Mapping pre and post earthquake land cover change in Melangkap, Kota Belud Sabah using multi-temporal satellite Landsat 8/OLI and Sentinel 2 Imagery

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Abstract. Earthquakes in mountainous belt can trigger major disturbance to the landscape impound a large amount of debris exported largely to the streams and forming landslide. During the 5th of June 2015, an earthquake of 5.9 Richter scale hit the heart of Mount Kinabalu, Sabah. The tremors caused the surrounding area to be affected largely to the population that is located near the river stream site. This study maps the land cover in Kota Belud following the earthquake that occurred in 2015 using Landsat 8 Operational Land Imagery (year 2014) and Sentinel-2 Multispectral Imagery data (2020). It was reported as one of the locations that severely impacted by the earthquake. Maximum likelihood algorithm was used to generate the map of land cover change of Kota Belud year 2014 and year 2020. Nine (9) classes of land cover were identified in the study area consisting of primary forest, secondary forest, shrubland, paddy, rubber plantation, bare rock, bare soil, built up, and river. The result obtained shows the most affected area is the river area, Sungai Panataran, that flow through Melangkap from Mount Kinabalu. Other land cover type also shows changes but mostly due to deforestation and agricultural activities. In conclusion, mapping the Kota Belud area using remote sensing and geographical information system (GIS) is useful for monitoring the landscape change of the site due to the vulnerability to natural disaster such as flood and earthquake.

Keywords: Land use planning; remote sensing; supervised classification; monitoring.

1. Introduction

Land cover is the terrestrial surface descriptor which shows the form of physical land cover such as forest, water body, grassland, urban area, agricultural land, and settlements [1]. Monitoring land cover change of certain area from the ground surveys could be difficult if the area is a remote area or has geographical barriers such as hilly land and wide water body. Nowadays with the expansion of geographic information system (GIS) and remote sensing, monitoring land cover can be cost-effective as the land cover data can be obtained from the satellite data or aerial data without direct contact to the actual field. Applying remote sensing satellite imagery to analyse land cover classification and characterisation opens the possibility of enhancing land use management while retaining natural resources [2]. Based on a scientific study [3], land cover can be influenced by deforestation/reforestation, water bodies degradation, and urbanisation. However, land cover change also can be influenced by the movement of soil occurred during landslides due to earthquake.

The land cover change due to earthquakes in mountainous area can generate major impact to the landscape particularly in river stream and its riparian area. This occurrence impounds a large amount of debris exported largely to the streams and triggering landslide to emerge [4,5,6]. The earthquake creates a large mudslide which generated from the drifted big rubbles, trees and sediments that damage the
properties of the existing landscape. The earthquake increases the weakening and withstanding of the rocks and soil corpus which will trigger the failure of the landscape structure to sustain in its current condition [7,8,9]. The change in landscape dynamics following the earthquake is poorly understood [9]. Various processes, such as the progressive depletion of the debris, restoration of the vegetation cover and bedrock healing have been shown to play a role [9,10,11]. Observation on the landscape change soon after earthquake can reveal the major effect rates on the affected area [11]. Complete inventories on the affect change rate and field investigations can certainly provide further insights [11].

The attention on the temporal spatial progress after major earthquake has escalate in the past years particularly after the 5th of June 2015, an earthquake of 5.9 Richter scale hit the heart of Mount Kinabalu, Sabah. The tremors caused the surrounding area to be affected largely to the population that is located near the river stream site. Kota belud is one of the neighbouring major areas that are being affected by the mountain earthquake. Most of the properties, water source and river banks in Kota Belud are transformed and damaged [12]. This study aims to highlight the dynamic of land cover change of Melangkap, Kota Belud, Sabah before and after the earthquake that occurred in 2015. The land cover change monitoring is important for the purpose of land use planning subsist the impact of further earthquake imminent.

2. Methodology

2.1 Study area
Melangkap located in the Kota Belud district (Figure 1), approximaely between 6°10'53.71"N, 6°9'15.32"N and 116°28'44.78"E, 116°30'46.44"E. According to folk tales, Melangkap got its name from the word “miniangkap” meaning layered in Dusun language. It is divided into five (5) sub village, Kampung Melangkap Baru, Kampung Melangkap Tiong, Kampung Melangkap Noriu, Kampung Melangkap Tomis, and Kampung Melangkap Kapa. The study area is a well-known as an ecotourism site and with various homestay operated in the area. It is popular among tourists with the scenic beauty of Mount Kinabalu and river, Sungai Penataran that flow from Mount Kinabalu, located approximately 14 km from Mount Kinabalu. The 2015 Ranau earthquake directly and indirectly affected Melangkap, Kota Belud land cover and its river system. As recorded in [3], Kampung Melangkap Baru where most homestay and ecotourism site residing, is the most impacted area as the main river, Sungai Penataran flow right through the village [13].

![Figure 1. Location of Melangkap, Kota Belud based on Google image taken on 28th July 2020.](image)

2.2 Data acquisition and pre-processing
The images used in this study were downloaded from USGS (https://glovis.usgs.gov/) database. Two images from Landsat 8 and Sentinel-2 from year 2014 and 2020 (Figure 2) were used to monitor the changes of land cover of the study site as detailed out in table 1. Image from 2014 was used to map Melangkap, Kota Belud before the natural disaster happened while the image from 2020 was used to
show the extent of landscape change for Melangkap, Kota Belud after the 6.0 magnitude earthquake strike at present. Landsat 8 carries 2 sensors known as Operational Land Imager (OLI) and Thermal Infrared Sensors (TIRS) [14]. The 2 sensors provide spatial resolution at 30 meters (visible, NIR, SWIR), 100 meters (thermal) and 15 meters (panchromatic). The Sentinel-2 consists of 2 satellites known as 2A and 2B and delivers 13 spectral bands ranging from 10 to 60 meters pixel size. Sentinel-2 aims on monitoring variability in land surface structure [15]. Two (2) scenes of Landsat 8 were used to map each 2014 and 2015 land cover while one (1) scenes of Sentinel-2 was used to map 2020 land cover.

Figure 2. Satellite Images for Landsat 8 OLI year 2104 (left) and Sentinel 2 year 2020 (right).

2.3 Pre-processing and land cover classification
Radiometric correction was applied to rectify the errors for both satellite images. The radiometric correction was carried out to convert digital image numbers to sensor radiance, digital image numbers converted to top-of-atmosphere reflectance with form and scale of raster data defined, topographic correction as well as the subtraction of dark objects. Radiometric corrections enable a more precise assessment of the properties of the ground surface and encourage comparison between images obtained at different times or in different areas [16]. Cloud covering the study site is unavoidable due to the location near to mountainous area. Therefore, the images covered with cloud are rectified by using Fmask algorithm that efficiently automatically detect cloud and cloud shadow to reduce the salt and paper effect in the images [17,18,19]. This helps in reducing the errors for further classification process. Then, Landsat 8 bands (Table 1) that had been pansharpened and all Sentinel-2 bands with 20 m resolution was resampled to 10 m by means nearest-neighborhood resampling to standardize the resolution of pixel of both satellite image. Arcgis 10.2 and tntmips 2017 software were used for the pre-processing and classification process.

Table 1. The data source of Satellite Images.

| SI. No. | Satellite | Sensor | Path/Row/Tile Number | Spatial Resolution | Band | Year |
|---------|-----------|--------|----------------------|--------------------|------|------|
| 1       | Landsat 8 OLI/TIRS | Operational Land Imager (OLI) | 118/056 | 30 × 30 m (Except Band 8 Panchromatic: 15m) | 7 | 2014 |
|         |           | Operational Land Imager (OLI) | 118/056 | 30 × 30 m (Except Band 8 Panchromatic: 15m) | 7 | 2015 |
| 2       | Sentinel 2 | Multi Spectral Imager (MSI) | T50NMN | 10 × 10 (Band 2,3,4) | 9 | 2020 |
Supervised classification using the maximum likelihood classification rule was applied to establish a land cover map of the study areas. Maximum likelihood classification is a robust algorithm, and it is well accepted classification due to its directness that leads to less risk of misclassification [20]. This classification method uses digitized pixel-based classification training areas, and the computer system is automatically trained to identify the spectral signature of various types of land cover classes [21]. Nine (9) classes of land cover were identified in the study area consisting of primary forest, secondary forest, shrubland, paddy, rubber plantation, bare rock, bare soil, built up, and river. The accuracy assessment was performed using references data that were collected by stratified random sampling and assigned 50 random points on each land cover type that were collected through ground truthing, interpretation of existing GIS database (River and Road) and maps (Google Earth and topographic map).

3. Results and discussion

3.1 Land cover change

The land cover classification using maximum likelihood algorithm illustrated the changes of land cover area between year 2014 and year 2020 in Figure 3 and 4, respectively. For the past six years, the predominant land cover type which is primary forest has shown major changes that results in the decrease of primary forest in Melangkap about 22% (1,134 ha) (Table 2). Meanwhile, the total area of the secondary forest expands from 865 ha in 2014 to 1,546 ha in 2020. There is also a drastic decrease in the river area with the total of 160 ha. Additionally, the bare rock has increased almost 50% within the access time frame. The river surface was also covered with bare rocks and vegetation before washed away by the flow of debris from Mount Kinabalu [13]. Rockfalls from slopes, gullies, and river valleys temporary damped the Sungai Mesilou East but when the dam collapses the debris flow increases causing the widening of Sungai Mesilou. There are also changes from shrubland to water occurred at the river due to former debris flow [2].

![Figure 3. Land cover classification of Melangkap, Kota Belud for year 2014.](image-url)
As indicated by Tongkul (2016), the Sungai Penatran flowing through Melangkap has become widened, deepened, and inundated the main road and houses alongside the Sungai Penatran due to 2015 earthquake [13]. The landslides or movement of soil that occurred after the earthquake is highly influenced by amount of rainfall received [22]. The increase in rainfall amount caused much greater changes to topographic changes and motion of larger total volumes of matter from landslides. Landslip and rockfall in highlands will directly affect the watershed area. The reduced vegetation cover decreased the ability of watershed to capture and store rainwater. Vegetation cover was destroyed during the initial earthquake which caused the soil erosion to occur in the site that eventually will impact the river system as well as affect the growth of vegetation in the watershed and forest area [13,23,24]. A scientific study also indicated that landslips induced by the earthquake occurred more than 30 km from epicenter (10 km beneath Mount Kinabalu) and area triggered with landslides is mostly within 225 km² according to the classification results from Landsat 8 [25]. This study also describes that there are two (2) slopes failure after the earthquake on Mount Kinabalu. One of the large slope failures is a 6 km² patch within the river on north-western side of Mount Kinabalu.
3.2 Overall accuracy and Kappa statistics ($K^*$)

The result from the accuracy assessment illustrates an overall accuracy from the random sampling for 2014 and 2020 are 82% and 85%, respectively. The Kappa statistics computes the user identified class data and the reference data following the completion of the land cover classification. The value of Kappa coefficient represents the value of 80% (year 2014) and 82% (year 2020). Apart from overall classification accuracy, the individual producer’s and user’s accuracy for each land cover classes reflects the reliability of the classification to both categories. Even though both satellite image has been standardized to the same higher pixel resolution, misclassification still take place in the land cover classification. This misclassifications of land cover are mostly due to uncertainty about the spectral land cover class signature [26].

4. Conclusion

This study estimated the extent of land cover change in Melangkap, Kota Belud, Sabah before and after the earthquake that occured in 2015. The land cover classification change that took place between the year 2014 and 2020 illustrates the dynamic change in the area predominantly in the primary forest area. The primary forest exhibited the decrease of more than 1,134 ha within the access time frame. Following this change, the bare rock area displays an increase of almost 50% for this class type. Finally, the land cover change occured in this study area for the past five years is not entirely caused by the earthquake. The epicenter is located within 10 km surrounding the Mount Kinabalu area and merely the landscape change near the riverbank can be associated with the natural disaster. Meanwhile the other land cover class changes can be associated with deforestation, agricultural activities, and land conversion.

5. References

[1] Wulder M A, Coops N C, Roy D P, White J C and Hermosilla T 2018 Land cover 2.0. *Int. J. Remote Sens.* **39** 4254–84
[2] Mohd Kamal N A, Razak K A and Rambat S 2019 Land use/land cover assessment in a seismically active region in Kundasang, Sabah. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* **42** 433–40
[3] Zhao S, Peng C, Jiang H, Tian D, Lei X and Zhou X 2006 Land use change in Asia and the ecological consequences. *Ecol. Res.* **21** 890–6
[4] Dadson S J, Hovius N, Chen H, Dade W B, Lin J C, Hsu M L, Lin C W, Horng M J, Chen T C, Milliman J and Stark C P 2004 Earthquake-triggered increase in sediment delivery from an active mountain belt. *Geology* **32** 733–6
[5] Fu Z, Hu C, Zhang H, Cai Y and Zhou Y 2011 The possibility of inferring rupture depths of fault earthquakes from zero-strain points of coseismic surface deformation. *Seismol. Res. Lett.* **82** 89–96
[6] Langat P K, Kumar L and Koech R 2019 Monitoring river channel dynamics using remote sensing and GIS techniques. *Geomorphology* **325** 92–102
[7] Parker R N, Hancox G T, Petley D N, Massey C I, Densmore A L and Rosser N J 2015 Spatial distributions of earthquake-induced landslides and hillslope preconditioning in the northwest South Island, New Zealand. *Earth Surf. Dyn.* **3** 501–25
[8] Scaringi G, Fan X, Xu Q, Liu C, Ouyang C, Domènech G, Yang F and Dai L 2018 Some considerations on the use of numerical methods to simulate past landslides and possible new failures: the case of the recent Xinmo landslide (Sichuan, China). *Landslides* **15** 1359–75
[9] Xu C C X, Sheng P S and Wan C C 2019 Experimental and theoretical research on shear strength of seismic-damaged SRC frame columns strengthened with enveloped steel jackets. *Adv. Civ. Eng.* **2019** 1–8
[10] Zhang S, Zhang L M and Chen H X 2014 Relationships among three repeated large-scale debris flows at Pubugou Ravine in the Wenchuan earthquake zone. *NRC Res. Press* **965** 951–65
[11] Yang F, He C, Huang R, Domènech G, Xu Q, Dai L, Guo X, Fan X and Scaringi G 2019 Two multi-temporal datasets that track the enhanced landsliding after the 2008 Wenchuan earthquake. *Earth Syst. Sci. Data* **11** 35–55
[12] Geraldine A 2018 Three years on after June 5 earthquake in 2015, Sabah now has 28 monitoring stations. *The New Straits Times*

[13] Tongkul F 2016 The 2015 Ranau earthquake: cause and impact. *Sabah Soc. J.* 32 16

[14] Yang I and Acharya T D 2015 Exploring Landsat 8. *Int. J. IT, Eng. Appl. Sci. Res.* 4 2319–4413

[15] Phiri D, Simwanda M, Salekin S, Nyirenda V R, Murayama Y and Ranagalage M 2020 Sentinel-2 data for land cover/use mapping: A review. *Remote Sens.* 12 2291

[16] Pons X, Pesquer L, Cristóbal J and González-Guerrero O 2014 Automatic and improved radiometric correction of landsat imagery using reference values from MODIS surface reflectance images. *Int. J. Appl. Earth Obs. Geoinf.* 33 243–54

[17] Zhu Z and Woodcock C E 2012 Object-based cloud and cloud shadow detection in Landsat imagery. *Remote Sens. Environ.* 118 83–94

[18] Qiu S, Zhu Z and He B 2019 Fmask 4.0: Improved cloud and cloud shadow detection in Landsats 4–8 and Sentinel-2 imagery. *Remote Sens. Environ.* 231 111205

[19] Zhu Z, Wang S and Woodcock C E 2015 Improvement and expansion of the Fmask algorithm: Cloud, cloud shadow, and snow detection for Landsats 4-7, 8, and Sentinel 2 images. *Remote Sens. Environ.* 159 269–77

[20] Sisodia P S, Tiwari V and Kumar A 2014 Analysis of supervised maximum likelihood classification for remote sensing image. *Int. Conf. Recent Adv. Innov. Eng. ICRAIE 2014* 9–12

[21] Kamlun K U, Bürger Arndt R and Phua M H 2016 Monitoring deforestation in Malaysia between 1985 and 2013: Insight from South-Western Sabah and its protected peat swamp area. *Land Use Policy* 57 418–30

[22] Gariano S L and Guzzetti F 2016 Landslides in a changing climate. *Earth-Science Rev.* 162 227–52

[23] Lin W T, Lin C Y, Tsai J S and Huang P H 2008 Eco-environmental changes assessment at the Chiufenershan landslide area caused by catastrophic earthquake in Central Taiwan. *Ecol. Eng.* 33 220–32

[24] Deng X, Jiang Q, Ge Q and Yang L 2010 Impacts of the Wenchuan Earthquake on the giant panda nature reserves in China. *J. Mt. Sci.* 7 197–206

[25] Wang Y, Wei S, Wang X, Lindsey E O, Tongkul F, Tapponnier P, Bradley K, Chan C H, Hill E M and Sieh K 2017 The 2015 Mw 6.0 Mt. Kinabalu earthquake: an infrequent fault rupture within the Crocker fault system of East Malaysia. *Geosci. Lett.* 4

[26] Miuse C F and Kamlun K U 2019 Multioral land-cover classification of Kinabalu Eco-Line site and the protected park areas. *J. Phys. Conf. Ser.* 1358

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