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Habitat suitability modelling of Pasak Bumi (*Eurycoma longifolia* Jack.) in Riam Kanan conservation forest zone using Sentinel-2 biophysical parameters

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Abstract. Pasak bumi usually grow under the tree canopies. So that the character of its habitat is assumed to be estimated using several biophysical parameters of the tree canopy around it. The purpose of this research was to model the suitability of the pasak bumi habitat in the Riam Kanan conservation forest zone, using a number of biophysical parameters extracted from Sentinel-2 MSI imagery. Those parameters are Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), Canopy Water Content (CWC), Fraction of Vegetation Cover (FVC), and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). Ground surveys were carried out to find the coordinates of pasak bumi using accidental sampling method. Pasak bumi coordinate points are overlaid with biophysical parameters. Statistical analysis was then applied to predict the range of population values from each biophysical parameter, using Confidence Interval (CI) 95%. The results of the research show that CI LAI 2.532-2.772, CI CCC 137.101-158.028 gr/cm2, CI CWC 0.05-0.057 gr/m^2, CI FVC 0.698-0.737, and CI FAPAR 0.732-0.765. The values of these biophysical parameters directly describe the biophysical characteristics of the pasak bumi habitat in the research location. These CI values are then implemented using binary modelling to predict the habitat of pasak bumi. Based on the results of modelling, it was found that the area suitable for pasak bumi plants was an area of 1,807.91 hectares. This area has a proportion of 1.55% of the total area of the conservation zone. To improve accuracy, other biophysical parameters can be considered to be involved in modelling.

1. Introduction

Pasak bumi (Eurycoma longifolia Jack.) plant or commonly known as tongkat ali, is an endemic plant that is commonly found in dense forests in Indonesia and in Malaysia. For a long time, this plant was known by the traditional society for its health benefits [1]. Especially used as traditional medicine for male vitality, and other medicines. According to [2], pasak bumi is commonly found in primary forests. According to [3], pasak bumi plants are spread in various elevation, but are dominant at an elevation of 300 meters or more above sea level. While according to [4], the population of pasak bumi plants can reach 130 individuals per hectare.

The condition of the pasak bumi habitat is found in areas that have elevation of 320 – 402 meters above sea level, found sporadically and in a group pattern, daily average temperature 25.6^{o}C, average daily relative humidity 73.6%, light intensity 0.9 klx , and red-yellow podsolic soils with textures ranging from clay to sandy clay. [5] and [6] states that pasak bumi are found at elevation of 170 – 200 meters above sea level in secondary forests, average daily temperatures of 28 – 41 ^{o}C, average daily relative humidity of 53-59%, and intensity light 2.10-3.91 klx.

Pasak bumi is a non-timber forest product with conservation status "not determined" and is commercially traded on the island of Borneo. At present, the population of pasak bumi plants in nature, such as on the island of Borneo, Indonesia, is indeed still very abundant. So even though large numbers of people have taken it, it is estimated that this plant will not run out for the next few years. However, the problem here is the land where it grows. Where the land or forest where the pasak bumi grows continues to be degraded. The area is continuously decreasing due to land conversion for residential or agricultural purposes. So that threatens the sustainability of the pasak bumi plant is not because it is harvested, but because of the disturbed habitat for its growth. So we really need to predict or model the suitability of the habitat where these earth pegs grow. Good for future development needs, if the population in nature has been reduced due to damaged habitat, or if there is a pharmaceutical industry that wants to make this pasak bumi as raw material for medicines.

Figure 1. Pasak bumi plant

Pasak bumi is a dwarf that usually grows under a tree canopy. Because the pasak bumi grows under the tree canopies, theoretically this plant is difficult to observe directly using remote sensing imagery. Even by using very high spatial resolution imagery such as the image from an Unmanned Aerial Vehicle (UAV), pasak bumi still cannot be directly observed visually. So that the only way to identify the location and mapping the spatial distribution of the pasak bumi accurately is by direct ground survey methods. By studying the data on the growth of pasak bumi obtained from the results of ground surveys, we can model the suitability of the pasak bumi plant habitat in the area we want.

Habitat where plants grow can be predicted using various parameters. Such as biophysical, topographic, edaphic, climatic, and so on. These parameters can be assessed directly based on ground data samples. Furthermore, these parameters can be involved in spatial modelling methods to extrapolate habitat suitability of certain plant species in the desired area. As mentioned earlier, that the pasak bumi grows under the canopy of other plants around it. So that the growth of the pasak bumi can be assumed to have a spatial correlation with the surrounding plants, especially the tree canopy parameters that shelter it.

Biophysical parameters such as tree canopy density, canopy moisture, chlorophyll content, plant health conditions, etc., can be extracted directly from remote sensing images. Biophysical parameters like this can be used directly to predict habitat suitability of a plant species, as do pasak bumi.

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Since its presence in 2015, the European Space Agency (ESA) Citra Sentinel-2 MSI (Multispectral Instrument) has attracted worldwide attention. Because in addition to its highly qualified spatial resolution, which is 10 meters, and its temporal resolution capability can record the same place every five days, this image can also be used by the public worldwide for free. of course, this multispectral image such as Sentinel-2 can be used as a base for extracting biophysical parameters, such as canopy density and so on, for modelling the suitability of pasak bumi plant habitat.

The purpose of this research was to model the suitability of the pasak bumi plants in the Riam Kanan conservation forest area, using a number of biophysical parameters extracted from Citra Sentinel-2 MSI. The biophysical parameters in question are Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), Canopy Water Content (CWC), Fraction of Vegetation Cover (FVC), and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).

2. Research Methods

2.1. Research Location and Ground Survey

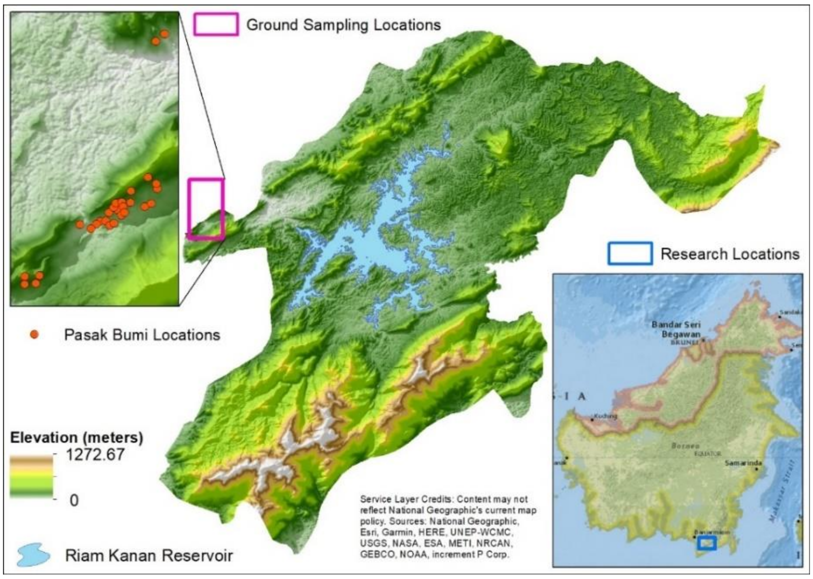

Figure 2. Research location and sampling locations

This research was conducted in the Riam Kanan conservation forest zone, South Kalimantan Province, Indonesia. According to the Decree of the Indonesia Minister of Environment and Forestry Number: SK.2308/MENLHK-PKTL/KUH/PLA.2/4/2017, the total area of the Riam Kanan conservation forest zone about is 112,000 hectares. Where there are two management in this conservation forest zone, namely the Sultan Adam Great Forest Park (Tahura) which is managed by the Forest Service (Dinas Kehutanan) of South Kalimantan Province, and the Forest Zone with Special Purpose (KHDTK) Forest of Education and Training which is managed by Lambung Mangkurat University.

A ground survey was conducted in October 2018 to find the location of the coordinates of the discovery of pasak bumi plants in the ground. The sampling method used is accidental sampling. The sampling area is only limited to the KHDTK Forest of Education and Training of Lambung Mangkurat University. Based on the results of the ground survey, 32 locations of pasak bumi plants were found. As can be seen in Table 1.

2.2. The Imageries Used and Pre-processing

The imageries used is the European Space Agency (ESA) Sentinel-2B imageries, acquiring on May 6, 2018. One of the bases in image selection is the presence of atmospheric disturbances, where we choose images that have the least atmospheric disturbances. In total there are three grid Sentinel-2B are required to meet the entire region Riam Kanan conservation forest zone, namely S2B_MSIL1C_20180506T022549_N0206_R046_T50MKA_20180508T021713, S2B_MSIL1C_ 20180506T022549_N0206_R046_T50MKB_20180508T021713, and S2B_MSIL1C_ 20180506T022549_N0206_R046_T50MLB_20180508T021713. These three Level 1C (Top of Atmospheric Reflectance) imageries are then calibrated into Top of Canopy reflectance (level 2A) using the Sen2Cor tool [7] [8], which is integrated in free and open source software namely European Space Agency (ESA) Sentinel Application Platform (SNAP). Furthermore, all Sentinel-2B bands that differ in spatial resolution being resampled to 10 meters all use the ESA SNAP.

2.3. Sentinel-2 MSI Biophysical Parameters

Sentinel-2 MSI Biophysical Parameters are parameters that can be extracted directly from Sentinel-2 imagery, namely Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), Canopy Water Content (CWC), Fraction of Vegetation Cover (FVC), and the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). The extraction process is done automatically using the ESA SNAP Biophysical Processor, which is also integrated in the SNAP ESA software. ESA SNAP extracts Sentinel-2 MSI Biophysical Parameters using a machine learning algorithm, namely artificial neural network [9]. Sentinel-2 MSI Biophysical Parameters have been validated by several researchers, including the newest one by [10]. Of course, these five parameters represent various biophysical characters that will give the descriptions of where the pasak bumi grows. LAI is defined as half the developed area of photosynthetically active elements of the vegetation per unit horizontal ground area. It determines the size of the interface for exchange of energy (including radiation) and mass between the canopy and the atmosphere [9]. FAPAR corresponds to the fraction of photosynthetically active radiation absorbed by the canopy. The FAPAR value results directly from the radiative transfer model in the canopy which is computed instantaneously. It depends on canopy structure, vegetation element optical properties and illumination conditions [9]. FVC is used to separate vegetation and soil in energy balance processes, including temperature and evapotranspiration [9]. The chlorophyll content is a very good indicator of stresses including nitrogen deficiencies[9]. It is strongly related to leaf nitrogen content [11]. CCC represents vegetation health parameters. While CWC represents climate parameters, both temperature, rainfall, intensity of irradiation, and air humidity.

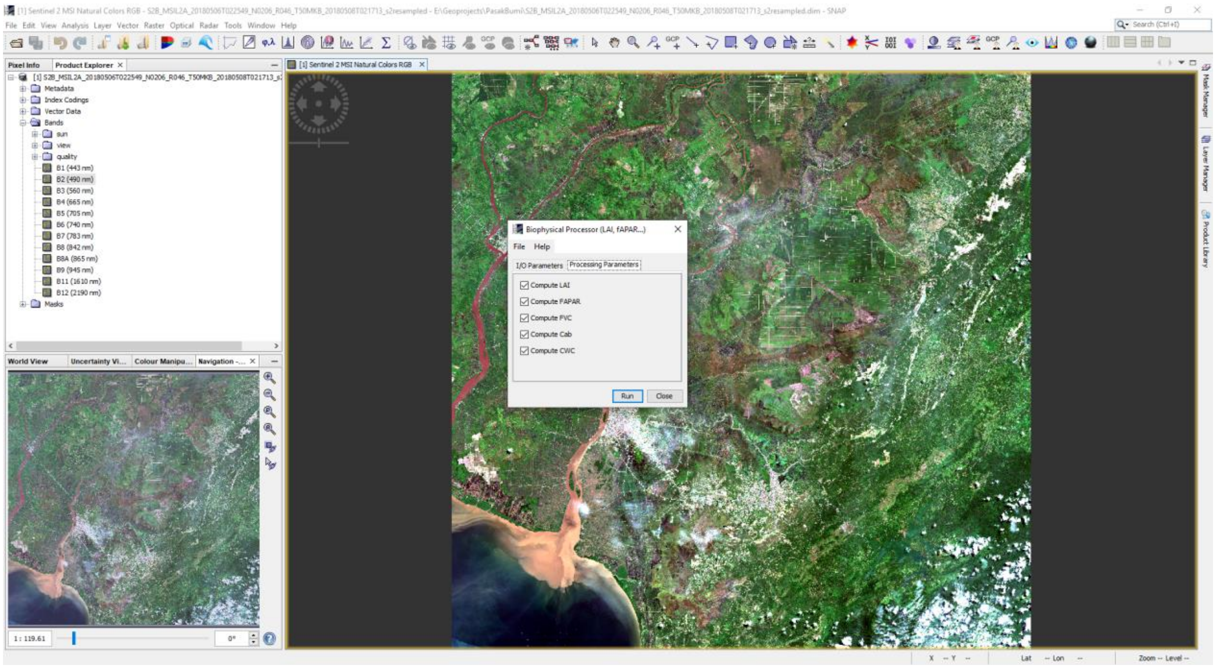

Figure 3. ESA SNAP Biophysical Processor

2.4. Statistical Analysis and Spatial Modelling

All the coordinates of the the pasak bumi plant are overlaid with the fifth Sentinel-2 MSI Biophysical Parameters. This aims to obtain quantitative biophysical data on the growth of the pasak bumi. Quantitative data from the overlapping of the pasak bumi and Sentinel-2 MSI Biophysical Parameters locations can be seen in Table 1. From this data, a number of statistical analyzes were conducted to look for certain values, namely mean, variance, standard deviation, and confidence interval. Confidence interval (CI) is calculated using a 95% confidence interval. Where CI itself is formulated as follows:

$$\mathrm{CI} = \bar{x} \pm z\frac{s}{\sqrt{n}} \qquad (1)$$

Where:

$\bar{x}$: mean
z: the z value at confidence interval 95%, i.e. 1.96
S: standard deviation
n: number of samples

The minimum and maximum values of CI resulting from the calculation of equation (1) above are assumed to be the quantitative limiting factors for the growth of the pasak bumi for each Sentinel-2 MSI Biophysical Parameter. Furthermore, CI values for each Sentinel-2 MSI Biophysical This parameter will be included as a parameter in spatial modelling, where the spatial modelling method used is binary modelling. Binary modelling is used because the output of the modelling has only two categories, which are suitable for habitat for pasak bumi, and not suitable for habitat for pasak bumi.

3. Results and Discussion

LAI parameters represent leaf or canopy density, FVC represents the presence of vegetation, CCC and FAPAR represent the health of vegetation, while CWC and also FVC can be expressed as representing climate parameters, especially temperature, rainfall, intensity of irradiation, and air humidity. These five parameters represent the character where the pasak bumi grow. For as stated earlier, that the pasak bumi grow under the canopy of the surrounding vegetation. So that the existence of the pasak bumi plant will have an association with the surrounding plants. Of course, in this study, the effects of other parameters that also determine the character of pasak bumi habitat, such as topography and so on, are ignored. This is a limitation in this research.

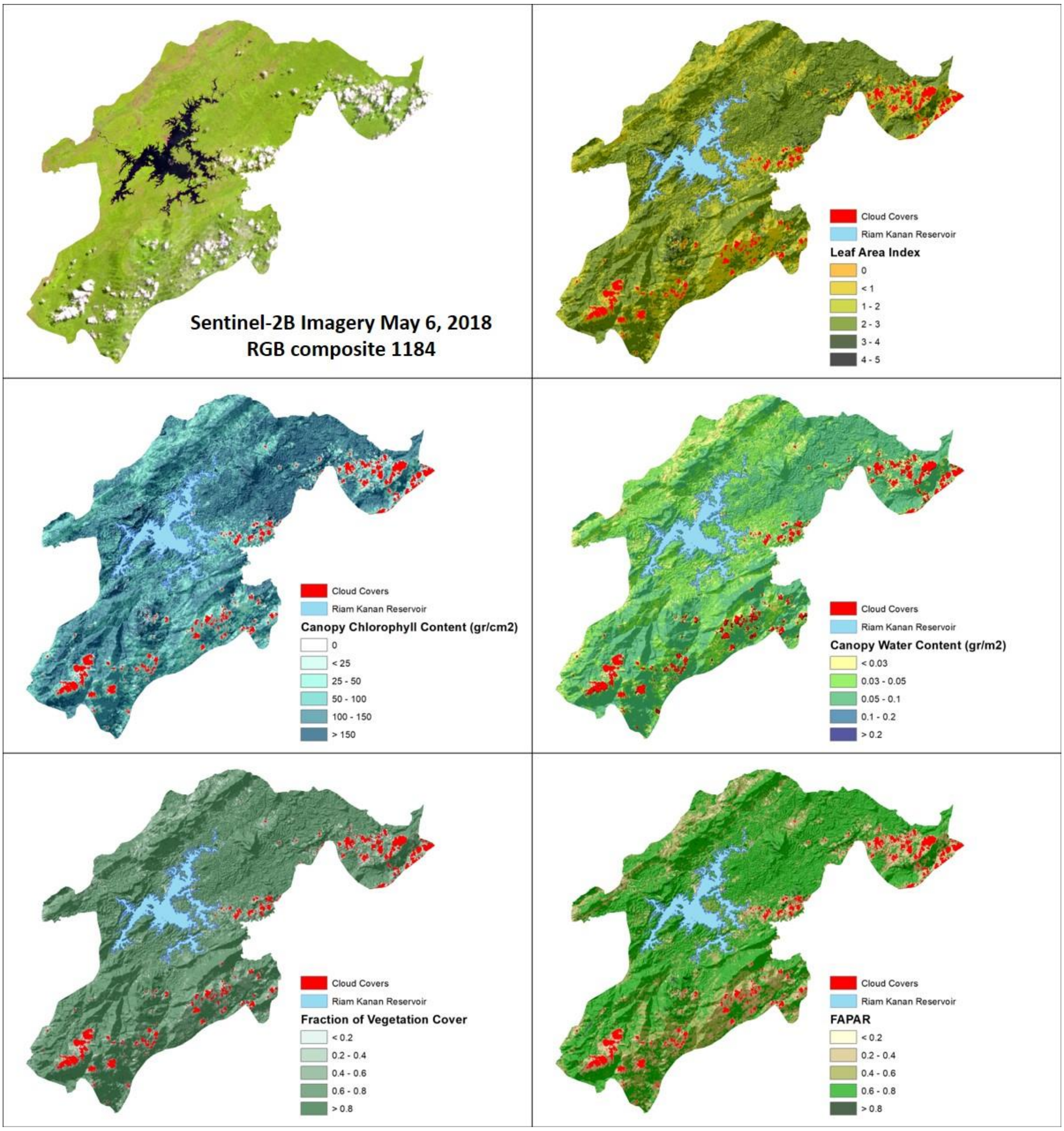

Figure 4. Sentinel-2B imagery and biophysical parameters

Table1. Sentinel-2 MSI Biophysical Parameters values and statistical analysis

No	Landcover	Σ	UTM Coordinates (Zone 50M)		LAI	CCC (gr/cm^2)	CWC (gr/m^2)	FVC	FAPAR
			X	Y					
1	SF	2	270630	9611438	2.616	143.878	0.053	0.707	0.744
2	SF	2	270733	9611445	2.541	126.772	0.055	0.708	0.734
3	SF	1	270808	9611364	2.396	150.795	0.038	0.674	0.720
4	SF	1	270808	9611364	2.396	150.795	0.038	0.674	0.720
5	SF	3	270884	9611405	2.425	151.081	0.037	0.705	0.735
6	SF	2	270951	9611653	2.362	134.618	0.040	0.705	0.724
7	SF	1	270789	9611598	3.157	172.154	0.068	0.798	0.814
8	SF	1	270875	9611689	3.072	166.506	0.066	0.800	0.810
9	SF	1	271049	9611706	3.291	194.115	0.070	0.808	0.827
10	SF	2	270916	9611780	2.756	136.548	0.062	0.754	0.767
11	SF	1	271026	9611791	3.040	175.670	0.061	0.786	0.805
12	SF	2	271026	9611791	3.040	175.670	0.061	0.786	0.805
13	SF	2	271182	9611782	2.227	113.247	0.046	0.656	0.689
14	SF	2	269514	9610435	2.146	91.012	0.052	0.641	0.667
15	SF	2	269240	9610426	2.373	103.624	0.062	0.680	0.702
16	SF	2	269239	9610276	2.237	97.510	0.058	0.638	0.676
17	SF	2	269239	9610276	2.237	97.510	0.058	0.638	0.676
18	SF	2	269442	9610296	2.611	121.288	0.063	0.731	0.744
19	SF	5	270559	9611386	2.633	146.250	0.051	0.721	0.750
20	SF	1	270456	9611302	2.711	147.199	0.056	0.728	0.758
21	SF	5	270254	9611378	2.110	113.694	0.036	0.672	0.684
22	SF	1	271021	9611545	2.381	134.045	0.042	0.700	0.723
23	SF	1	271049	9611706	3.291	194.115	0.070	0.808	0.827
24	SF	1	271649	9614753	2.289	120.145	0.044	0.680	0.702
25	SF	2	271813	9614892	2.816	168.325	0.050	0.765	0.786
26	PF	5	271076	9611600	2.745	162.273	0.056	0.697	0.753
27	PF	1	271450	9611705	2.577	145.716	0.054	0.643	0.722
28	PF	3	271566	9611769	2.605	161.886	0.055	0.637	0.728
29	PF	1	271675	9612041	2.776	171.736	0.053	0.711	0.763
30	PF	1	271662	9612130	3.051	192.866	0.056	0.780	0.808
31	PF	1	271508	9612251	2.745	159.634	0.055	0.723	0.761
32	PF	1	271196	9611999	3.211	201.389	0.053	0.814	0.831
	Minimum				2.110	91.012	0.036	0.637	0.667

Maximum	3.291	201.389	0.070	0.814	0.831
Mean	2.652	147.565	0.054	0.718	0.749
Variance	0.121	912.004	0.0001	0.003	0.002
Standard Deviation	0.348	30.199	0.010	0.057	0.049
Confidence Interval minimum	2.532	137.101	0.050	0.698	0.732
Confidence Interval maximum	2.772	158.028	0.057	0.737	0.765

Information:

Σ: Number of pasak bumi plant(s) at each location
SF: Secondary Forest
PF: Primary Forest

The extraction results of LAI, CCC, CWC, FVC, and FAPAR use the SNAP Biophysical Processor ESA on the Sentinel-2B imagery can be seen in Figure 4. Of course, the output of the SNAP ESA Biophysical Processor is raster as the data source, that is the Sentinel-2B imagery. The coordinates of each location found in the ground of pasak bumi are overlaid with each of these rasters. So that the pixel value of each parameter is obtained for each coordinate of earth pasak, as shown in Table 1.

The extraction of pasak bumi habitat suitability cannot be done on the entire research area, because some areas, especially on mountain peaks, are covered with dense clouds and cloud shadows in the imagery used. So that there is a possibility that the area of habitat suitability results of spatial modelling in this study is under estimate. Habitats that are suitable for pasak bumi in the ground may actually be wider than predictive results in this research.

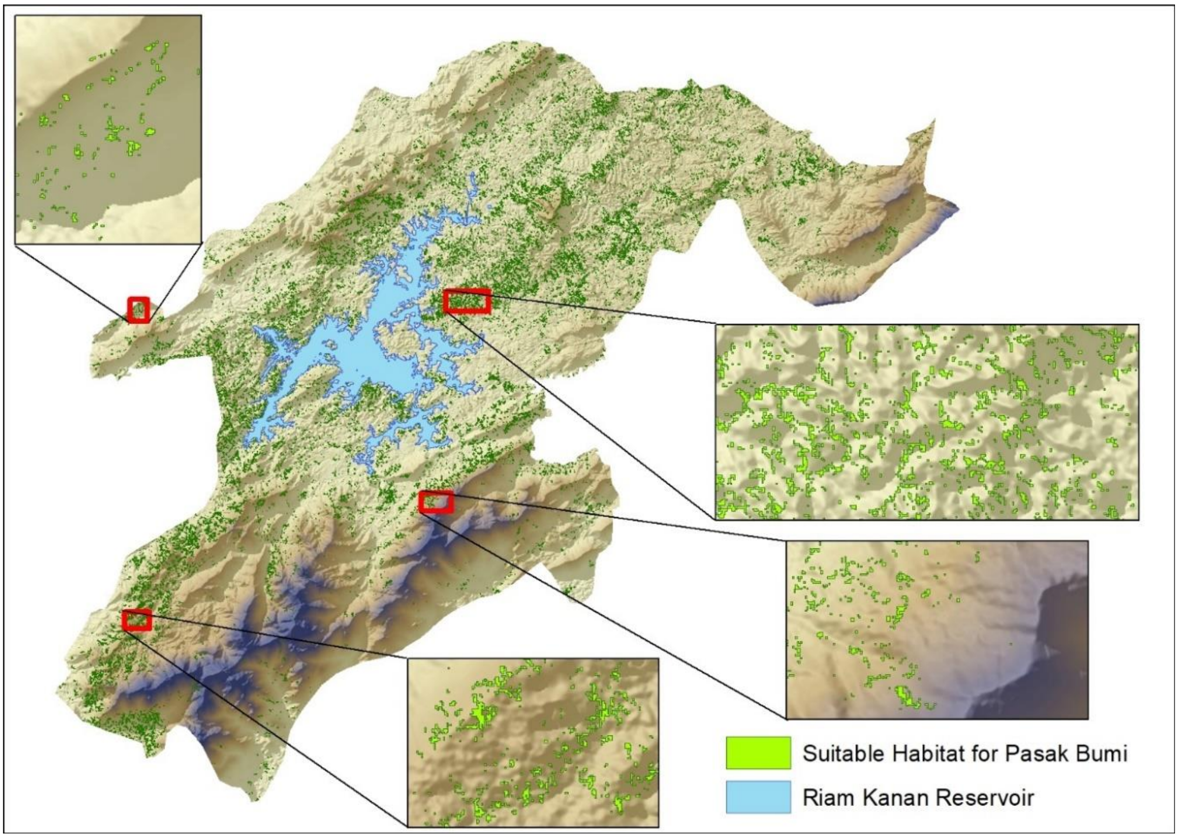

Figure 5. Habitat suitability of pasak bumi

CI values for each biophysical parameter generated from statistical analysis, as shown in Table 1, directly describe the biophysical characteristics of the pasak bumi habitat in the research location. These CI values are then implemented using binary modelling to predict the habitat of pasak bumi. We do not directly use the minimum and maximum values of each parameter to determine the quantitative limiting factor for the pasak bumi habitat. This is because to avoid bias in sampling. So we use the minimum and maximum CI values at 95%, to describe the habitat of the pasak bumi plants.

Based on the minimum and maximum CI values in Table 1, the binary modelling formula implemented in this research is as follows:

Habitat Suitability = (LAI>=2.532 & LAI<=2.772)*(CCC>=137.101 & CCC<=158.028)*(CWC>=0.050 & CWC<=0.057)*(FVC>=0.698 & FVC<=0.737) *(FAPAR>=0.732 & FAPAR<=0.765)

The formulation above is implemented using GIS software. The results of the binary modelling formula above will produce a new image which is a binary image. That is an image that only has a pixel value of 0 (zero) and 1 (one). Where the pixel value of 0 means the area that is not suitable for the pasak bumi habitat, while the pixel value of 0 means the area suitable for the pasak bumi habitat. Based on the results of modelling, it was found that the area for suitable earth plants was an area of 1,807.91 hectares. Of course, with the exception of the cloud-covered area of the Sentinel-2B imagery. The spatial distribution of the suitable area for the pasak bumi can be seen in Figure 5.

The results of the statistical analysis show that of the five biophysical parameters, the CCC is the highest variant parameter. While CWC is the lowest variant parameter. So that we can guess that the chlorophyll concentration in the leaves of vegetation around the pasak bumi plant does not have much influence on the presence of pasak bumi. The most influential is the moisture of the leaves or the canopy and the density of the canopy itself. So pasak bumi plants actually need more presence of surrounding vegetation for shade and weather stability around the place of growth.

For future research, to improve accuracy, other biophysical parameters can be involved. Including non-biophysical parameters, such as topographic, edaphic, climatologic, and so on. This research is also limited to only using one-time imagery. So that the description of the biophysical condition of the habitat of the pasakbumi which is obtained relative to time, may change at any time. Particularly representative of climate parameters such as CWC and FVC. In the future, it can be considered to use multitemporal imagery, or at least represented between the conditions of the rainy season and dry season conditions.

4. Conclusions

The suitable habitat for pasak bumi plants in Riam Kanan conservation forest zone was an area of 1,807.91 hectares. This area has a proportion of 1.55% of the total area of the conservation zone. For future research, to improve accuracy, other biophysical parameters can be considered to be involved in modelling. Even other non-biophysical parameters, such as topography, edaphic, and climatic, can be directly involved in modelling.

This research is also limited to only using one-time imagery. So that the description of the biophysical condition of the habitat of the pasak bumi which is obtained is relative according to time, it may change any time. Especially climate parameter representatives like CWC and FVC. In the future, it can be considered to use multitemporal imagery, or at least represented between the conditions of the rainy season and dry season conditions.

5. Acknowledgement
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