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CASE STUDY

Satellite imagery system in malaria transmission resulting from the land use/land cover change

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study analyzed the changes in land use and land cover trends and their implication on malaria transmission using satellite imagery applications. Deforestation or human land use activity related to water and development has expanded the ideal habitats for malaria-carrying mosquitoes, resulting in an upsurge of malaria transmission.

The presence of these habitats and breeding increased the contact between humans and mosquitoes, thus increasing the number of malaria cases. The decrease of canopy and forest cover has increased the temperature, resulting in the shortening of aquatic stages and sporogony development of the mosquitoes. This study aims to provide an understanding of the relationship between the topography effect over the land-use factor and land cover change on malaria for more than ten years from 2005 to 2019 of transmission.

METHODS: Malaria case data obtained were analyzed for the trends, incidence rate, and spatial distribution. Remote Sensing and geographic information system were used to determine the land use and land cover change in selected districts of North Borneo in Sabah, as the study areas.

FINDINGS: The malaria incidence rate shows an increase from 2005 to 2019, with 149.64%. The transmission of the malaria vector dynamics and abundance with topography changes has changed with time, including with forest declination at 8.38%, and cropland change decreased at 16.61%. However, an expansion of 33.6% was observed for oil palm plantations. Overall, the results have shown that the range of incidence rate was found` highly viable from 0.29/1000 persons to 4.09/1000 people.

CONCLUSION: In conclusion, using geographic information system remote sensing with malaria integrated topography transmission information will be targeted by zoning most affected areas or the most productive larval habitat for remedial measures. This study can help to reduce the malaria vector population through environmental management related to the mosquito larval cycle in different land-use settings and change by minimizing the transmission by the targeted malaria control program.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
42	6	5

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INTRODUCTION

Urbanization is one of the main contributors to land-use change and contributes to an increase in the occurrence of malaria (Tatem *et al*., 2013). It builds a suitable environment for mosquito breeding, thus inducing higher malaria occurrence. The hidden place that will be removed from mosquitoes' breeding habitats (Tucker *et al*., 2017) will lead them to travel to the nearest residential area, thus increase the transmission. Apart from that, man-made activities which have converted land for agriculture, such as oil palm plantations, logging, or mining (WWF, 2020), will alter the ecological balance and suitable climatic conditions for breeding, thus transmitting malaria (Baeza *et al*., 2017). The population changes will increase malaria transmission as it increases the rate of spreading cases from one region to another due to higher contact between humans and mosquitoes (Martens and Hall, 2000). Mosquitoes' larval abundance and survival rates are affected by land-use change such as reducing the canopy of forest cover, increasing the availability of open and sunlit habitats and crop activity that will provide higher breeding ground (Yadav *et al*., 2014). The larval habitat that has altered makes the larval survivorship increased by accelerating their development rate or increasing larval pupation rate, and adult emergence rate (Brown *et al*., 2018). Deforestation and land clearance will change the climate effect by increasing the temperature that will also increase the malaria vector reproductive rate. Blood meal digestion rates have been found directly proportional to the surrounding temperature. Weather conditions during rainy weather with a lower temperature will slow the blood meal digestion compared to warmer temperatures (Mawili-Mboumba *et al*., 2013). The temperature will affect the gonotrophic cycle length with the time between a blood meal and oviposition (Bousema and Drakeley, 2011). In the adult stage, an increase in ambient temperature will accelerate the digestion of blood meals (Babaie *et al*., 2018). Increased biting frequency and faster blood meal digestion also mean increased fecundity and reproductive fitness (Lowassa *et al*., 2012). For rainfall amount, it will influence the habitat of mosquitoes breeding, and humidity will control their activities and life duration (Le *et al*., 2019). During rainy seasons, it is attributed to lower larval density due to the flush effect by washing eggs and larvae from the habitat (CDC, 2018). However, some findings show rainfall coincided with the abundance of adult mosquitoes due to a habitat rich with food resources and nutrients (Kweka *et al*. 2016; Mukhtar *et al*., 2019). Lower humidity in houses coincided with a negative survival rate of malaria mosquitoes, and they have a higher net reproductive rate with higher fecundity (Haque and Basak, 2017). The study of land use and land cover (LULC) changes is essential for effective natural resource planning, exploitation, and management (Pohl, 2014). Traditional methods for gathering demographic data, censuses, and environmental sample analysis are insufficient for multicomplex environmental studies (Rawat and Kumar, 2015). Geographic information system (GIS) is computer software capable of acquiring, analyzing, and presenting geographically related (spatial) LULC changes information (Mark and George, 2018). Geographic information systems and remote sensing have a wide range of applications in agriculture, environment, and integrated eco-environmental evaluation to assist in development-oriented management and decision-making processes (Torbick *et al*., 2016). GIS and satellite remote sensing has evolved into a viable tool for developing and interpreting global, physical processes impacting the environment (Bouzekri *et al*., 2015). When dealing with land-use changes with visualization tools and imaging using satellite, it can be more efficient if compared to the traditional/conservative application of using time series and long-term statistical analysis just for looking at the significant changes (Mark and George, 2018). Due to the involvement of multiple data sets, we used the latest technologies, remote sensing, and GIS, to quantify LULC and its impact on the emergence of malaria cases. This study is useful in assessing relative mosquito abundance by above-ground biomass from different land cover classifications such as forested land, cropland and oil palm conversions. Based on GIS analysis, a targeted malaria control strategy was suggested to achieve cost-effective measures of malaria on a sustainable basis. Sabah's forest resources have been over-exploited for the last 30 years and mostly were cleared due to oil palm plantation (Toh and Grace, 2005). Sabah recorded 45% of malaria cases reported in Malaysia from 2010 to 2014 (Ramdzan *et al*., 2020). However, the major causes of spatial differences in vector distribution and abundance in this region with heterogeneous environments with various changes in land use and land cover have never been investigated, mainly using satellite imagery by GIS and remote sensing. Therefore, this study aimed to determine the presence and magnitude of malaria transmission related to the land use and cover change in North Borneo of Sabah, Malaysia, from 2005 to 2019.

MATERIALS AND METHODS

Description of the study area and context

The study area in this study was focused on the North Borneo of Sabah. The locations involved in this study, Ranau, Tambunan, Keningau and Tenom, were coincidentally designated as study sites. One of the reasons these highland districts were chosen for the study was the large increase in malaria cases recorded in these areas. Highland area had reported experiencing a surge in the number of malaria cases, and the spatial-temporal patterns in the different mountainous regions have yet and seldom focused in this area (WHO, 2014). The total land area of the study area is approximately 10267 kilometers square (Ranau 2978 km^2; Tambunan 1347 km^2; Keningau 3533 km^2; Tenom 2409 km^2). Fig. 1 shows the geographic location of the study area in the highland districts of Sabah, Malaysia.

Besides the climate factor, land use has many effects on disease transmission and occurrence. The Sabah's land use and land cover (LULC) map that the public can obtain is only updated to 2008 (MAMPU, 2018). Lack of up-to-date data is hard to implement better planning and management on land. In this study, an updated land use map of selected districts in Sabah was produced for a specific study period of 2005, 2010, 2015, and 2019. The LULC maps are required to provide information on which activities have been done from the past then compare them to the present and how they affected the environment. It is also helpful for assessing land cover change of origin and occupied areas in each period. The information can be used to evaluate the relationship between land use type changes and the occurrence of malaria in a specific region. The multi-temporal satellite image was acquired from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite, and Geographic Information System (GIS)

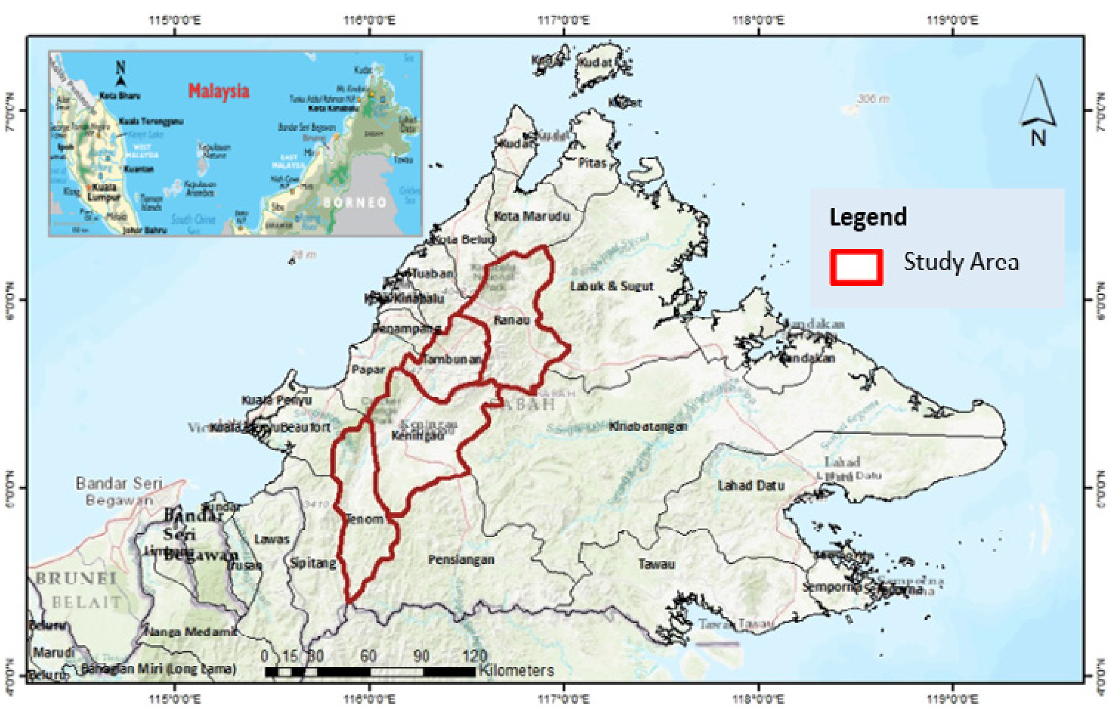

Fig. 1: Geographic location of the study area in selected districts of Sabah, Malaysia with a red line indicated the boundary of each district which the study was conducted

software was employed to generate the land cover map for highland districts of Sabah for the years 2005, 2010, 2015, and 2019 for malaria cases data in selected districts of Sabah.

Land cover change data and accuracy assessment

Multi-temporal satellite image of the study area was acquired from the United States Geological Survey (USGS) (USGS, 2020). The 14 years range time frame of the satellite image was obtained from MCD12Q1 Version 6 with 500 m spatial resolution. The year of satellite image selected is from 2005 as a starting point of widespread malaria after 2004, with a five-year interval period. The year 2019 will represent the latest changes that can be observed in the study area. Moderate Resolution Imaging Spectroradiometer (MODIS) images have a low spatial resolution (500 m), yet it has a higher observation frequency (Miuse and Kamlun, 2019). MODIS images were chosen for this study over Landsat images (higher spatial resolution) because the study area is highland, where the cloud will always be prevalent. All satellite images obtained from MCD12Q1 Version 6 were cloud-free images. Land cover is classified based on the International Geosphere-Biosphere Program (IGBP) classification scheme, consisting of 17 classes. In this study, the 17 classes from the IGBP classification scheme were simplified into 4 main classes, forests, oil palm, croplands, and urban. The accuracy assessment in the land cover classified map indicated the accuracy level of the study comparison of a classified map and ground truth data (Kamlun *et al*., 2016). Ground truthing data was chosen to conduct field inspection, and the random points were generated from ArcGIS software (ArcMap 10.8). The point's data was then transferred into KML file type to refer on Google Earth Pro in the specific study period of 2005, 2010, 2015, and 2019. The steps of this accuracy assessment involve stratified random sampling, which proceeds on the defined land cover classes. In this study, 50 random points were assigned for the forest and oil palm areas, respectively (study area main focus), and 20 random points were assigned for cropland and urban areas. The land cover change classification accuracy was evaluated by calculation on error matrix that includes user's accuracy, producer's accuracy, overall accuracy, and Kappa coefficient. Kappa coefficient is a statistical measure that can be used to validate the generated map. It is also an accuracy assessment that has been widely used by the study on remote sensing field (Phua and Tsuyuki, 2004). Kappa statistics can help determine how closely the occurrences are classified by matching the data labelled as ground truth with the random classified data by estimated accuracy. This study conducted post-classification change detection for land cover changes analysis on each class. Change detection is a process to determine the changes in the state of something by observing it from time to time (Alawamy *et al*., 2020). The advantages of applying change detection in post-classification include minimization of atmospheric or environmental differences between maps, thus more information provided from matrix table of land cover changes, and a better evaluation of the change rates (Ukor *et al*., 2016). Calculation of change for each land cover class includes the magnitude of change (the difference between years), percentage of change (magnitude of change divided by the initial year and multiplied by 100%), and the annual rate of percentage change (magnitude of change divide by the initial year times number of years of the period and multiply with 100%) (Alawamy *et al*., 2020). The changes in the land cover area of each highland district from 2005 to 2019 are shown in the land cover conversion map and tabulated in a cross table to analyse the 'from-to' of each land cover class. Thematic map involved in this study is the land cover classification, which are forest, cropland, and oil palm, to assess land cover changes by above-ground biomass, and based on malaria incidence rates category of risk, with remote sensed data and topo sheets of 1:50,000 and 1:125,000 in preparing the thematic maps. Digitized overlaid maps were subjected to computer analysis using ARC/INFO 3.1 software.

Malaria transmission cases and data analyses

The malaria cases data in Sabah were obtained from the Malaysian Ministry of Health. Malaria cases have shown increased from the year 2005 in the highland district, data from the year 2005 to 2015 was chosen to make a comparison by an interval of 5 years range (2005, 2010, and 2015), whereas 2019 was chosen as MODIS image only available latest in this year. Data analysis was conducted to show the spatial movement of malaria transmission in study areas from 2005 to 2019. The incidence rate of malaria in each selected district will be calculated based on the population from each district according to the Malaysian Census. The annual population of the district was estimated based on the 2000 Malaysian Census, 2010 Malaysian Census and open population data from the Department of Statistics Malaysia. The annual incidence rate of malaria was calculated using the number of malaria cases per year divided by the annual population data for each district and multiplied by 1000. A map of malaria incidence rate per 1000 population annually for each district was generated using ArcMap 10.8. Data acquired from the Malaysian Ministry of Health was used to analyse the peak occurrence of malaria disease and combine it with the land cover to determine the transmission factor. The malaria incidence rate per 1000 persons and the land cover changes data were used to analyse the cumulative changes from 2005 to 2019. Only land cover of the forest, oil palm, and cropland were chosen for the analysis because urban had no significant effect or changes during the study period. Pearson's correlation and Multiple Linear Regression analyses were carried out to determine the relationship between annual land cover changes and malaria incidence rate per 1000 persons in the study area yearly from 2005 to 2019. This analysis is important to reveal the susceptibility of malaria cases towards the land cover changes (Franzese and Iuliano, 2019).

RESULTS AND DISCUSSION

Spatial distribution of malaria in highland districts

Fig. 2 shows the trend of incidence rate per 1000 persons for the four selected districts. From 2005 it was recorded at 3.26 to 6.98 incidence in 2019 with an increment of 149.64%. Overall findings show that the malaria incidence rate is highest at Ranau district at 2.67 incident rate and 40.56% compared to the other districts percentage. The second-highest recorded at 2.26 for Tenom district (17.95%), followed by Tambunan (31.78%) at 1.20 and the least Keningau district (9.71%) at 0.83 incident rate during 2005 until 2019. However, by annual rate, Tenom recorded the highest increment with 946.67%, followed by Ranau 155.46%, then Tambunan 79.31%, and Keningau 36.46% of increased for the 14-years. Apart from that, the malaria incidence rate has dropped significantly from 2009 until 2011, recorded at 6.87 (-9.42%, 2009), 5.11 (-29.64%, 2010) and 4.39 (-40.12%, 2011) from 7.84 incident rate and decreased during the year 2015 to 2016 at 4.23 (43.64%, 2015) and 2.91 (-58.96%, 2016) from 7.19 incidence rate for all of the districts. For temporal distributions, the findings show that 2017 recorded the highest malaria transmission rate at 10.33, followed by 2018 at 9.03 incident rate, and thirdly in 2008, recorded at 7.84.

The incidence rate of malaria for each district was found highly variable from the year 2005 to

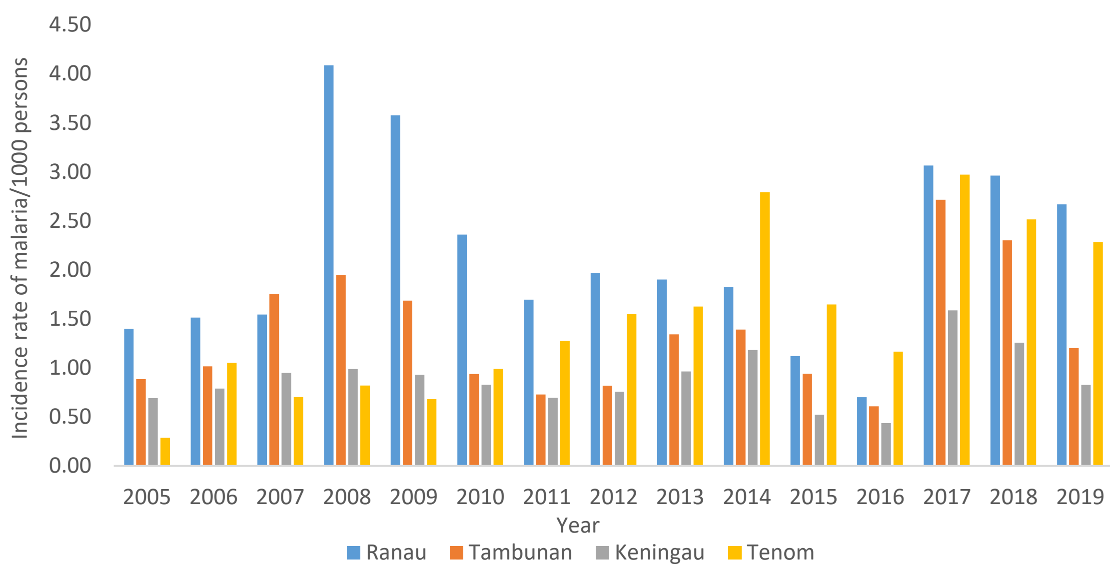

Fig. 2: Malaria incidence rate/1000 persons for study areas

2019, and the range of incidence rate was found from 0.29/1000 persons to 4.09/1000 persons. Fig. 3 shows the malaria incidence rate per 1000 persons in each highland district (Ranau, Tambunan, Keningau, Tenom) in 2005, 2010, 2015, and 2019.

The level of malaria incidence rate was classified as low (0 – 1.0), moderate (1.1 – 2.0), and high (2.1 – 3.0). In 2005, only the Ranau district showed a moderate incidence rate, whereas the other three districts were under a low incidence rate. In the year 2010, the malaria incidence rate of Ranau district increased to a high level, whereas the other three districts remained at a low-level incidence rate. In 2015, the malaria incidence rate of Tenom district increased to a moderate level together with Ranau district (decreased from a high level), and the other two districts remained a low level of malaria incidence rate. In 2019, only Keningau district remained a low malaria incidence rate where Tambunan district increased to a moderate level of incidence rate, Ranau district, and Tenom district increased to a high level of malaria incidence rate. Overall, the malaria incidence rate is decreased in 2015 as the malaria cases were reported lesser. Meanwhile, through visual observation on distribution maps, the malaria incidence rate increased from 2005 to 2010 and 2015 to 2019. Ranau district has the highest incidence rate, followed by Tenom district, Tambunan district, and Keningau district. This may be due to the expansion of oil palm plantation from forest land cover, which mainly occurs nearby Ranau district and Tenom district, as observed from the land cover map in the following subsection.

Land cover change in highland districts

The land cover changes in selected districts of Sabah (Ranau, Tambunan, Keningau, and Tenom) were compared for the years 2005, 2010, 2015, and 2019. The land cover map was generated consisting of four primary spatial information: forest, oil palm,

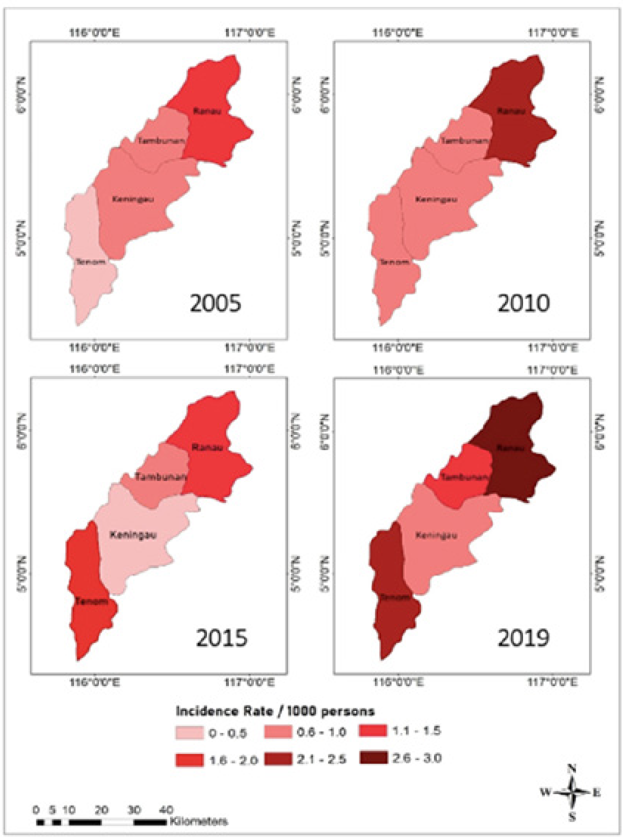

Fig. 3: Spatial distribution of malaria incidence rate per 1000 persons in each selected district of Sabah

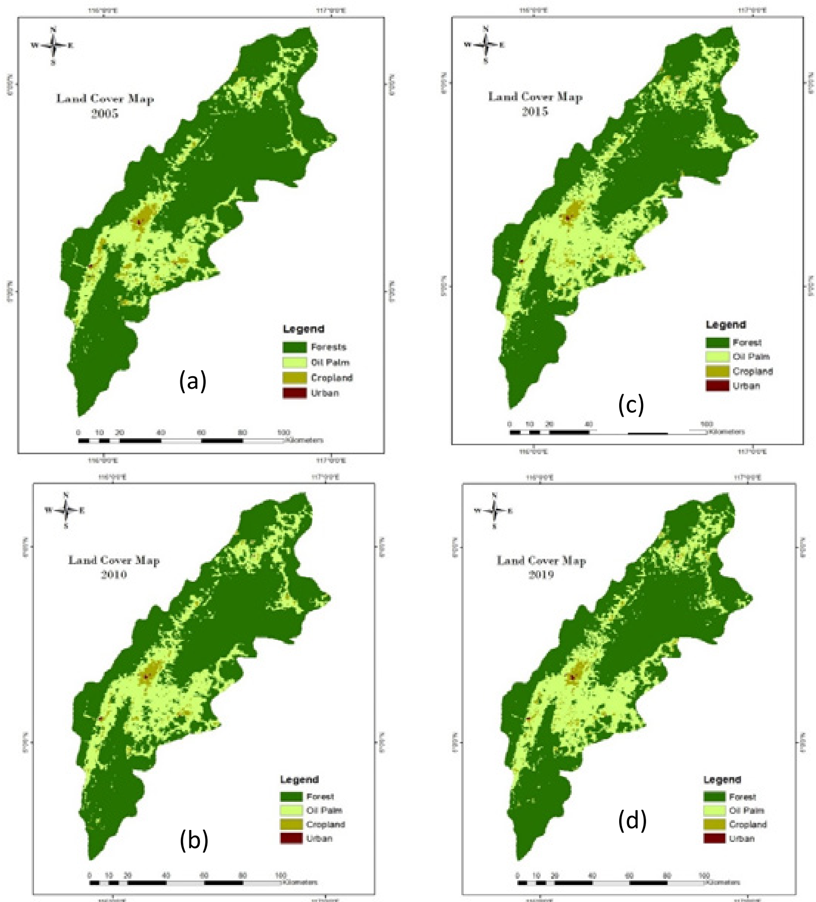

Fig. 4: Land cover map of each district for the year (a) 2005; (b) 2010; (c) 2015; and (d) 2019

cropland, and urban for this study. Fig. 4 shows the land cover classification map of highland districts in the years 2005 (a), 2010 (b), 2015 (c), and 2019 (d).

From the observation of the maps, the forest was found to predominate the land cover type followed by oil palm, cropland, and urban. A visual comparison of the land cover maps from 2005 to 2015 revealed that the forest coverage on the land cover map decreased significantly, and oil palm coverage increased significantly. However, from 2015 to 2019, forest coverage had been slightly increased. Forest class had the most extensive coverage area with 7958 km^2 (76.73%), followed by oil palm with 2134 km^2 (20.57%), cropland with 271 km^2 (2.61%), and urban with 9 km^2 (0.09%) in 2005; and 2010 with 7512 km^2 (72.13%), followed by oil palm with 2633 km^2 (25.39%), cropland with 217 km^2 (2.09%), and urban with 9 km^2 (0.09%). In the year 2015, the most extensive coverage of land cover class in the study area was also forest with 7076 km^2 (70.76%), followed by oil palm with 3035 km^2 (29.26%), cropland with 252 km^2 (2.43%), and urban with 9 km^2 (0.09%). However, the lowest coverage of forest investigated in 2015 may be related to the occurrence of an earthquake at Ranau district, Sabah. In the year 2019, forest class remained the most extensive coverage in the study area with 7291 km^2 (70.30%), followed by oil palm with 2846 km^2 (27.44%), cropland 226 km^2 (2.18%), and urban 9 km^2 (0.09%). The overall classification accuracies for the generated highland district map images are recorded at the range of 86% to 100% accuracy with kappa coefficients value of 0.78 to 0.83. Fig. 5 shows the changes for each land cover type in study areas during the study period. In the

14 years, forest coverage showed a drastic decline. Between years 2005 – 2010 and years 2010 – 2015, forest area showed extreme losses by 446 km^2 and 436 km^2, while between years 2015 – 2019 showed a moderate increase in area by 215 km^2.

This may be due to the implementation of the land usage policy by the Sabah state government on the restoration of degraded forests (Jaafar *et al.*, 2020). Between years 2005 – 2010 and years 2010 – 2015, the oil palm area showed a drastic increase by 499 km^2 and 402 km^2, whereas between the years 2015 – 2019 showed a moderate decline by 189 km^2. The decline of oil palm plantations was associated with the Crude Palm Oil prices, which were relatively low in that period (CPO, 2019). Also, the efforts of NGOs and some journalists may have impacts on the implementation of constrained plantation expansion by the government (Gaveau *et al.,* 2018). Cropland area showed slightly decreased between years 2005 – 2010 and years 2015 – 2019 by 54 km^2 and 26 km^2 respectively but increased somewhat between years 2010 – 2015 by 35 km^2. The slight increase in cropland area from 2010 to 2015 may be due to the Sabah earthquake in Ranau district, which induced barren land coverage (Miuse and Kamlun, 2019). However, the urban area does not change from 2005 to 2019. The area changes indicated that most forest reduction was related to expanding of oil palm plantations. Over time, the cover type of land was changed due to various anthropogenic activities such as plantation, agriculture, construction, and more to overcome human demands and population growth (Kweka *et al.,* 2016). A recent study by Miuse and Kamlun (2019) indicated that the land cover changes of highland districts of Sabah were related to both natural and anthropogenic factors, as the protected forest area also found drastic losses in the study period. Table 1 shows the total area changes and annual change rate from 2005 to 2019.

Overall, cropland area had found dramatically

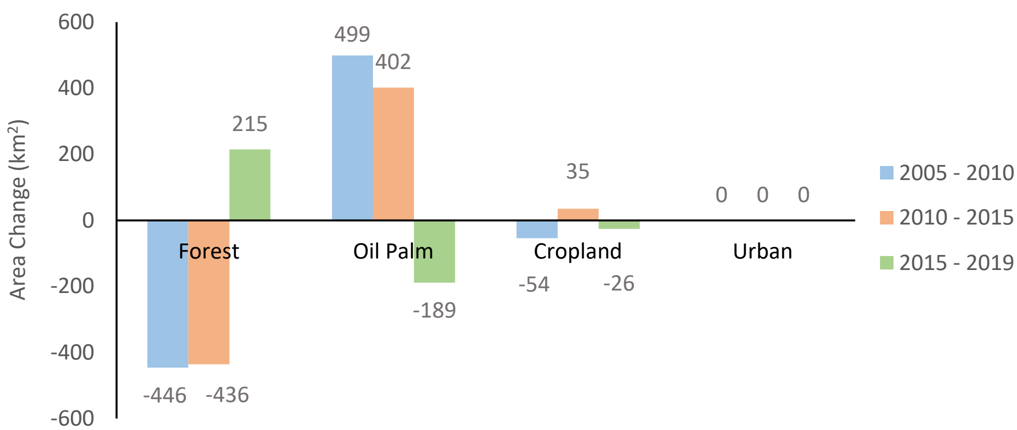

Fig. 5: Land cover change trends of study areas during the study period

Table 1: Land cover change from the year 2005 to 2019

Land Cover Classes	2005	2019	Area change		Annual change rate	
	Area (km^2)	Area (km^2)	km^2	%	km^2/year	%
Forest	7958	7291	-667	-8.38	-47.64	-0.60
Oil Palm	2134	2846	712	33.36	50.86	2.38
Cropland	271	226	-45	-16.61	-3.21	-1.19
Urban	9	9	0	0	0	0

decreased in 16.61% with 45 km^2, and the annual rate of change was -3.21 km^2/year (1.19%). Forest area also dropped in extensive coverage with 667 km^2, but lower in percentage (8.38%), and the annual rate of change was -47.64 km^2/year (0.60%). A recent study by Jaafar *et al.* (2020) indicated that a large percentage of oil palm cover was on the agricultural land compared to the forest in Sabah from 1990 to 2018. This can be explained due to the implementation of the land usage policy by the Sabah state government, which restricted the cultivation of oil palm in specific designated agricultural land. The oil palm area had drastically inclined between the years 2005 to 2019 with 712 km^2 (33.36%) in a total of study areas, and the annual rate of change was 50.86 km^2/year (2.38%). This result indicated that the oil palm plantation had expanded rapidly in highland areas of Sabah specifically between these periods. However, this study does not significantly change urban areas due to MODIS images with low spatial resolution. Table 2 shows a more detailed land cover change rate for each district from 2005 to 2019. For Ranau and Tambunan district, only forest cover decreased in the area where oil palm cover and cropland cover gained between the years 2005 to 2019. For Keningau and Tenom districts, cropland

Table 2: Land cover change for each district from the year 2005 to 2019

Land Cover Classes	2005	2019	Area change		Annual change rate	
	Area (km^2)	Area (km^2)	km^2	%	km^2/year	%
			Ranau district			
Forest	2515	2353	-162	-6.44	-11.57	-0.46
Oil Palm	421	569	148	35.15	10.57	2.51
Cropland	20	34	14	70.00	1.00	5.00
Urban	1	1	0	0	0	0
			Tambunan District			
Forest	1366	1295	-71	-5.20	-5.07	-0.37
Oil Palm	121	190	69	57.02	4.93	4.07
Cropland	8	10	2	25.00	0.14	1.79
Urban	0	0	0	0	0	0
			Keningau District			
Forest	2143	1785	-358	-16.71	-25.57	-1.19
Oil Palm	1309	1713	404	30.86	28.86	2.20
Cropland	195	149	-46	-23.59	-3.29	-1.68
Urban	6	6	0	0	0	0
			Tenom District			
Forest	1934	1858	-76	-3.93	-5.43	-0.28
Oil Palm	283	374	91	32.16	6.50	2.30
Cropland	49	35	-14	-28.57	-1.00	-2.04
Urban	2	2	0	0	0	0

cover was found mainly loss, followed by forest cover where oil palm cover gained between years 2005 to 2019. A generated land cover conversion map from the change detection analysis from 2005 to 2019 is shown in Fig. 6. The land cover classes have their gain, loss, and unchanged area between these 14 years. From the visual observation on the map, the most apparent conversion occurred was forest cover to oil palm cover (pink color), followed by cropland cover converted to oil palm cover (blue color), and oil palm converted to the forest (orange color). The conversion of mostly land-use class to oil palm was due to fulfilling the growing demand of the oil palm industry (Wicke *et al*., 2011). Besides, the Sabah state government also implemented a specific land usage policy to restore degraded forests to overcome oil palm cultivation and reduce environmental impacts (Jaafar *et al*., 2020). The total area of land cover conversion 'from-to' for each class between the years 2005 to 2019 would be determined in the cross-tabulation matrix.

Table 3 shows the cross-tabulation of land cover class 'from-to' between 2005 and 2019. The cross-tabulation of land cover conversion analysis consists of rows representing land cover in 2005 and columns representing land cover in 2019. The highlighted diagonal value in Table 3 represented each class's unchanged area from 2005 to 2019. Readings according to rows show the land cover area loss from 2005 to 2019, and the readings

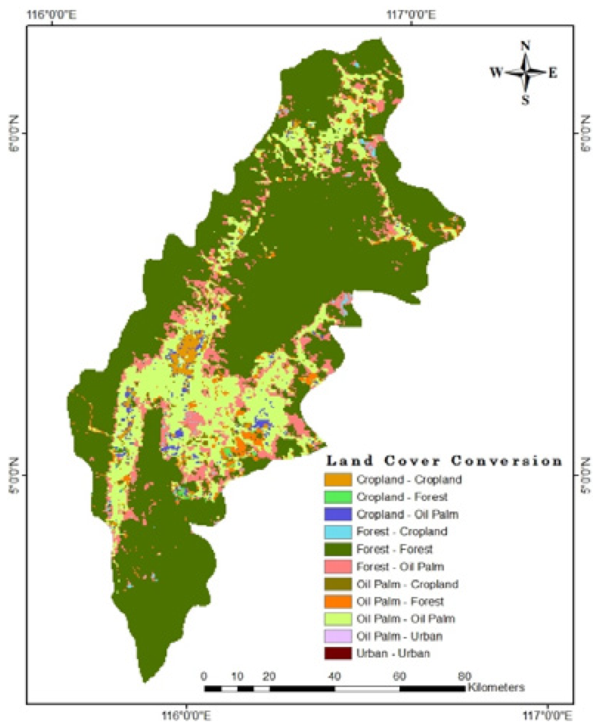

Fig. 6: Land cover conversion of study areas from the year 2005 to 2019

Table 3: Cross-tabulation of land cover change between the year 2005 to 2019

Land cover class area (km^2)		2019				
		Forest	Oil palm	Cropland	Urban	Grand total
2005	Forest	7002.60	916.59	39.07	0	7958.26
	Oil Palm	261.02	1810.65	61.61	0.64	2133.92
	Cropland	27.26	118.28	125.79	0	271.33
	Urban	0	0	0	8.80	8.80
	Grand total	7290.88	2845.52	226.46	9.44	10372.31

Table 4: Correlation of land cover changes and malaria incidence rate in selected districts of Sabah

Coefficient (r)	Forest	Oil palm	Cropland	Malaria incidence
Forest	1			
Oil Palm	-0.999	1		
Cropland	0.102	-0.146	1	
Malaria incidence	-0.135	0.144	-0.219	1

according to columns show the land cover area gain of the year 2019 from 2015. Out of the 7958.26 km^2 of forest area coverage in 2005, 7002.60 km^2 remained unchanged in 2019, while 916.59 km^2 and 39.07 km^2 were converted to oil palm and cropland, respectively. Also, some forest areas increase from oil palm (261.02 km^2) and cropland (27.26 km^2) from 2005 to 2019. Oil palm area out of 2845.52 km^2 in 2019 gained mainly from the forest as mentioned before, and cropland gained 118.18 km^2 in 2005. Oil palm area from 2005 remains unchanged to 2019 at 1810.65 km^2. Out of 271.33 km^2 of cropland area in 2005, 125.79 km^2 remained unchanged in 2019. The cropland area gained in 2019 from oil palm at 61.61 km^2. Out of the 9.44 km^2 urban class in 2019, 8.80 km^2 remained unchanged from the year 2005. Only a minimal area from the oil palm class (0.64 km^2) in 2005 was converted to urban in 2019.

Land cover change effects on malaria occurrences

Statistical analysis was performed on the cumulative annual land cover changes and annual malaria incidence rate per 1000 persons of the study area. Table 4 shows the correlation of land cover changes and malaria incidence in study areas of Sabah. Interpretation of analysis focused on each land cover type change and the malaria incidence rate. Where r = -0.135 shows a weak negative correlation for the forest, r = 0.144 shows a weak positive correlation for the oil palm, and r = -0.219 shows a weak negative correlation for the cropland.

The correlation performed between forest area changes and malaria incidence showed a weak negative result indicating there was a possibility that the more significant the forest change (forest loss) it will cause the higher malaria incidence rate. The result was consistent with previous studies in African highlands where deforestation was the main factor that promoted the vector population growth and survival rate that caused the high occurrence of malaria, mainly in the deforested area (Kweka *et al.,* 2016; Tuno *et al.,* 2005), which indicated that forest area changes might have indirect impacts on the malaria cases in highland districts of Sabah. The correlation performed between oil palm area changes and malaria incidence showed a weak positive result, indicating that there was a possibility as the more significant the oil palm change (oil palm gain), the higher the malaria incidence rate reported. From the result of land cover change presented before, most of the deforestation area in the highland of Sabah was due to conversion to oil palm plantation. A recent study by Yusof and Rusli (2018) reported that 24.2% of the land-use area of Sabah converted to oil palm plantation in the year 2000 to 2016 was due to the increase of oil palm industry demand. For the cropland area changes and malaria incidence, the correlation performed showed a weak negative result, which indicated there was a possibility that the more significant the cropland area change (cropland loss), the malaria incidence rate would be higher. An interesting study found that cropland activity was positively associated with malaria prevalence but only with a specific condition (fire-fallow cultivation), not including deforestation (Vittor *et al.,* 2009). Therefore, the changes of cropland area to oil palm area in the study areas of Sabah were probably through deforestation. Multiple linear regression analysis was used to define the association between land cover changes (forest, oil palm, and cropland) and malaria incidence in highland districts of Sabah. Table 5 shows the relationship between land cover changes and malaria incidence in the study area. The regression statistics adjusted R square showed a negative value (-0.183), which indicated insignificance on independent variables. The same goes for evaluating the ANOVA table, which showed the same results. The significance of F > 0.05 concluded that this model is not a significantly good fit. Also, since all of the p-value > 0.05, a large p-value represented

Table 5: Regression analysis of land cover changes and malaria incidence rate

Regression Statistics					
Multiple R		0.300			
R square		0.090			
Adjusted R Square		-0.183			
Standard Error		2.239			
Observations		14			
ANOVA	df	SS	MS	F	Significance F
Regression	3	4.973	1.658	0.331	0.803
Residual	10	50.120	5.012		
Total	13	55.093			
Variable	Coefficients	SE		t Stat	P-value
Intercept	4.326	2.187		1.978	0.076
Forest	0.682	1.198		0.570	0.582
Oil Palm	0.682	1.196		0.570	0.581
Cropland	0.626	1.161		0.539	0.602

insignificantly, indicating that the land cover changes have no significance associated with the malaria incidence.

Therefore, land cover changes did not significantly associate with the malaria incidence rate in selected districts of Sabah. This work's efforts to do the statistical analysis for correlation and regression can still be the framework and guidance for assessing the relationship of malaria transmission cases related to land use and cover change. Both analyses show no significance and weak relationships are believed due to the sample number of cases that are relatively low for a time series type of analysis. The study only depends on the limited data given by the Health Ministry of Malaysia, which only involved the total average by yearly cases that may affect the significant and relative comparison for the statistical analysis. Nevertheless, still with the added value of using GIS and remote sensing application onto the imaging map produced from this study, it could help to show how significant increased and decreased of the malaria cases only by viewing the maps based on the targeted area, rather than depending 100% on the statistical analysis for time series. Anyhow, this result was acceptable by referring to Singkong and Aralas (2017) study, which found that land cover changes significantly explained the malaria cases but not malaria incidences in Malaysia. Overall, land cover changes weakly correlate with the malaria incidences, as they may not be directly impacted. Many other factors, such as vector population, growth rate, survival rate, or temperature rise, show more significant direct effects toward malaria incidences that not been covered by this study; and in this research, only the land cover changes were the main drivers for promoting those factors (Kweka *et al*., 2016). Moreover, an overview study in Africa concluded that land cover change effects on malaria transmission were regionally unique according to the vector distribution and adaptation preference. According to the vector species in this case study, a specific analysis will better understand the relationship between land cover change and malaria transmission. This research application can be a tool that is easy to interpret by visualizing the transmission cases and contributes to a more interactive and visualization instrument by GIS mapping and remote sensing simulation. Thus, it can ultimately support policymaking to target the general condition of whether the disease is hazardous or not. This research is novel based on the application of GIS as a visualization instrument to map the malaria cases associated with the land use/cover type. By this study, we also utilize fewer malaria cases data by getting the absolute mean average, which is the same thing that will be used at the end of the long-term analysis, as the components of variation (trend, seasonality and the remainder) (Archer *et al*., 2017). It also fits to be applied for the extreme event (extreme data) when it reoccurs at the specific period of time and the specific period of that transmission peak (Rani *et al*., 2018). The absence of data set and the problem of accessibility to this kind of database for some countries makes it even more difficult to do the long-term analyses that normally will involve lots of databases and extensive work that is complex in technicality and interpretations for the final findings. These obstacles and limitations create a research gap in environmental science and health that often will stop other researchers from continuing the long-term analysis due to the incomplete dataset for the analysis, which they forget this type of limited data set can be very important to extract the information from it. By this research, instead of using a huge number of the database for the time series and long-term analysis, the absolute average of the mean yearly from any existing data could be used, which will give the same results as the traditional method (Lang *et al*., 2019). Hence, this research was performed to maximize the usage of GIS and remote sensing mapping by filling up the gap in the efforts to simplify the methodology to be more practical and functional by targeting the specific event at the exact period of time, in order to overcome data limitations and deem to maximizing the efficiency of the malaria diseases control and management. However, in a different context, it is recommended that future research include all the other factors together in the analysis, especially for climate effect analysis integrated with the malaria transmission for a better significance of findings. In addition, number sets of data probably are required just for getting a more reliable of difference and relationship significantly for the statistical analysis. Comparison for the selected study areas located at the highlands with the lower lands for the malaria transmission cases is also important for future research to analyze the emergence of highland malaria transmission. By this, it can detect the affected by the climate-driven or non-climate factor such as the topography factor in the different altitudinal zone to minimize the transmission so that more robust and effective management can be conducted for public health.

CONCLUSION

In conclusion, the malaria incidence rate for each district was found highly viable from 2005 to 2019, ranging from 0.29/1000 persons to 4.09/1000 persons. In 2019, Ranau and Tenom districts had a high malaria incidence rate compared to previous years. Overall, the malaria incidence rate shows an increment from 2005 to 2019, increasing 149.64%. Through visual observation on distribution maps produced, the malaria incidence rate shows the increment from 2005 to 2010 and the year 2015 to 2019, and Ranau district still showing in the transmission map the highest distribution of malaria among the other districts of Sabah during the final year of 2019. This is believed due to the expansion of 33.6 % oil palm plantation with an annual rate of 2.38 %, which mainly occurs near Ranau and Tenom district as observed from the land cover map. Overall, cropland area had found dramatically decreased in 16.61% with an annual rate of change at 1.19%. Forest area also dropped in extensive coverage 8.38%, with an annual change rate of 0.60%. The correlation result showed a significant relationship but rather weak between land cover changes and malaria incidence in highland districts of Sabah. Somehow, regression results showed an insignificantly associated for independent variables (land cover changes of forest, oil palm, and cropland) towards the dependent variable (malaria incidence rate/1000 persons). In addition, the land cover change of forest to oil palm class was significant, yet there was no causality relationship with regards to the malaria incidence. More factors need to be investigated, including climatic (rainfall density, land surface temperature, or humidity) and non-climatic (vectors population or human movement) to understand malaria transmission better. Improvement of these data and analysis tools was helpful to develop the policies and implementation methods for malaria control and future vector-borne disease prevention. Nevertheless, the study can be the blueprint and guideline framework to analyse the emergence of malaria transmission so that a more pragmatic and dynamic health control program can be conducted.

AUTHOR CONTRIBUTIONS

C. Payus conceptualized the study framework and performed the experimental design, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. J. Sentian helped in the experiments and literature review, compiled the data and manuscript preparation. A. Farrah helped with the proofread preparation and the final draft of the manuscript.

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ABBREVIATIONS

%	Percentage
-	Negative
/	Per
°E	East of prime meridian
°N	North of equator
ANOVA	Analysis of variance
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ArcMap	Aeronautical Reconnaissance Coverage Map
df	Degree of freedom
E	East
F	F-test
Fig.	Figure
GIS	Geographic Information System
IGBP	International Geosphere-Biosphere Program
Km^2	Square kilometer
KML	Keyhole markup language
LULC	Land use land cover
MCD	MODIS land cover product and modeling grid
MODIS	Moderate resolution imaging Spectroradiometer
MS	Mean square
m	Meter
N	*North*
P. knowlesi	*Plasmodium knowlesi*
P-value	Probability value
R	Regression
r	Coefficient value
Significance F	Significance value from F-distribution table
S	South
SE	Standard error
SS	Sum of square
t Stat	T-test calculation statistic value
USGS	United States Geological Survey
W	West
WHO	World Health Organization

REFERENCES

Alawamy, J.S.; Balasundram, S.K.; Hanif, A.H.M.; Sung, C.T.B., (2020). Detecting and analyzing land use and land cover changes in the region of al-jabal al-akhdar, libya using time-series landsat data from 1985 to 2017. Sustainability. 12(11): 4490 **(8 pages).**

Archer, E.R.; Landman, W.A.; Tadross, M.A.; Malherbe, J.; Weepener, H.; Maluleke, P.; Marumbwa, F.M., (2017). Understanding the evolution of the 2014–2016 summer rainfall seasons in Southern Africa: Key lessons. Clim. Risk Manage., 16: 22–28 **(7 pages).**

Babaie, J.; Barati, M.; Azizi, M.; Ephtekhari, A.; Sadat, S.J., (2018). A systematic evidence review of the effect of climate change on malaria in Iran. J. Parasit. Dis., 42(3): 331-340 **(10 pages).**

Baeza, A.; Santos-Vega, M.; Dobson, A. P.; Pascual, M., (2017). The rise and fall of malaria under land-use change in frontier regions. Nat. Ecol. Evol., 1(5): 0108 **(7 pages).**

Bousema, T.; Drakeley, C., (2011). Epidemiology and infectivity of Plasmodium falciparum and Plasmodium vivax gametocytes in relation to malaria control and elimination. Clin. Microbiol. Rev., 24(2): 377-410 **(34 pages).**

Bouzekri, S.; Lasbet, A.A.; Lachehab, A., (2015). A new spectral index for extraction of built-up area using Landsat-8 data. J. Indian Soc. Remote Sens., 43(4): 867-873 **(7 pages).**

CDC, (2018). About Malaria: Lifecycle. Centers for Disease Control and Preventions.

CPO, (2019). Average yearly price calculated from monthly prices in USD using IMF data, Federal Reserve Bank of St. Louis, citing: International Monetary Fund.

Franzese, M.; Iuliano, A., (2019). Correlation analysis. Institute for Applied Mathematics (IAC) (**128 pages**).

Gaveau, D. L.; Locatelli, B.; Salim, M. A.; Yaen, H.; Pacheco, P.; Sheil, D., (2019). Rise and fall of forest loss and industrial plantations in Borneo (2000–2017). Conserv. Lett., 12(3): e12622 (**8 pages**).

Haque, I.; Basak R., (2017). Land cover change detection using GIS and Remote Sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. Egypt. J. Remote Sens. Space Sci., 20(2):251-263 **(13 pages).**

Jaafar, W.S.W.M.; Said, N.F.S.; Maulud, K.N.A.; Uning, R.; Latif, M.T.; Kamarulzaman, A.M.M.; Mohan, M.; Pradhan, B.; Saad, S.N.M.; Broadbent, E.N.; Cardil, A., (2020). Carbon Emissions from Oil Palm Induced Forest and Peatland Conversion in Sabah and Sarawak, Malaysia. Forests, 11(12): 1285 **(10 pages).**

Kamlun, K.U.; Arndt, R. B.; 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: 418-430 **(13 pages).**

Kweka, E.J.; Kimaro, E.E.; Munga, S., (2016). Effect of deforestation and land use changes on mosquito productivity and development in Western Kenya Highlands: implication for malaria risk. Public Health Front., 4: 238 **(9 pages).**

Lang, P.E.; Carslaw, D.C.; Moller, S.J., (2019). A trend analysis approach for air quality network data. Atmos. Environ.: X, 2: 100030 **(10 pages).**

Le, P.V.; Kumar, P.; Ruiz, M.O.; Mbogo, C.; Muturi, E.J., (2019). Predicting the direct and indirect impacts of climate change on malaria in coastal Kenya. PloS One, 14(2): e0211258 **(7 pages).**

Lowassa, A.; Mazigo, H.D.; Mahande, A.M.; Mwang'onde, B.J.; Msangi, S.; Mahande, M.J.; Kimaro, E.E.; Elisante, E.; Kweka, E.J., (2012). Social economic factors and malaria transmission in Lower Moshi, northern Tanzania. Parasites Vectors. 5(1): 1-9 **(9 pages).**

MAMPU, (2018). Senarai Peta Topografi Siri T931 - Senarai Peta Topografi Siri T931. Malaysian Administrative Modernisation and Management Planning Unit.

Mark, D.C.J.; George, R.P., (2017). Land use and land cover (LULC) change detection using multi- temporal landsat imagery: A case study in Allah Valley Landscape in Southern, Philippines. J.Biodevers. Environ. Sci., 12(2): 98-108 **(11 pages).**

Martens, P.; Hall, L., (2000). Malaria on the move: human population movement and malaria transmission. Emerg. Infect. Dis., 6(2): 103 **(6 pages).**

Mawili-Mboumba, D.P.; Akotet, M. K.B.; Kendjo, E.; Nzamba, J.; Medang, M.O.; Mbina, J.R.M.; Kombila, M., (2013). Increase in malaria prevalence and age of at risk population in different areas of Gabon. Malar. J., 12(1): 1-7 **(7 pages).**

Miuse, C.F.; Kamlun, K.U., (2019). Multi-temporal Land-Cover Classification of Kinabalu Eco-Linc Site and the Protected Park Areas. In Journal of Physics: Conference Series, 1358(1): 012034. IOP Publishing **(5 pages).**

Mukhtar, A.Y.; Munyakazi, J.B.; Ouifki, R., (2019). Assessing the role of climate factors on malaria transmission dynamics in South Sudan. Math. Biosci., 310: 13-23 **(11 pages).**

Phua, M.H.; Tsuyuki, S., (2004). Deforestation detection in Kinabalu Area, Sabah, Malaysia by using multi-sensor remote sensing approach. J. Plan., 10(1): 31-40 **(10 pages).**

Pohl, C., (2014). Mapping palm oil expansion using SAR to study the impact on the CO2 cycle. 7th IGRSM International Remote Sensing and GIS Conference and Exhibition. IOP Conf. Ser. Earth Environ. Sci., 20: 012012 **(8 pages).**

Ramdzan, A.R.; Ismail, A.; Zanib, Z.M., (2020). Prevalence of malaria and its risk factors in Sabah, Malaysia. Int. J. Infect. Dis., 91: 68-72 **(5 pages).**

Rani, N.A.; Azid, A.; Khalit, S.I.; Juahir, H.; Samsudin, M.S., (2018). Air pollution index trend analysis in Malaysia, 2010-15. Pol. J. Environ. Stud., 27(2): 801 – 807 **(7 pages).**

Rawat, J.S.; Kumar, M., (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, District Almora, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci., 18(1): 77-84 **(8 pages).**

Singkong, F.B.; Aralas, S.B., (2017). An Empirical Study of Malaria Incidence and Land Use Change of Palm Oil Industries in Malaysia. Malaysian Journal of Business and Economics (MJBE) **(16 pages).**

Tatem, A.J.; Gething, P.W.; Smith, D.L.; Hay, S.I., (2013). Urbanization and the global malaria recession. Malar. J., 12(1): 133 **(10 pages).**

Toh, S.M.; Grace, K.T., (2005). Case study: Sabah forest ownership. Report produced for Food and Agriculture Organization of the United Nations. Global Forestry Services Inc, Kuala Lumpur **(23 pages).**

Torbick, N.; Ledoux, L.; Salas, W.; Zhao, M., (2016). Regional mapping of plantation extent using multisensor imagery. Remote Sens., 8(3):236 **(21 pages).**

Tucker Lima, J.M.; Vittor, A.; Rifai, S.; Valle, D., (2017). Does deforestation promote or inhibit malaria transmission in the Amazon? A systematic literature review and critical appraisal of current evidence. Philos. Trans. R. Soc. Lond., B, Biol. Sci., 372(1722): 20160125 **(11 pages).**

Tuno, N.; Okeka, W.; Minakawa, N.; Takagi, M.; Yan, G., (2005).

Survivorship of Anopheles gambiae sensu stricto (Diptera: Culicidae) larvae in western Kenya highland forest. J. Med. Entomol., 42(3): 270-277 **(8 pages).**

Ukor, C.D.; Ogbole, J.; Alaga, A., (2016). Analysis of Land Use Land Cover Change in Ikeja, Lagose State. Nigeria Using Remote Sensing and Gis Techniques. Int. J. Eng. Sci. Technol., 5(10): 462-472 **(11 pages).**

USGS, (2020). MCD12Q1VOO6 MODIS/Terra Aqua Land Cover Type Yearly L3 Global 500 m SIN Grid. United States Geological Survey.

Vittor, A.Y.; Pan, W.; Gilman, R.H.; Tielsch, J.; Glass, G.; Shields, T.; Sánchez-Lozano, W.; Pinedo, V.V.; Salas-Cobos, E.; Flores, S.; Patz, J.A., (2009). Linking deforestation to malaria in the Amazon: characterization of the breeding habitat of the principal malaria vector, Anopheles darlingi. Am. J.Trop. Med., 81(1): 5 **(16 pages).**

Wicke, B.; Sikkema, R.; Dornburg, V.; Faaij, A., (2011). Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. Land Use Policy, 28(1): 193-206 **(14 pages).**

WHO, (2014). International Travel and Health Publication 2014. World Health Organization, Geneva **(244 pages).**

WWF, (2020). Borneo_Forest: The Problems. World Wide Fund For Nature.

Yadav, K.; Dhiman, S.; Rabha, B.; Saikia, P.K.; Veer, V., (2014). Socio-economic determinants for malaria transmission risk in an endemic primary health centre in Assam, India. Infect. Dis. Poverty, 3(1): 1-8 **(8 pages).**

Yusof, A.A.; Rusli, N., (2018). The investigation of the Land Use Changes from Forest to Oil Palm in Sabah. Geomatics Res. Innovation Competition **(5 pages).**

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