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Research Article

Combining Moderate and High Resolution of Satellite Images for Characterizing Suitable Habitat for Vegetation and Wildlife

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ABSTRACT
Combining different resolution of remote sensing satellites becomes a unique approach for vegetation and wildlife habitat assessment study. Remote sensing technology can reach land and water on the Earth's surface, and it can interpret signals from spectral responses. When these techniques are combined with Geographical Information Systems (GIS), land can be monitored in a variety of ways. Meanwhile, changes in land use led to changes in vegetation on the ground, with natural vegetation being removed from natural forests, leaving a degraded forest. This issue was not investigated for assessing habitat suitability for important plantations such as Eucalyptus plantation. Therefore, the study employed remote sensing and Geographical Information System (GIS) to model suitability of habitat to live and to survive in the Eucalyptus plantation. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) derived from a mathematical equation can demonstrate intensity of greenness of green vegetation in particular area and time, and availability of soil moisture, respectively, is very suitable to model the greenness of the area. WorldView-2 satellite image was pre-proceed, proceed, and classified to produce land use indicator in Sabah Softwoods Berhad plantation majoring Eucalyptus spp. tree planted in Tawau, Sabah. Sentinel and Landsat 8 image were used for vegetation and water stress indicator were downloaded from Land Viewer application. Net Primary Productivity (NPP) at monthly scale was also calculated and ranked the productivity for the suitability mapping. Climatic condition based on monthly precipitation and seasonality derived from ASEAN Specialized Meteorological Centre (ASMC) was employed for ranking its suitability value. In this study, natural forest and oil palm plantation is tested to developed suitability map for vegetation and wildlife habitat to live with. All indicators were ranked 10 to 40 presenting benefit and usefulness of the indicator to vegetation and wildlife in the study area. Then, final classification was made from accumulation of those indicators into 0 to 200 (Not suitable to Highly suitable). The results showed 59.9% of the area classified as moderately suitable, 36.9% highly suitable, 3.2% least suitable and no area was classified as not suitable. This type of study assisted forest managers and policymakers for better managing of their forests for better life of trees and wildlife under their management. The methodology adapted in the study is ecologically sounded and economically viable to be modified and complied in Sustainable Forest Management (SFM) in Malaysia and other tropical forest regions.

INTRODUCTION

Remote sensing technology enables acquisition of satellite image for numerous land monitoring, for example for forest and agricultural lands application. The capable technology of using mathematical equation of multispectral images into vegetation indices for vegetation vigour and risk analysis. The operated technology was based on different satellite resolutions, for example, it has demonstrated with multispectral wavelengths on Landsat Thematic Mapper (TM) and WorldView satellite. The satellites that carry 30-meter and 1.8-meter of cameras, respectively.

WorldView with multispectral range of wavelengths is capable to construct vegetation index build from near-infrared and red bands. These two important wavelengths making WorldView satellite is very beneficial for vegetation study in tropical forest area. In previous study, O'Neil et al. (2020) conducted a study based on vegetation indices for vegetation productivity estimation. At global level, more studies using the indices for land cover change the analysis. A study by Chen et al. (2021), modelled human factor in China pastureland, located in Wulagai River Basin based on the vegetation indices.

Normalized Difference Water Index (NDWI) is an example of index which is a significant index in forest fire study and it is found having good relationship in drought study as demonstrated in Bowyer & Danson (2004) and Razali et al. (2015). Remote sensing is continually showed its capability in above-ground biomass estimation demonstrated in pantropical forest (Abbas et al. 2020). Before present, simple ratio shortwave infrared (SWIR) spectral indices were employed for quantifying landscape-level foliar moisture in an ecosystem dominated by *Pinus ponderosa* P. & C. Lawson. However, most studies were using SWIR for estimating foliar moisture in mid- and high-latitude sites (Toomey & Vierling 2005).

Established from information provided, NDVI is a tropical regional index that suitable for the current study proposed. In fact, NDVI has been used a precursor for Leaf Area Index (LAI) and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) used for carbon assimilation assessment (Nunes et al. 2012). From there on, NDVI was employed with high-resolution Unmanned Aerial Vehicle (UAV) imagery for monitoring species outbreak built from foliar discolouration (Dash et al. 2017). NDWI has a potential in semi-arid land, which it has been modelled in (i) closed and open canopy crops, (ii) semi-arid shrublands, and (iii) boreal conifer forests (Cheng et al. 2006). Generally, NDWI showed good correlations with Equivalent Water Thickness (EWT) tested with AVIRIS, and appeared to provide better estimations of canopy positioned by Moderate Resolution Imaging Spectroradiometer (MODIS) as a moderate resolution satellite image (Cheng et al. 2006).

Application of remote sensing established from different satellite resolution permits various problem solving. This is because there was scarce approach that has been identifying by various agencies managing human-wildlife conflicts in tropical forest region. Central Forest Spine (CFS) or IC-CFS, Improving Connectivity (IC) is a collaborative effort by Malaysian Government and international bodies for developing area with sensitive ecosystem as a results of forest fragmentation. The programs restore the connectivity between three critical landscapes of forest complexes (IC-CFS 2021). The efforts must be continued, and modelling habitat suitability built from low and moderate satellite remote sensing resolution which can be set up in this Eucalyptus plantation landscape.

Specifically, in Malaysia, wildlife habitat creates conflict zone which human frightens and troubles by wildlife nearby their housing area. In that case, it was because natural habitat has been diminished and changed into agricultural land area, i.e palm oil plantation, pineapple, and rubber plantation. Sabah Softwoods Berhad (SSB) is a company that was experienced in mitigating human wildlife conflicts (Nathan 2016). The company's primary activities are oil palm and tree plantation that make it about 60,000 hectares of land, reported in 2016. The company adopted 7,000 hectares of that area as a reserve land for conservation, meanwhile about 3,000 hectares were earmarked for housing and infrastructure. With the allocation, the company was one of the earliest companies obtained certification for its palm oil operation for Malaysian Sustainable Palm Oil (MSPO) (MPOCC 2022). Elsewhere, in North End of Assateague Island, there are needs for habitat suitability modelling, particularly from the vulnerable to climate change area. Habitat distribution maps play an essential intermediary step towards justifying conservation and planning efforts highlighted by Russ et al. (2022). The company hold down human -elephant conflicts engaged with estimated around two thousand Pygmy elephants that roam the landscape. The elephants get into human activities and the company is using translocation and fencing the plantation.

Human and wildlife conflict is a tough task to handle. Therefore, the objective of the study is to identify as a major criterion in ensuring the security of the wildlife and sufficient land for their lives. This is important to solve the above problem by merging recent advancement of satellite sensor resolution data integrated with climatic data.

MATERIALS AND METHODS

Study Area

To test the site suitability for this study, we examined a plantation area located in Brumas, districts of Tawau, Sabah state. For this study, Softwoods Berhad located at latitude 4°35'36" and longitude 117°45'31" retrieved from Google Map (Figure 1) was chosen. Located at between 200 - 600 m of elevation above sea level, the plantation has luxuriant high disease tolerant tree species. Softwoods Berhad plantation area holds about 18,000 hectares of high demand of *Eucalyptus pellita* and *F. moluccana* tree species. Specifically, *F. moluccana* tree species are planted in the conservation area in the plantation. The plantation is Tanjung Lipat type with clay texture of 25% to 35%. In addition, it is Kumansi type with more than 40% clay. This study adopted from the spirits to see long life of Sungai Umas, Sungai Landau, Sungai Indit and Sungai Umas-Umas in the plantation. Data collected from www.worldweatheronline.com showed monthly temperature with a minimum of 24^{o}C, a maximum of 31^{o}C, and a mean of 28^{o}C recorded in 2016. Meanwhile, data referred from Markos et al. (2018) depicted monthly precipitation of 50 mm recorded in 2014. In the meantime, annual precipitation was collected from Malaysia Meteorological Station as shown in Figure 2.

Methods

The Sentinel and Landsat 8 data were obtained from Land viewer application purchased online. Before that, the image was atmospherically corrected using atmospheric correction wizard, which allows users to execute a variety of atmospheric corrections in the simplest and fastest possible methodology. The wizard automatically in most of the required parameters uses image information and walks the user through each key step. The software's focus application was used to prepare data, and then ATCOR ground reflectance tools were used to analyse atmospheric correction.

A year time series analysis was performed on the NDVI and NDWI data. Inclusion of Sabah's dry and wet seasons. Both satellites' NDVI and

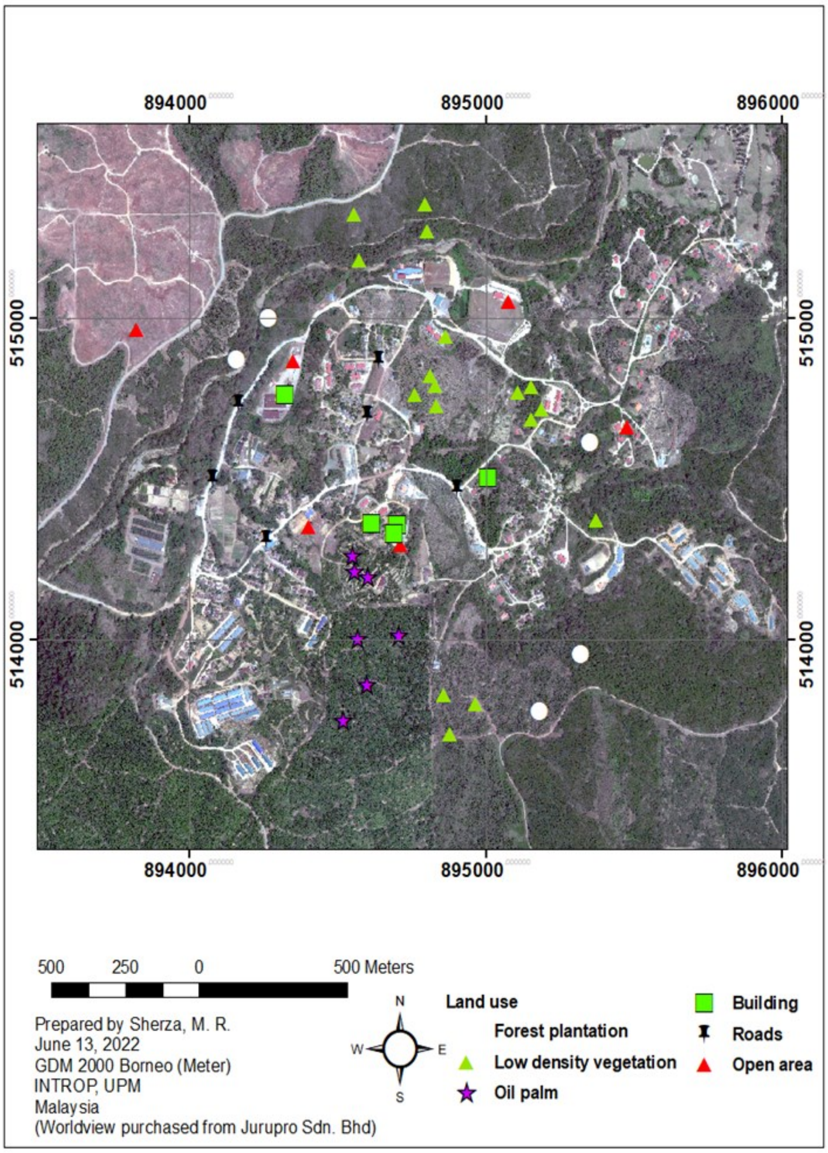

Figure 1. Map of the study area with location of various land uses and land covers.

NDWI were calculated. According to theory, NDVI was calculated using the approach that using the index vegetation status can be identified as healthy and full vegetation coverage between 0.5 and 0.9. The index is very suitable for use in tropical areas as a study by Braswell et al. (2003) discovered that NDVI should not be used in too dry conditions such as Iran and other areas with similar conditions. In the meantime, Pujiono et al. (2013) used NDVI to monitor mangrove forest in Indonesia. A year later Darmawan & Sofan (2012) used the Enhanced Vegetation Index (EVI) and NDVI to detect changes in Indonesia's tropical forest. NDVI was also used to assess vegetation stress in vegetative and agricultural land in India many years ago (Bhuiyan et al.2006). The NDVI showed an increasing trend of anthropogenic vegetation change (Chen et al. 2021). A study by Rouse et al. (1973) was cited.

$$NDVI = (\rho NIR - \rho Red) / (\rho NIR + \rho Red) \quad \text{.....}(1)$$

Meanwhile, NDWI was found very applicable to use in detection of water-stress forest such as in mangrove (Vidhya et al. 2014). Again, it was applied by Razali et al. (2015) in monitoring vegetation drought in West Malaysia. NDWI measured sensitivity to changes in liquid water content (Gao 1996). NDWI showed a good relationship with plant stress,

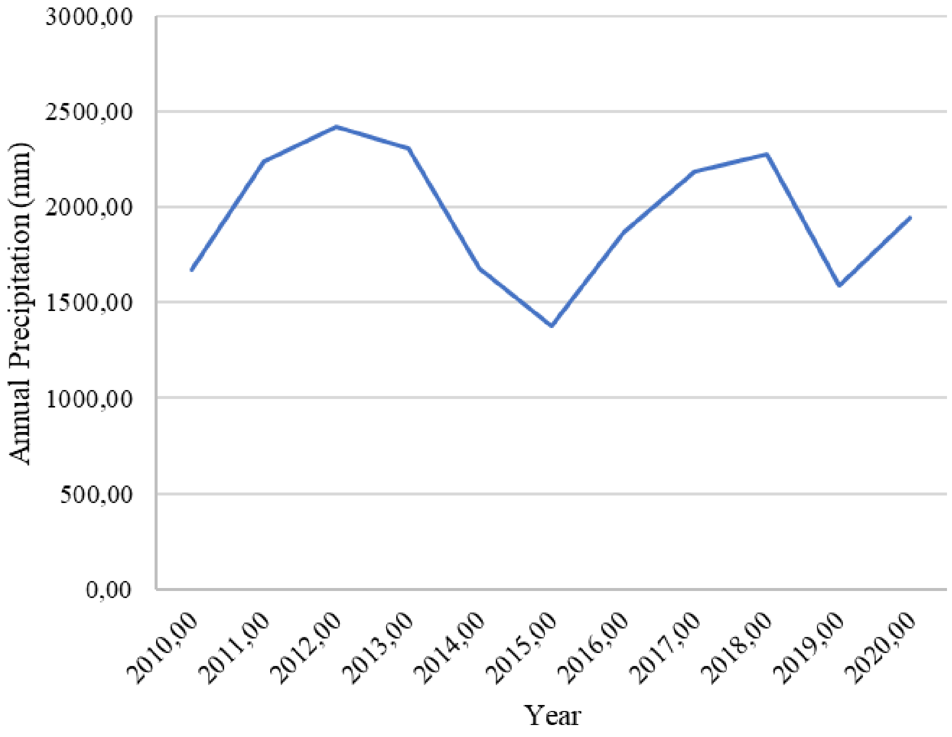

Figure 2. Annual precipitation of Tawau based on data from Malaysia Meteorological Department for 2010 – 2020.

which was used in a study by Vidhya et al. (2014) in classification of mangrove heath status. A recent study of Caturegli et al. (2020) tested NIR at two wavelength of 1240 µm and 2130 µm. The study tested NDWI without water on Bermuda grass in Italy. Based on theory, the index was calculated based on below equation (Gao 1996):

$$NDWI = (\rho NIR - \rho SWIR3) / (\rho NIR + \rho SWIR3) \quad \text{.................................(2)}$$

In details, the time series started from June 2017 until April 2022. About 39 samples were collected between the time frames. The study hypothesized that the distribution of Sentinel and Landsat 8 for NDVI and NDWI indices were similar across categories of wet season influenced by Northeast monsoon in Sabah region.

Worldview satellite image for 2016 was derived to calculate NDVI as comparison with the 2021 and 2011 NDVI data. Inadequate spectral properties in Worldview image of shortwave to calculate NDWI for the comparison. This is because the availability for comparison makes use of previous data for related study (Razali & Lion 2021). Overall flowchart of the study is presented below (Figure 3).

Land Use Mapping

The study employed PCI for mapping the land use. Object-based image analysis (OBIA) embedded in Catalyst Professional software, once known as PCI Geomatics is advocated to facilitate the classification. Worldview 2 satellite image was pre-processed by employing Atmospheric Correction (ATCOR) in set up in the software. ATCOR unnecessary enables users to carry out a variety of atmospheric corrections in the most straightforward and available in efficient method. Further efficient way was data preparation, then after that ground reflectance tools will be analysed by the ATCOR. Overall flow of the land use mapping are shown in figure below (Figure 4).

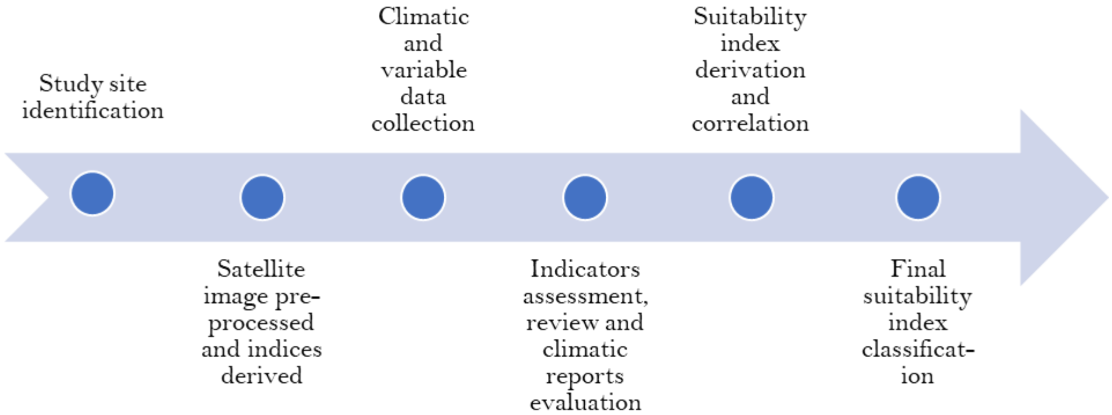

Figure 3. Overall flowchart of the study.

NPP Estimation

The NPP in this study was derived from the GPP, which was based on (Xiao et al. 2004). This is since GPP is the rate of CO2 fixation via photosynthesis in the forest canopy. As a result, GPP is calculated as follow:

$$GPP = fAPAR \; x \; PAR = \varepsilon \; x \; APAR \quad (3)$$

Where, the ε is Light Use Efficiency (ε), which has long been recognised as important component of the radiation regime for tree growth, incoming photosynthetically active radiation (PAR) ($gMJ^{-1} \; m^{-2}$) and the fraction of PAR intercepted by foliage (Fraction of photosynthetically active radiation of fAPAR) explained in Xiao et al. (2004).

Moreover, this study estimated PAR from 50% of incoming solar radiation as a result of solar radiation data collected from Sukarno et al. (2017) study. Instruments allocated on rooftop of building on 17 March 2016 as one method adopted for the research. The instruments were installed in Universiti Malaysia Sabah (UMS), in Kota Kinabalu, Sabah. Furthermore, absorbed fraction of photosynthetically active radiation (APAR) (gMJ^{-1}) was derived by combining two aforementioned variables, fAPAR and PAR (Coops et al. 2010). The said components, LUE, [18] was calculated as follows:

$$LUE = 0.8932 + TMonth + 0.0015(PRECIPMonth) - 0.002(GDD) \quad (4)$$

Meanwhile, fAPAR was derived as below:

$$fAPAR = 1.25 \; x \; NDVI - 0.025 \quad (5)$$

An index for vegetation, NDVI determined using red and near-infrared

$$NDVI = (\rho NIR - \rho Red) \,/\, (\rho NIR + \rho Red) \quad (6)$$

The equation can be explained as, ρNIR is the reflectance of the WorldView image at 0.77 – 0.895 nm (Near-infrared band) and ρRed is the reflectance of the satellite image at 0.63 – 0.690 nm (red band). The NPP ($gCM^{-2} \; month^{-1}$) was therefore, derived by applying 50% of GPP.

RESULTS AND DISCUSSION

Vegetation and Water Stress Indicator

The study conduct correlation for NDVI and NDWI of the Sentinel and Landsat satellite. From R^2 values, the NDVI in Sentinel was 0.95, whereas R^2 for Landsat was 0.99. These results, showed that the NDVI had a

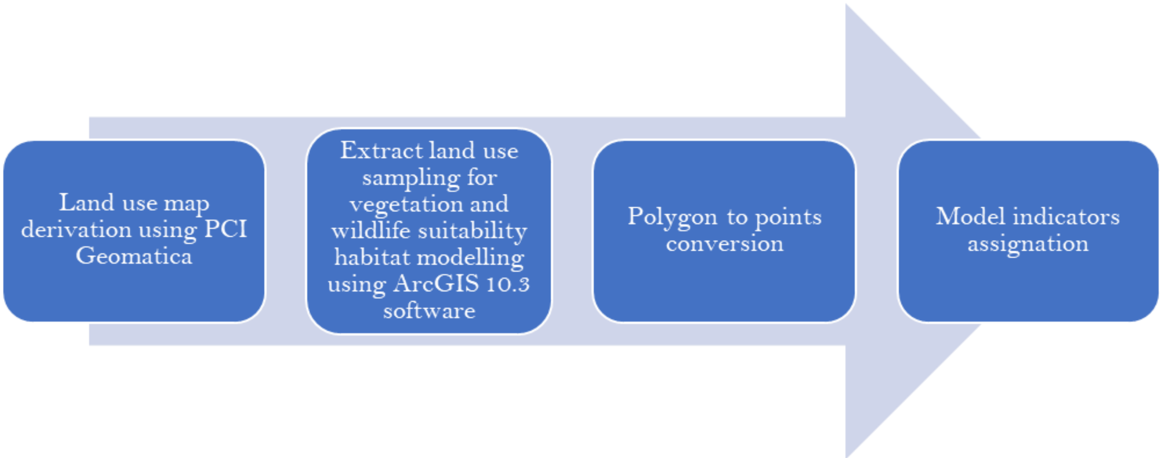

Figure 4. Overall flowchart of land use mapping.

good indicator to predict forest productivity for both satellite, hence, capable at assessing forest health and biomass changes over time. It is potential for drought and post-fire recovery in Eucalyptus forest such as demonstarted by (Caccamo et al. 2011; 2015). NDVI within similar satellite shown relative differences in lower resolution of METOP-A-NOAA-9 and NOAA-9 reported in Trishchenko (2009). The differenced was demonstrated by NIR and red spectral bands of NDVI equation. In a separated study in tropical forest of Peninsular Malaysia, NDVI showed strong correlation with NDWI (Razali et al. 2015) (Figure 5).

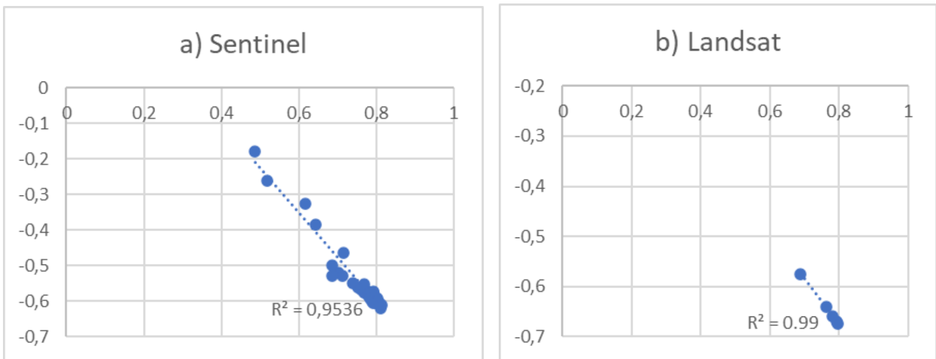

Figure 5. Correlation between NDVI and NDWI Sentinel and Landsat.

It can be seen, based on the two indices, that the NDVI very useful for application in vegetation community is broadleaved and evergreen. Changes on the season scale was also anticipated that higher NDVI values, pursue NDWI to be lower, due to plant capability to maintain water supply for biomass accumulation, hence no water stress was recorded. Some studies define NDWI as Land Surface Water Index (LSWI), whereby as the LSWI served similar indicator. This finding was supported by the LSWI, which showed the fortnightly percentage increase of LSWI and NDVI from the previous fortnight for 2002 and 2005, for a few typical districts of Andhra Pradesh (Chandrasekar et al. 2010). Meanwhile, another study (Penuelas et al. 1997), mentioned Water Index (WI) have good agreement with NDVI (NDVI vs WI, $R^2 = 0.66$) and improved when rationing WI with NDVI (WI/NDVI=0.71).

Vegetation and Wildlife Habitat Indicator

NDVI for 2016 that was overlaid with land use map showed NDVI > 0.8 is located on Eucalyptus plantation area. Whereas NDVI of > 0.7 is located on mostly on oil palm plantation. Meanwhile, NDVI > 0.6 can be found in Eucalyptus forest plantation but with presence of oil palms features (light green colour). The oil palm features have a high agreement with ground data with 100% of accuracy assessment, however, is very uncertain to found oil palm features in Eucalyptus plantation. The features could be misclassified with low growth in the forest plantation. This is making forest plantation has lower NDVI than found in full covered forest. NDVI colour map shown in Figure 6 meanwhile scale and suitability index is tabulated in Table 1.

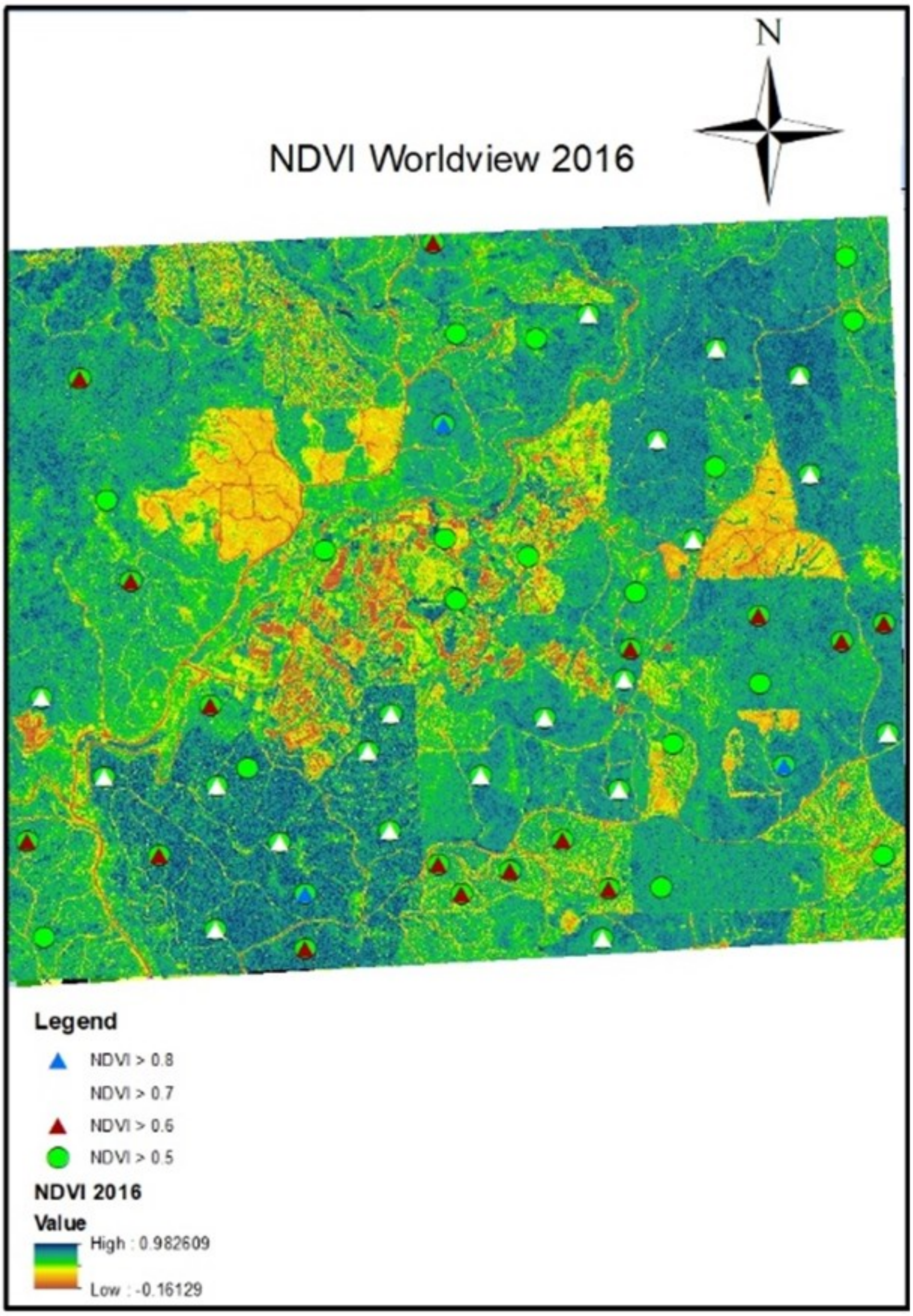

Figure 6. NDVI of the study area.

NDVI range 0 to 0.4 and below was associated with population concentration city as demonstrated in a study by (Potter et al. 2013). Meanwhile, in a mangrove forest with stress environmental condition NDVI was recorded 0.1 to 0.26 (Razali et al. 2019). This is corresponding to stress location due to sand deposition by sand packages that in fact caused poor tidal inundation.

Table 1. NDVI scale and suitability index value for analysis.

NDVI scale	Suitability index
NDVI > 0.8	40
NDVI > 0.7	30
NDVI > 0.6	20
NDVI > 0.5	10

Land Use

The land use accuracy was:

- Producer's accuracy for Eucalyptus plantation, buildings, low-density vegetation, oil palm, open area and roads were, 100%, 81.25%, 94.12%, 100%, 100% and finally 25%, respectively.
- User's accuracy was, 94.12%, 61.90%, 100%, 76.92% and finally 80%, respectively.

Each of the class was ranked according to its priority for wildlife to live within the removal of forest to a forest plantation. Higher forest coverage is ranked higher whereas lower forest cover or vegetation cover is ranked as lower (Table 2).

Table 2. Land use type and suitability index.

Land use	Suitability index
Forest plantation	40
Oil palm	30
Low density vegetation	20
Open area/Buildings/Roads	10

The forest plantations were given higher ranking for wildlife habitat suitability because it is associated to primary biodiversity area. According to a study conducted in Eucalyptus plantation in tropical forest of Brazil, forest plantation is the second-growth forest that is becoming dominant components of many tropical forest landscapes (Gardner et al. 2007). Similarly, about 30% of 35% of all amphibian species were confined to primary forests, which recorded in eastern Madagascar according to (Vallan 2002) and, a proportion identical to (Gardner et al. 2007). A recent study, Maliau Basin Conservation Area and Danum Valley Conservation Area, and one mature oil palm plantation were tested for ecosystems energetics. The study concluded that conversion of logged forest into oil palm plantation resulted in the collapse of most energetic pathways (Malhi et al. 2022). Therefore, oil palm was assigned to a suitability index of 30 (Figure 7).

Precipitation

In general, Sabah and Sarawak are influenced by Northeast monsoon which happens on November to April with approximately bringing heavy rain to east coast area, that including Tawau area. In 2015, a study by (Ng et al. 2019) found Tawau recorded 207.0 mm ±92.98 of monthly precipitation. Monthly average for 2010 – 2020 shown in Figure 8 for better evaluating condition of the study area. This making Tawau has higher precipitation than districts of Sabah, namely, Kota Kinabalu, Beufort, Kudat and Keningau. For additional information, the value similarly recorded by Sandakan area which is located far much northern area. Finally, precipitation rank is shown in Table 3.

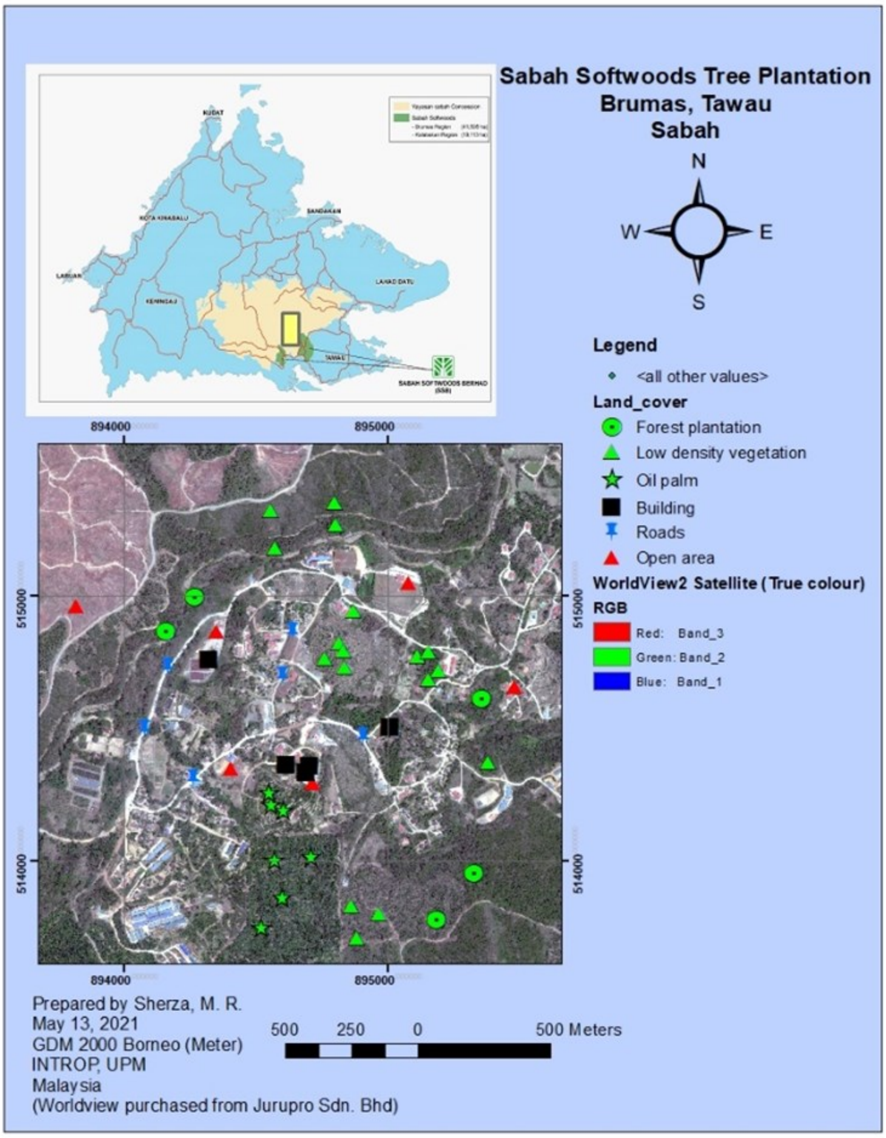

Figure 7. Land use for the study employed for map calculation.

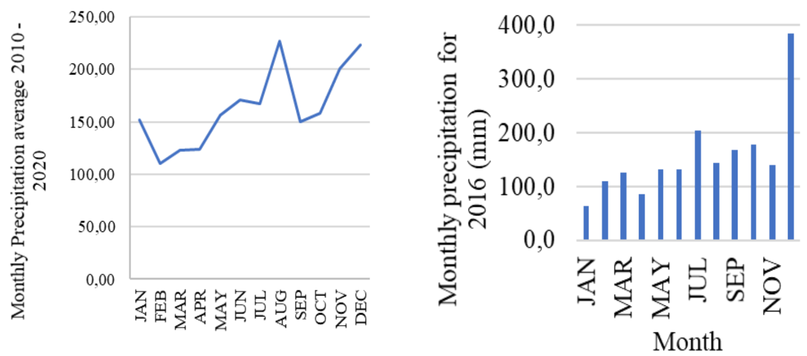

Figure 8. Monthly and annual precipitation for the study area.

Table 3. Mean monthly precipitation and suitability index.

Mean monthly precipitation (mm) of Year 2016, Tawau, Sabah	Suitability index
0 – 80	40
80 – 160	30
160 – 280	20
280 – 340	10

Seasonal

According to a website, www.malaysia.gov.my, Malaysia experiences humid weather throughout the year with the average daily temperature across Malaysia is between 21°C and 32°C. Typically, the Malaysian climate is influenced by the winds blowing from the Indian Ocean (Southwest Monsoon - May to September) and the South China Sea (North-Eastern Monsoon - November to March) (The Malaysian Administrative Modernisation and Management Planning Unit 2016).

Seasonal data was assessed based on ASEAN Specialized Meteorological centre (ASMC) report. The comprehensive report comprising data of ASEAN information on haze situation which rank as in Table 4.

Table 4. Indication of seasonal parameters derived from ASMC report and suitability index.

ASEAN Specialized Meteorological Centre (ASMC) based on Worldview satellite image acquired March 2016	Suitability index
March to May 2020	40
December – January 2016 – 2017	30
September - November 2020	20
Unidentified	10

NPP Productivity

The NPP was interpolated through using instruments in ArcGIS Spatial Analyst to map the proportion of NPP on the ground, as shown in Figure 9.

Estimation of NPP for Pasoh Forest reserve, Peninsular Malaysia was 213.5 gCm-2 month-1, accepted as a maximum value for tropical forest study (Razali et al. 2015). The proportion was identical to this study of moderate NPP suitability index, 20 (Table 5).

Table 5. Indication of NPP scale and rank value.

NPP scale (650 gCm-2 month-1)	Suitability index
NPP > 500	40
NPP > 300	30
NPP > 200	20
NPP > 100	10

Final Suitability Index

The final index was developed based on accumulation of all indicators suitability index value that was calculated using ArcGIS 10.8 software attribute table. Table 6 showed overall indicators that employed for the index based on below equation:

$$\text{Habitat Wildlife Indicator} = VEG + LU + NPP + PREP + SEAS$$

Vegetation and wildlife habitat indicator = VEG
Land use indicator = LU
Net Primary Productivity = NPP
Precipitation indicator = PREP
Season = SEAS

The study was successfully mapping suitability index for vegetation and habitat in Sabah Brumas, Tawau Eucalyptus and oil palm plantation. Habitat and vegetation classification derived after each of the pix-

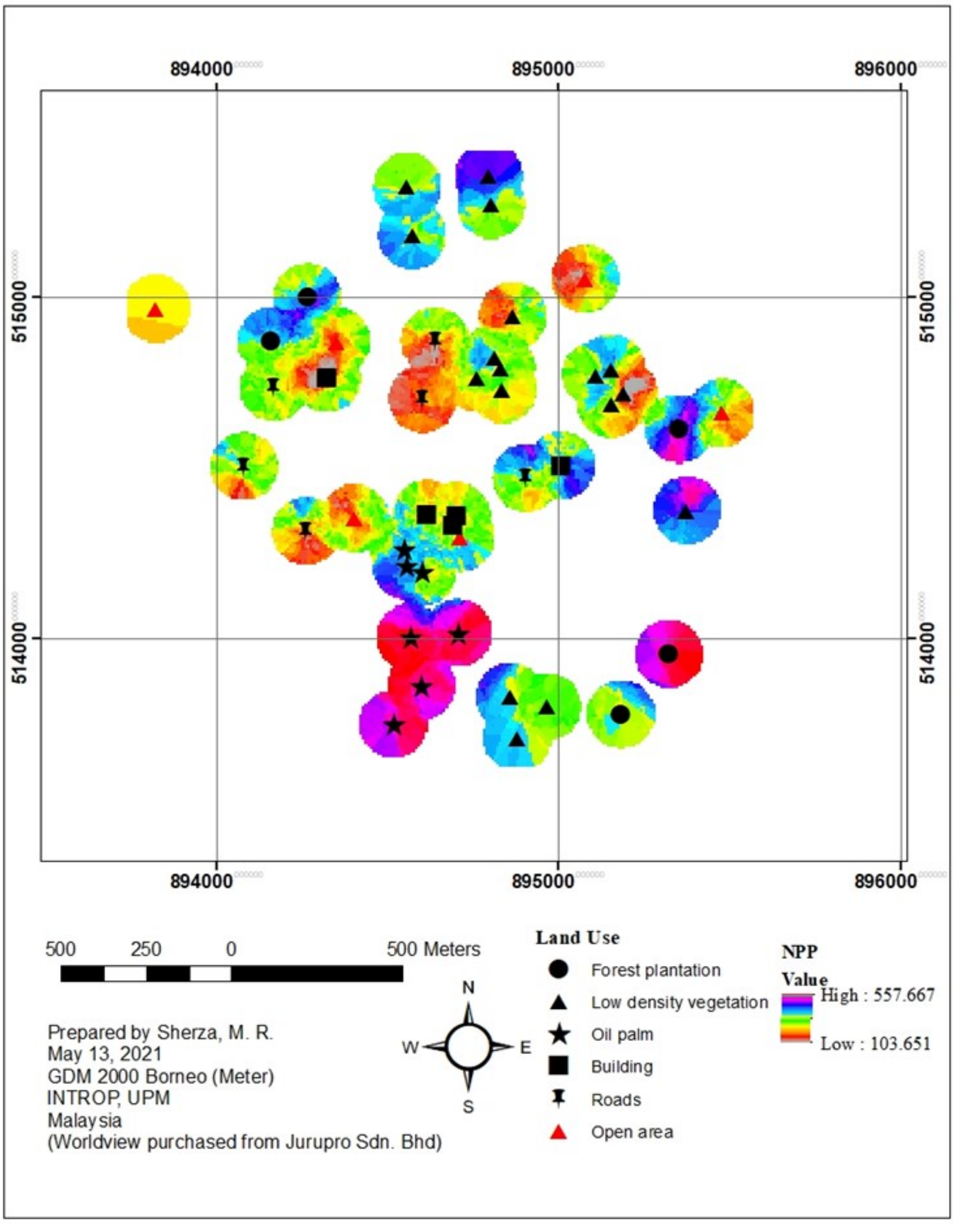

Figure 9. Overall NPP value interpolated on land use layer with points marked showed major area of the land use type.

els accumulated based on its suitability index. An index approaching 200 classified and highly suitable for the wildlife and vegetation to live and to sustain its live for a long term. A value less than 50 indicates as not suitable habitat for wildlife and vegetation to be in the area (Table 7).

Area of the habitat and vegetation classification pixels were classified based on Equal interval and Natural Breaks classifier. Based on the methods, percentage of the area classification derived and shown in Figure 10.

CONCLUSION

The results show the practical use of multispectral index of multiple resolution of satellite image in estimation of vegetation vigor and biomass in Eucalyptus plantation, Sabah, East Malaysia. Land use change has negative impact to wildlife and pursues wildlife conflicts in tropical forest. The research examines how integration of multi-resolution of satellite image may be used to generate a suitable area for wildlife habitat in eucalyptus plantation. Based on Sentinel, Landsat and WorlView-2, the study

Table 6. Indication of accumulation of vegetation and wildlife habitat suitability index.

No.	Indicator/Scale	Description	Suitability index	Source of References
1.	Vegetation and wildlife habitat indicator			Rock/Sand/Snow: Value approaching zero, 0.1 < X < 0.1 Greenness/Vegetation: Value low positive, 0.1 < *X* < 0.4 Tropical rainforest value approaching 1, X→1 Hansen et al. (2017)
	Biomass			
	NDVI > 0.8	Adequate biomass	40	
	NDVI > 0.7	Moderate biomass	30	
	NDVI > 0.6	Low biomass	20	
	NDVI > 0.5	Inadequate biomass	10	
2.	Land use indicator			Field observation and author experienced
	Habitat			
	Forest plantation	Natural habitat	40	
	Oil palm	Plantation	30	
	Low density vegetation	Degraded land	20	
	Open area/Buildings/Roads	Infrastructure and non-vegetated land	10	
3.	Net Primary Productivity			NPP evaluated for the plantation is 650 gCm-2 month-1 (Razali et al. 2022). NPP from WorldView-2 particularly valuable if applied to temporal NDVI data to assess the monthly NDVI for the study area (Razali et al. 2022)
	NPP > 500	Adequate biomass	40	
	NPP > 300	Moderate adequacy biomass	30	
	NPP > 200	Low adequacy biomass	20	
	NPP > 100	Inadequate biomass	10	
4.	Precipitation indicator			200 mm during June and July 350 mm in November and December (climateknowldegeportal.worldbank.org)
	Mean monthly precipitation (mm)			
	280 – 340	High	40	
	160 – 280	Moderate	30	
	80 – 160	Low	20	
	0 – 80	Very low	10	
5.	Seasonal indicator			ASEAN Specialized Meteorological Centre (ASMC) report (2016)
	ASEAN Specialized Meteorological Centre (ASMC)			
	September - November 2020	Wetter	40	
	December – January 2016 - 2017	Wetter than average	30	
	March - May 2020	Wetter and drier effects are averaged	20	
	Unidentified	Unidentified	10	

Table 7. Indication of vegetation and wildlife habitat classification for the study.

Rank	Suitability Index	Habitat & Vegetation classification
1	150 - 200	Highly suitable
2	100 - 150	Moderately suitable
3	50 - 100	Least suitable
4	0 - 50	Not suitable

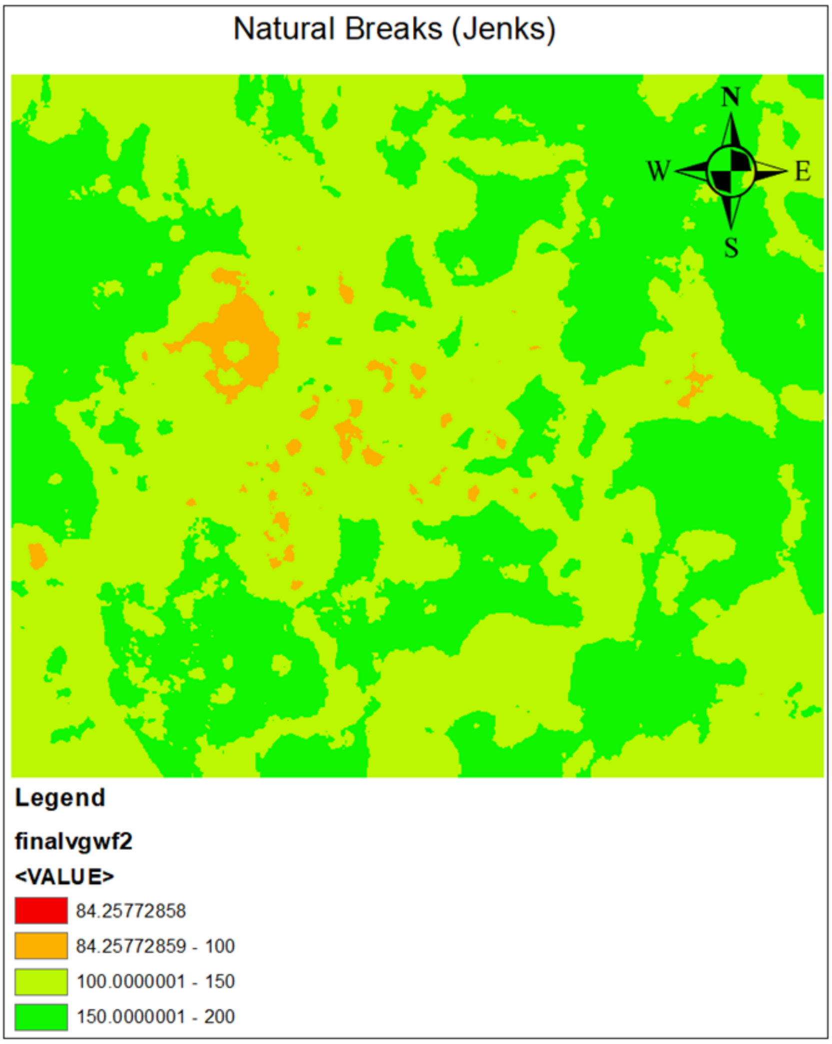

Figure 10. Final index classification for the study area.

found that most of the study area which is about 59.9% was moderately under suitable average habitat for vegetation and wildlife. The variable employed for the study covered land use, climatic condition presented by precipitation, NPP and seasonal variation of the study area showed overview of year 2016 condition of the study area.

Based on the direct approach, the condition of the study area as plantation area is very suitable for natural habitat to live. In addition, considering cost-effective within tropical context, it is also proposed that Landsat data that is free and available can be useful for obtaining land cover and can be economically estimate for larger area. The study suggested a temporal land use change to be conducted in future study to reveal forest-to-oil palm conversion as the primary driver of deforestation.

AUTHOR CONTRIBUTION

S.M.R. designed the methodology that including data collection and analysis which using ArcGIS software. Whereas Z.S. provided research materials and permission for data collection including overall research expenses. M.L. worked on manuscript improvements and given an original idea.

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CONFLICT OF INTEREST

There are no conflicts of interests.

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