reflective radiance (R_r) and then apparent reflectance (R_a) by using this following equations:

$$R_r = DN\ x\ (Gain + Offset) \quad (1)$$

and

$$R_a = \frac{Rr\ x\ \Pi\ x\ SB}{SI\ x\ cos(\Theta)} \quad (2)$$

Where SB is the spectral bandwidth, SI is the exoatmospheric solar irradiance and Θ is the sign of solar zenith angle. On this paper, we are only using two bands (red and NIR) by convert both of them into NDVI, so that we just doing the radiometric correction for band 3 and band 4 respectively in our data. The SB value for band 3 is 0,06 µm and band 4 is 93,2 µm, while the SI value of band 3 is 93,2 W/m^2 and band 4 is 148,8 W/m^2 (Tsai *et al*, 2010). Solar zenith angle can be measure by doing simple calculation between 90˚ minus sun elevation, while sun elevation can be checked in the metadata of imagery. Chen and Cheng (2012) stated that for the FORMOSAT-2, the offset values were zero, this is for all bands, whereas the value for gain is 0.2553 and 0.3062 (W µm^{-1} m^{-2} sr^{-1}) respectively for band 3 and 4.

2.5 Normalized Different Vegetation Index (NDVI)

As a one of widely known image transformations especially for vegetation, NDVI also playing a big role on this research. We use NDVI to extract the distribution of pyroclastic materials that covered the body of Kelud volcano as our research area. NDVI will recognize the DN by value -1 up to 1, where the values of pixel which nearly to 1 is the most vegetated area. On the other side, any pixel that has 0 value or less than it, it will shows a barren land or the absence of vegetation. By this assumption, we want to applied the NDVI transformations to delineate the pyroclastic materials, because when the eruptions happen, any area that swept out by pyroclastic materials can be ascertained has no vegetation so the value that will appear is about 0 or nearly from it.

The NDVI will have several classes that indicate the range of pixel which including on a vegetated areas or not. On this research, we only need the range value of pyroclastic area. So we determined it by visual evaluation and doing some spatial data manipulation process on vector format.

3. RESULTS AND DISCUSSIONS

3.1 The OBIA and NDVI Results

According to spectral dimensions in VLUIS by Danoedoro (2009), we can divided our land-use classes into four level. First level was so general and the fourth level is very specific. In the first level, it seems like we only separate the land-use type by the existence of vegetation although we tried to make it more definitive in term of built up classes or barren soil. While in the next level, we have to define the characteristic of land-use with very specific way. We have to mention the shape, heterogeneity, pattern, even what is the contain on each polygon.

It is quite hard to make sure we only use a same level land-use classes on each grade of classification. This is one of challenging thing in Indonesia whenever somebody wants to mapping a land-use. We need to mix it with another level to reach the classification that make us satisfy. On our research area, we found eight classes land-use, namely volcanic barren land, built up features with network pattern, built up features with moveable units, specifically shaped and homogenous, mosaic of mixed vegetation and barren land, non-specifically shaped with heterogeneous and irregular, mosaic trees and grass and the last is mosaic tree and shrub. Those classes are combination between third level and the fourth, except volcanic barren land, that was lies on the second level because the classification scheme has no further explanation of it.

Maximum value of NDVI on our research area is only 0,5. It is just normal because the density of vegetation on the site of research was not so dense. We found the range of pyroclastic material is about -0,19 up to 0,16. Actually, these ranges are divided into three classes, but we make it into a class to be more efficient.

3.2 The Classification of Land-use Damage

As one of big event in Kelud history, the 2014 eruption have a huge magnitude although the peak of eruption process only take several hours. We have done several field survey to check the real conditions and we can understand that the major event was so deadly. Child of Kelud, located in the middle of crater, that being rise since last eruptions in 2007 has been ejected from its current position as high as 25 km. It makes another pyroclastic fall are being spread out into a half of Java and disturb several flight on the island about a week.

According to our imagery processing by using OBIA and NDVI to do the damage mapping of land-use in the western flank of Kelud, we can say that there are three level of destructed land-use due to the 2014 event. Figure 1 below shows our damage map classes.

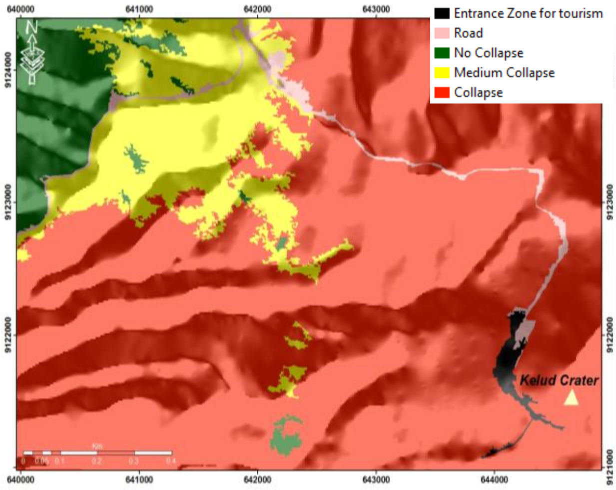

Figure 1. Damage land-use map

There are collapse, medium collapse and no collapse. A land-use that has been collapse are located very near with the crater, as a source of eruptions. Those are many vegetation and built up area with moveable unit and with network pattern. Actually, Kelud is a tourism site. So, the built up area with moveable unit is park area and built up area with network pattern is a road to access the location. Another land-use that just medium collapse or even no collapse are located in another side part of slope. The topography covered themself to face pyroclastic flow directly. So, they are safe and several of them only burn in the top parts.

4. CONCLUSIONS

Remote sensing plays a big role on a mapping of post disaster conditions due to its ability in temporal and spatial resolutions. By temporal resolutions we can check the situations of an environment before a tragedy and by its high spatial resolutions allow us make the land-use mapping with very detail. Both of imagery has an ability to do that. The processing is not too complex and the results are acceptable.

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