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Spatial - Temporal variability of Land Use Land Cover at Mount Merapi, Indonesia

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ABSTRACT

One of the most active volcanoes in the island of Java is Merapi mount which was experienced the last major eruption peak on October 26th, 2010. This volcanic eruption was effusive eruption type where magmatic gas pressure in the crater was not too strong and magma eruption was just flown out past the slopes of the Merapi mount area. However, magmatic gas pressure and magma volume still result in deformation changes that have a direct impact on residential areas throughout the Merapi mount area. Residential areas were obtained through supervised classification process from Landsat 7 and 8-satellite imagery in the 2009, 2011 and 2019 acquisition year. The reason of observation year selection was based on pre and post eruption concept to get pattern of Merapi's mountain body change through deformation analysis. The work focuses on spatial-temporal variability of land use land cover analysis at Mount Merapi pre and post 2010 eruption event considered here. The technique is based on NDVI (Normalized Difference Vegetation Index), Maximum Likelihood Classification (MLC) and False Colour Composite methodology. Based on change in number of pixels it was analysed. Actually, some portion of land was covered with clouds and its shadows. From the results it was observed that, water body, barren and built up features were miss classified. So finally False Colour Composite (FCC) images are used to identify the misclassified classes.

Keywords : NDVI, MLC, False Colour Composite (FCC), Mount Merapi Volcano, Landsat 7 & Landsat 8.

I. INTRODUCTION

The social and economic development of a society is completely dependent on its expansion. This is the primary motivation for conducting socioeconomic surveys. Both spatial and non-spatial datasets are included in this type of survey. At the local, regional and national levels, LULC maps play a critical role in programme design, management, and monitoring. On the one hand, this type of information aids in the understanding of land use issues, and on the other, it aids in the formulation of policies and programmes necessary for development planning. It is vital to monitor the ongoing process of land use land cover pattern throughout time in order to ensure sustainable development. To accomplish sustainable urban development and to prevent haphazard expansion of towns and cities, authorities involved in urban development must establish planning models that allow every available piece of land to be used in the most reasonable and optimal way possible. So it is necessary to have information about the existing and former land use land cover data of the area. LULC maps also aid in the investigation of changes in our ecology and surroundings. The precise information regarding the research unit's Land Use Land Cover [1], will be helpful to formulate regulations and implement programmes to protect our ecosystem.

The Earth is in a perpetual state of flux. Some of this transformation happens slowly over millennia, while others happen quickly over decades. Volcanoes, continental shifts, mountain building and erosion, reorganisation of oceans, appearance and disappearance of deserts and marshlands, advances and retreats of great ice sheets, rise and fall of sea and lake levels, and the evolution and extinction of vast numbers of species are all caused by major natural forces. Volcanic eruptions are also monitored by using thermal remote sensing by estimating Land Surface temperature values [5, 10, and 11].

Mount Merapi is one of the most active volcanos in Indonesia, which is located in central Java. It has a lengthy history of major eruptive episodes. Activity has included lava flows, pyroclastic flows, lahars, Plinian explosions with heavy ash-fall, incandescent block avalanches, block-and-ash flows, and dome growth and destruction. Fatalities from these events were reported in 1994, 2006, and in 2010 when hundreds of thousands of people were evacuated. The impact of active volcano activity will be felt in the densely populated area where the island of Java became one of the islands with the largest residential area in Indonesia.

The organization of this document is as follows. Section 2 presents a literature review of the existing methods used to detect Land Use Land Cover change. Section 3 which discuss about materials methodology i.e. study area and input images for the study purpose and proposed method for detecting changes. Results and discussions were presented in the section 4. Finally section 5 states the conclusions and future scope.

II. LITERATURE REVIEW

Halah Qahtan Hamdy (2018) et.al. Digital change detection method applied to find LU/LC change detection using maximum likelihood estimation. And also NDVI (Normalized difference Vegetation Index) used to classify two classes vegetation and no-vegetation. NDWI (Normalized Difference Water Index) used to identify water and no-water areas [2]. NDBI (normalized Difference Built-up Index) used to classify urban area and no-urban area. Number of indices is used for better identification of each individual class. But there is no comparison between maximum likelihood estimation and indices based estimation.

Zubair Saing (2021) et.al. LULC change detection done for the area South Sulawesi Province, Indonesia for the two years 2005 and 2019[7,3]. Here classification had done using ISO cluster classification which is unsupervised [13]. Training samples considered based on ISO cluster and topographical map of Indonesia. Then finally maximum likelihood classifier [14] applied and results validation had done using random point and field check. Accuracy achieved was 82% and 86% for June 2005 and March 2019 respectively.

Anjan Roy (2019) et.al. used Integrated hybrid classification technique, which comprises of unsupervised and supervised classification techniques, was applied combined human knowledge. NDVI and NDWI [6] maps are used for cross verification of the results. The confusion matrix-based accuracy assessment and Kappa coefficient were considered for assessing the performance of the classification system. The results showed an overall accuracy of 91.36% and kappa index of agreement value of 0.91.

Sophia S. Rwanga, (2017) et.al [8] proposed supervised classification algorithm for Land Use Land Cover classified map generation. Finally classified image accuracy assessment was done using error matrix (Confusion matrix) by comparing with ground truth data. The overall classification accuracy of 81.7% and kappa coefficient of 0.722 observed. Name of the applied supervised classification algorithm was not mentioned.

Md. Inzamul Haque (2017) et.al. Proposed pre-classification approach with CVA (Change Vector Analysis), NDVI and NDWI analysis were implemented to assess the change scenario [9]. Maximum likelihood supervised classification technique was performed to create the signature class of significant land cover category (deep water, shallow water, vegetation, and settlement). The evaluation of accuracy was not taken into account.

III. MATERIALS AND METHODOLOGY

Study Area:

Mount Merapi, Gunung Merapi (Fire Mountain) It is the most active volcano in Indonesia and has erupted regularly since 1548. It is located approximately 28 kilometres (17 mi) north of Yogyakarta city which has a population of 2.4 million, and thousands of people live on the flanks of the volcano, with villages as high as 1,700 meters (5,577 ft) above sea level. For geographical area of research lies in latitude position 110°14'60" E- 110°32'30" E and in longitude position 7°29'47" S-7°47'53" S and can be seen clearly in Figure 1.

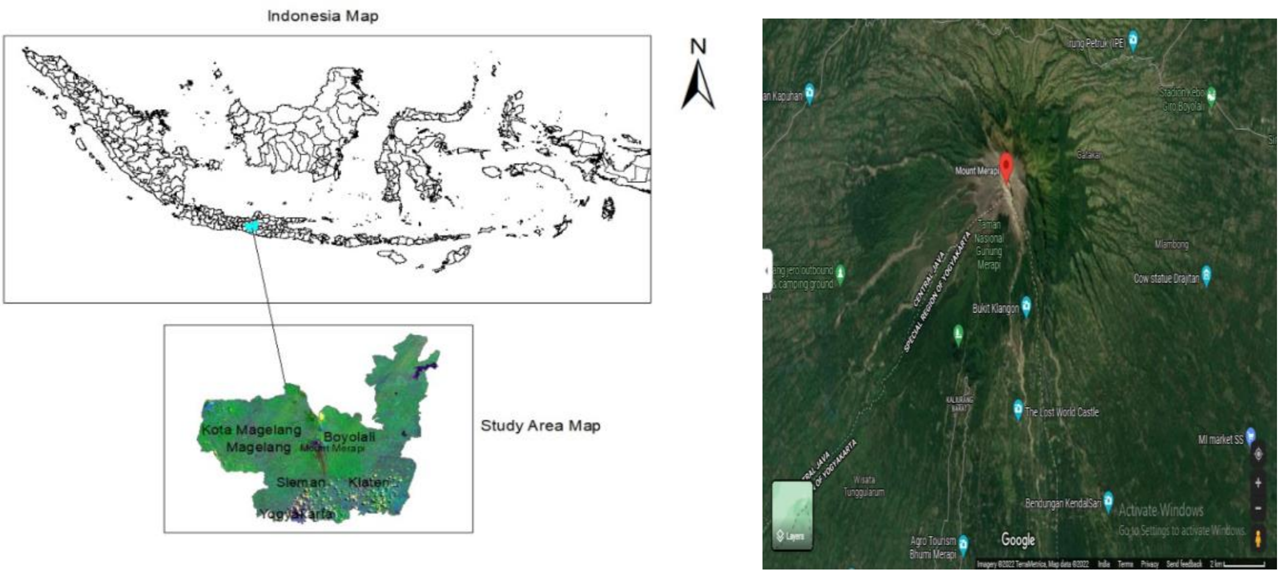


Figure 1. Study area of Mount merapi and its surrounding districts

Mount Merapi rises to roughly 2,930 metres above sea level. On the 26th of October, 2010, Mount Merapi erupted. The Merapi volcanic eruption is a kind of effusive eruption characterised by lava melts and low magmatic gas pressure. For the magma to flow out of the cavity, it must pass through the top of the mountain's slopes. Despite being a type effusive eruption, this one produces significant physical, environmental, and economic damage. The lava flow will change the land cover in the area, therefore there will be changes in land cover before and after Mount Merapi erupts. Prior to the eruption, this results in substantial deforestation (deformation). Volcanic deformation is caused by volcanic activity in the form of magma movements beneath the surface, which effect pressure changes in the magma pocket. Submarine motion is a precursor to eruption and a rise in pressure, both of which will cause ground deformation. This study will look at the deformation pattern that happened on Mount Merapi before and after the eruption. It also includes a study of the effects on land cover land use changes in the study area.

Materials:

Multispectral band pictures of Landsat8 Level 1 OLI / TIRS C1 Level 1 & Landsat 7 (ETM+) were used to detect spatiotemporal changes in land use/land cover at Mount Merapi, 2010 pre and post eruption. WGS84 is the reference datum. Landsat image path-120 and row-65 of the study area were considered. Landsat 7 has a pixel spatial resolution of 28.5 meters and Landsat 8 has a pixel spatial resolution of 30 meters. The satellite image acquisition dates are June 21, 2009, May 10, 2011 from landsat7 and June 25, 2019 from landsat8. Satellite data is shown in Table 1. Images courtesy of https://earthexplorer.usgs.gov. This study considered images having <10% cloud coverage for attaining best classification as well as change detection results. For the development of LULC change detection maps GIS software used is ArcGIS 10.3.

Table 1. Spatial Image Sources

Data source	Sensor	Date	Spatial resolution	Bands
LAND SAT 7	ETM+	21-06-2009	28.5 meters	3,4&5
		10-05-2011		
LAND SAT 8	OLI /TIRS	25-06-2019	30 meters	4,5 &6

Methods:

The methods utilized to detect changes at Mount Merapi volcano before and after the huge eruption on October 26, 2010 are depicted in Figure 2 in the form of flow diagram. The entire procedure is divided into four sections. 1)Pre-processing of images 2) Classification based on NDVI thresholds 3)Classification based on maximum likelihood 4) Change detection using statistical analysis 5)Comparison using FCC image.

Image pre-processing:

The initial step in picture pre-processing is to use the landsat toolbox to remove scan-lines errors from Landsat7 band images. Mount Merapi surrounding areas were selected by using Area Of Interest (AOI) selection process using map clipping process. For subsequent processing, an AOI map is clipped from the needed band images. All the selected images were projected onto a UTM (universal Transverse Mercator) coordinate system, datum WGS84 in the north zone 49N (WGS_1984_UTM_Zone_49N).

NDVI Threshold based Classification:

The Normalized Difference Vegetation Index is a prominent vegetation index that is used by remote sensing to analyse vegetation health and land use land cover [5,6]. The mathematical formula for estimating the NDVI using RED band and NearInfraRed (NIR) band images is given below.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

$$Landsat\ 7 - NDVI = \frac{Band4 - Band3}{Band4 + Band3}$$

$$Landsat\ 8 - NDVI = \frac{Band5 - Band4}{Band5 + Band4}$$

NDVI values ranges from -1 to +1. The classification was done based on NDVI threshold values. It was divided into five classes a) Water bodies b) Barren

Land c) Built up d) Low density vegetation e) High density vegetation.

Maximum Likelihood Classification:

Maximum likelihood classification determines the probability that a given pixel belongs to a specific class based on the statistics for each class in each band being normally distributed. All pixels are categorised unless a probability threshold is set. It was chosen because of its ability to appropriately classify items. This is the most widely using algorithm for creating land use and land cover classification maps and detecting changes based on them. Signature files, which can be constructed from NDVI threshold classified image [4]. It was used as base for maximum likelihood classification.

Change detection using statistical analysis:

Change detection requires understanding the changes in land use land cover that happened as a result of such a huge volcanic eruption [12]. Here, pixel-based variations were calculated to quantify the changes in distinct LULC classes. Images from 2009, 2011 and 2019 were used in this study, which were taken before and after Mount Merapi's massive volcanic eruption in 2010.

Comparison with FCC: Finally comparison between Maximum likelihood classified images with False Colour Composite (FCC) image of that study area was done. By visual interpretation of the FCC image with classified images results were presented.

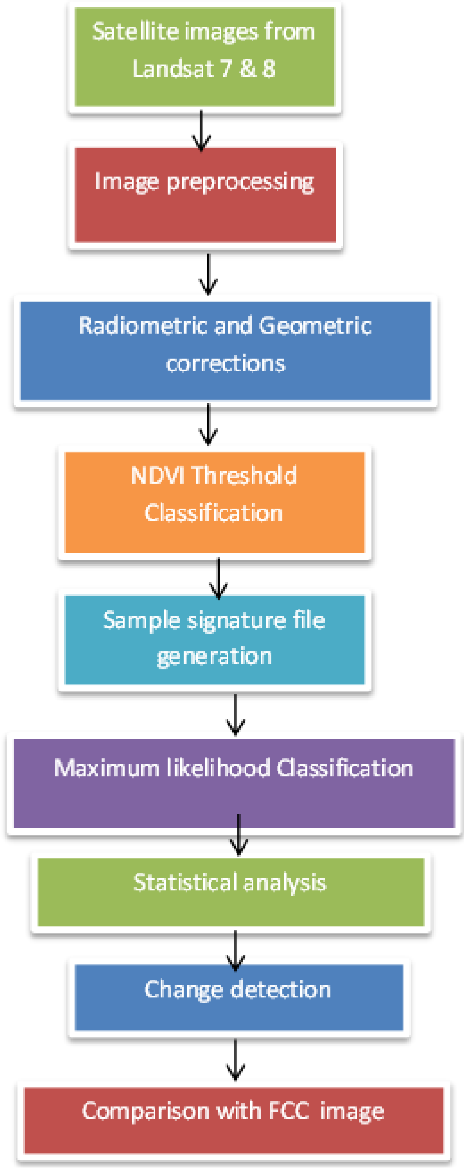
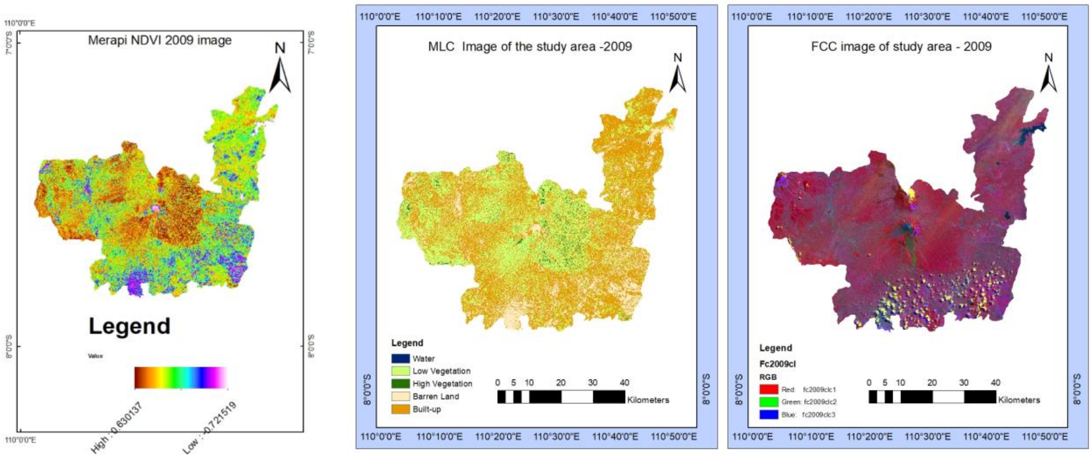


Figure 2. Change detection methodology flow diagram

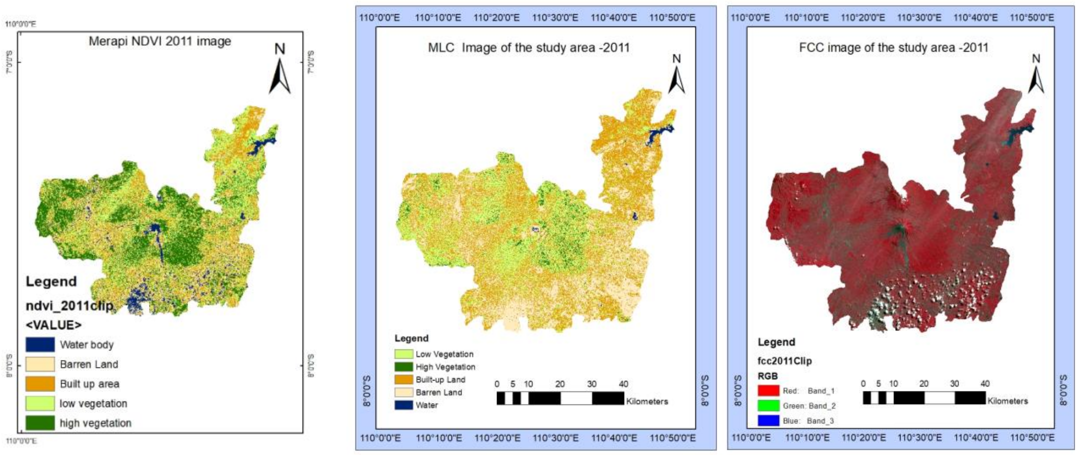
IV. RESULTS AND DISCUSSION

The goal of this study was to determine how land use and land cover were before and after the 2010 volcanic eruption. This data is required by the government officials to take appropriate action plan in response to the observed changes. They will be able to rebuild and recreate the essential facilities as a result of this. To compensate those who have been affected. Normalized Difference Vegetation Index images for the years 2009, 2011 and 2019 are shown in the figures 3(a), 4(a) and 5(a) respectively. Maximum Likelihood Classified (MLC) images are shown in the figures 3(b), 4(b) and 5(b) for the years 2009, 2011 and 2019 respectively. False Colour Composite (FCC) images for the years 2009, 2011 and 2019 are shown in the figures 3(c), 4(c) and 5(c) respectively. Basically Composite band images are used for visual interpretation of the changes in Land use and Land cover. This composite band image was generated using 3bands.



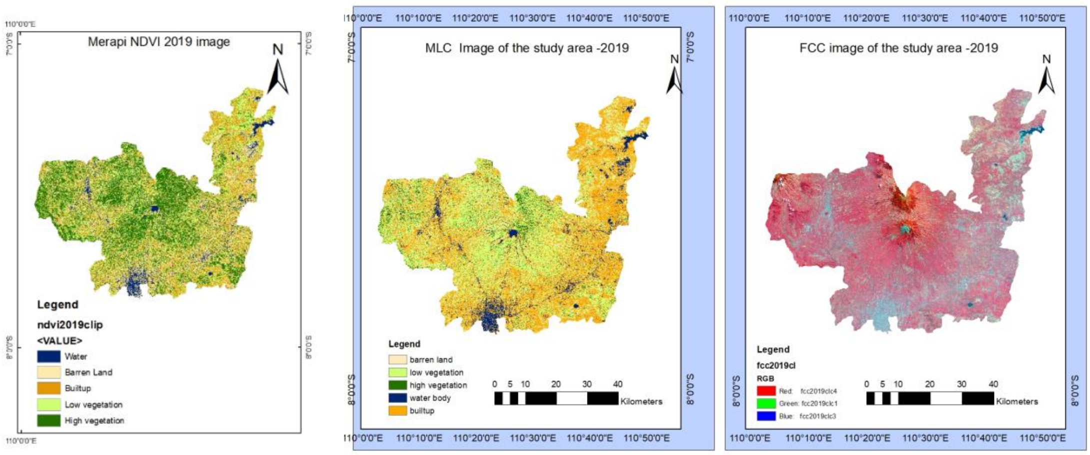
(a) (b) (c)

Figure 3. Study area (a) NDVI Threshold (b) MLC image (c) False Color Composite image for the year 2009



(a) (b) (c)

Figure 4. Study area (a) NDVI Threshold (b) MLC image (c) False Color Composite image for the year 2011



(a) (b) (c)

Figure 5. Study area (a) NDVI Threshold (b) MLC image (c) False Color Composite image for the year 2019

Table 2: Classified parameters in terms of no. of pixels count, Area (%) and differences

Land use Land cover parameter	No. of Pixels	Area (%) 2009	No. of Pixels	Area (%) 2011	No. of Pixels	Area (%) 2019	Difference between 2011 & 2009	Difference between 2019 & 2009
Barren land	584879	15.0429	1179577	30.34	619042	15.92	15.2971	0.8771
Low vegetation	1340772	34.4843	1126659	28.98	1212421	31.18	-5.5043	-3.3043
High vegetation	75228	1.9348	136442	3.51	173903	4.47	1.5752	2.5352
Water body	226	0.0058	22933	0.59	262547	6.75	0.5842	6.7442
Built- up	1886964	48.5322	1422458	36.59	1620156	41.67	-11.9422	-6.8622

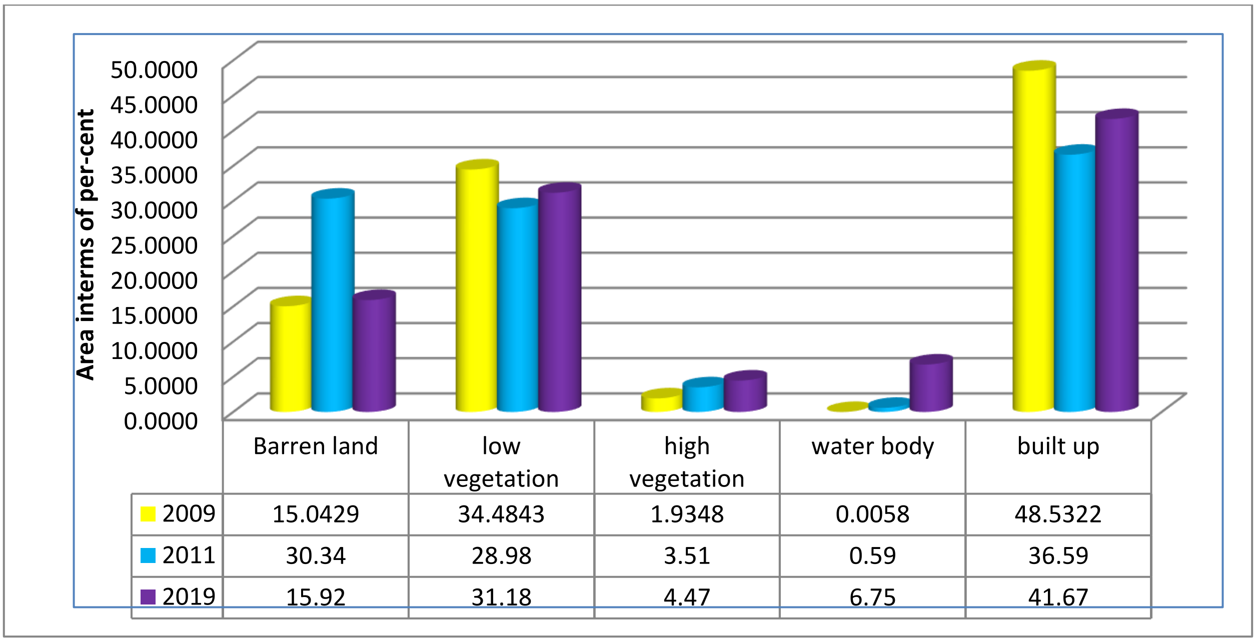


Figure 6. LULC parmeters for the years 2009, 2011 and 2011 interms of Area (%)

From the above results it was observed that, due to clouds and its corresponding shadows some of classes are misclassified. Which can be clearly observed in False Colour Composite (FCC) images shown figures 3 (c),4 (c) and 5 (c). The study area was classified into 5 classes i) Water body ii) Barren Land iii) Built-up area iv) Low vegetation and v) High vegetation. Table 2 presents the land use land cover parameters change in-terms of number pixel count per year, parameter wise area (%) occupancy and difference between 2011 & 2009 and 2019 & 2009. LULC parameters and its quantification using area wise (%) occupancy presented in the figure 6 for the three years data. After quantifying the results it was observed that, water bodies were very less in the year 2009, due to cloud masking over that area. In the year 2019 built-up was about to 41.67 % actually it was more than that. In the year 2011 barren land was approximately double to 2009 and 2019. All these observations are made by comparing the NDVI and MLC classified images with FCC images. So, finally for achieving better classification results it requires cloud free images.

V. CONCLUSION

Mount Merapi volcano and its surrounded places are classified for finding change detection before and after occurrence of massive eruption in the year 2010. After the eruption major change occurred in vegetation areas and barren and built-up land. For the analysis of change in land use land cover, June 2009, May 2011 and June 2019 images were classified using two stage processes. First step to apply NDVI threshold and then Maximum likelihood classifier for better classification was done. The advantage of FCC images clouds and its shadows are identified. Whereas in NDVI based classification it considers clouds and shadow feature as water body so misclassification chances are there. From the above results it was observed that cloud areas are wrongly classified. From this study it can be concluded that, with cloud free images maximum classification accuracy can be achieved. Here the observations are made by comparing the classified images of NDVI and MLC with False Colour Composite images. FCC images can able to present clouds and its shadows. After quantifying the results it was observed that, water bodies were very less in the year 2009, due to cloud masking over that area. In the year 2019 built-up was about to 41.67 % actually it was more than that. In the year 2011 barren land was approximately double to 2009 and 2019. All these observations were made by comparing the NDVI and MLC classified images with FCC images.

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