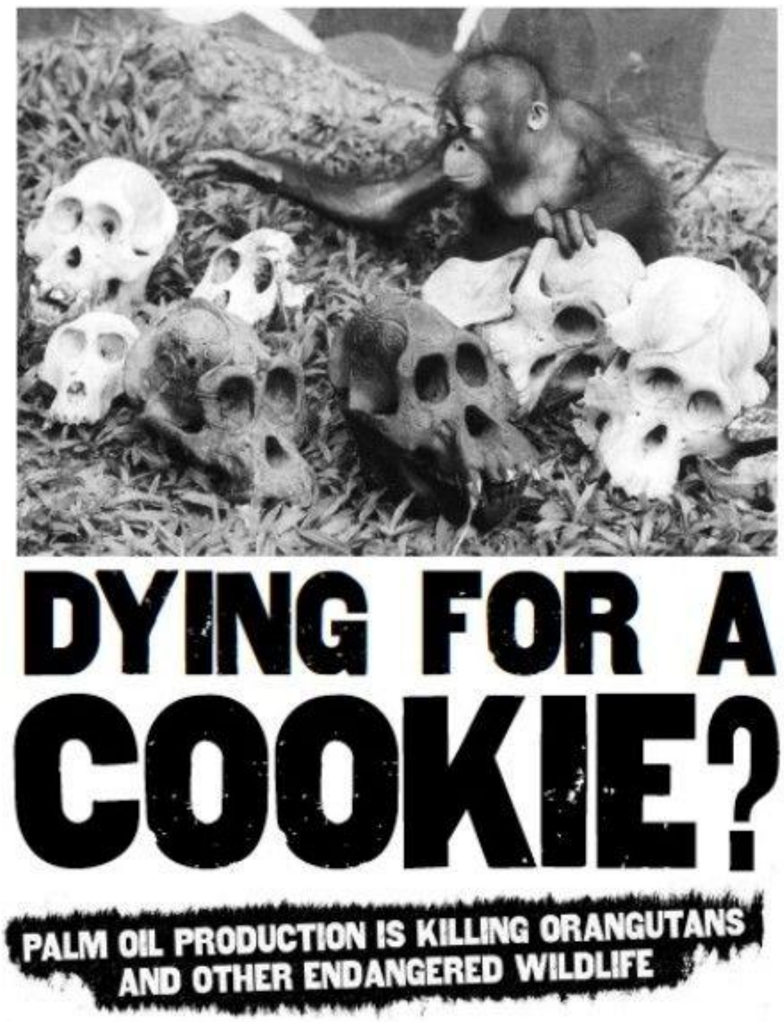
ECOSYSTEM SERVICE ASSESMENT FOR KALIMANTAN, INDONESIA



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INTRODUCTION

Oil palm (Elaeis guineensis) supplies >30% of world vegetable oil production (FAO 2012). Sumatra and Kalimantan produce ~50% of palm oil worldwide, and Indonesia plans to double national palm oil production primarily by expanding landholdings in Kalimantan and Papua.

Over the last few decades, palm oil plantation has been rising globally around the world especially in Indonesia and Malaysia. Since it is very cost and area effective (cheapest vegetable oil), growing palm oil in these regions is expected to rise in future as the demand for food increases with increasing population (FAO 2015).

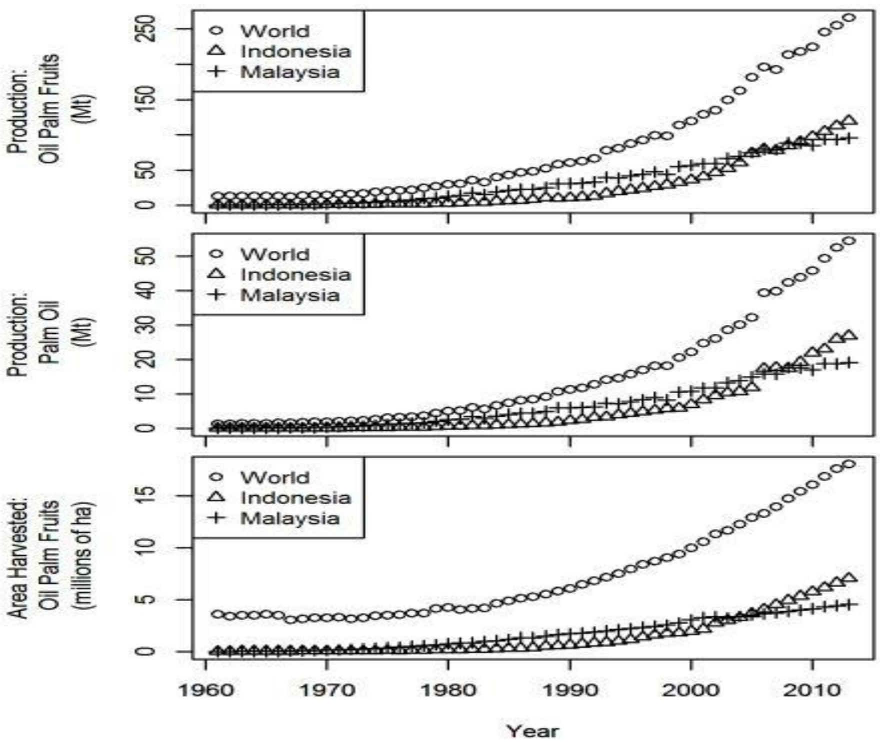
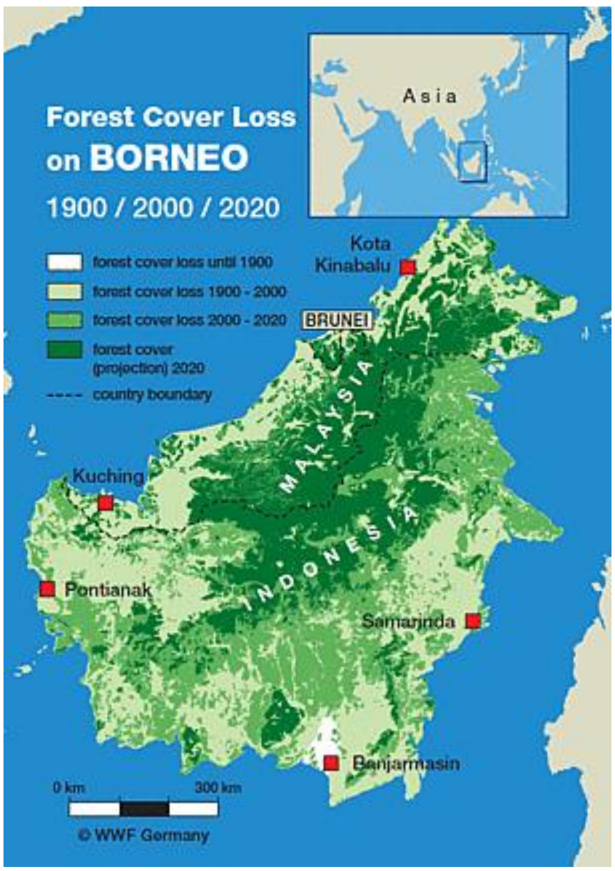


Fig 1. Production of oil palm fruits, palm oil, and hectares of oil palm harvested have all increased over time globally and for the two main oil palm producers. Hectares planted were calculated based on production and yield estimates. Data source: FAO 2015

Kalimantan (Indonesian part of Borneo) is the third largest island in the world and the largest in Asia. Administratively, it is divided into North, East, South and West Kalimantan. From 1990 to 2015, Kalimantan expanded oil palm by 4.67 million ha. About three-quarters of the plantation (3.47 million ha) occurred in the areas previously occupied by natural forests and the remaining one-quarter in non-forest land (Gaveau et al. 2014). Along with this there has been a significant rise in small scale oil palm plantations across the island. In 2013, smallholder oil palm plantation accounted for more than 40% of the total oil palm plantation in Indonesia (Glenday and Paoli 2015).

Following is a graph (whole of Borneo) by WWF showing deforestation and predicting the remaining forest cover in 2020.



Between 1985 and 2005 Borneo lost an average of 850,000 hectares of forest every year. If this trend continues, forest cover will drop to less than a third by 2020.

Fig 2. WWF Germany reports on deforestation in Borneo; Satellite studies show that some 56% of protected lowland tropical rainforests in Kalimantan were cut down between 1985 and 2001 to supply global timber demand – that's more than 29,000 km² (almost the size of Belgium).

From this graph it is clear that the oil palm plantations (along with other plantations like rubber etc.) are a threat to the natural tropical rainforests. Furthermore, this rate of decline is uneven across the ecosystems, with freshwater swamp forest and heath forest down more than 75% of historic levels to 23% and lowland forest down by more than 50% of historic levels, to 42.3%. The lowland forests of Kalimantan a critical habitat for the conservation of many unique species - is by far the most converted ecosystem type. Consequently, many unique species are on the verge of rapid decline.

Orangutans – the most iconic species of the tropical rainforests were recategorized from "Endangered" to "Critically Endangered" in 2015 by the IUCN Red List ; all due to degradation , destruction and fragmentation of its natural habitat in the rainforests. Between 1973 and 2005, orangutan lost almost half their distribution area due to large scale conversion and forest fire. The Environmental Status of Borneo 2016 Report by WWF indicates that between 2005 and 2015 another 9% of that was lost, with significant increased fragmentation of the area that was left.

This impact is not just limited to the Orangutans, but the Proboscis monkey (declined by 30% between 2005 and 2015) and the Borneo Elephants (habitat decline from 37% in 2005 to 31% in 2015) are also in gray waters.

In terms of Carbon emissions from replacing tropical forests to oil palm plantations, it is expected to reach 0.12–0.15 GtC yr^{-1} of Indonesia's 2020 CO_2-equivalent emissions. Since Kalimantan harbors diverse land covers; containing variable carbon stocks, accurate emission calculations from land use conversion needs to be done. The residual intact Kalimantan forests supports considerable above-ground carbon. However, since the 1980s, ~80% of this forest was under federally managed for industrial timber; and thus, this extensive logging reduced carbon stocks. Mosaics of community-managed agroforests and agricultural fallows may also have relatively high above-ground carbon. In addition, Kalimantan contains ~13% of the world's tropical peatlands, with substantial stores of below-ground carbon. Peat draining and burning for oil palm threaten these peatland carbon storage systems (Carlson et al 2013).

Thus, to summarize, Kalimantan is in danger of losing its major ecosystems and the valuable ecosystem services which are important for its local communities and economies both at regional and national level. With this background, in this report, I try to assess the changes in 2 ecosystem services i.e. habitat quality and carbon sequestration in

Kalimantan; from 1992 to 2015 using the InVEST model developed by the Natural Capital Project and Standford University. It is a tool with models for mapping and valuing ecosystem services provided by land- and seascapes.

These two services are particularly important to analyze in Kalimantan as there is a rapid decline in habitat quality for the biodiversity of the tropical rainforest as well as a drastic reduction in carbon sequestration potential of the forests due to massive conversion to oil palm plantations.

METHODS

1. Study Area – Kalimantan (Indonesian part of Borneo)

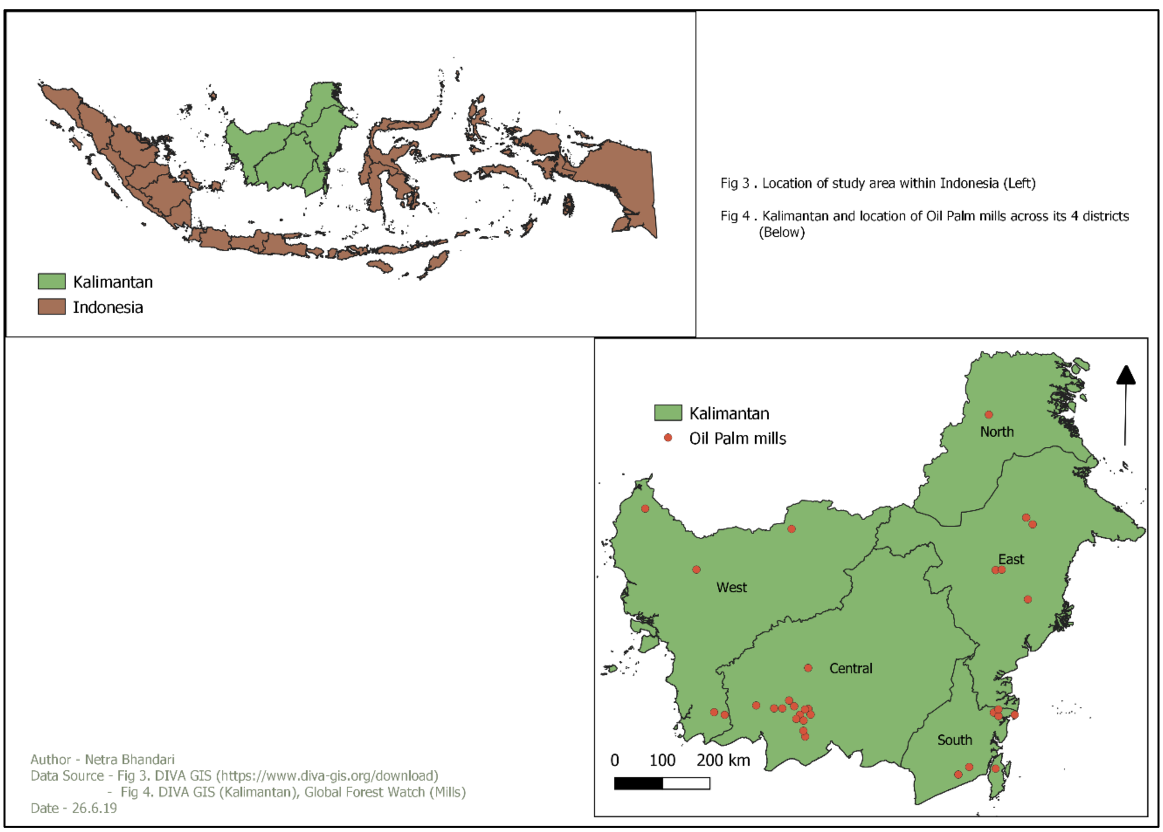


Fig 3 . Location of study area within Indonesia (Left)
Fig 4 . Kalimantan and location of Oil Palm mills across its 4 districts (Below)

Fig. 3. Study area

2. Ecosystem Services to be assessed – Habitat quality and carbon storage and sequestration service of the Kalimantan rainforests.

2.a. **Habitat Quality Model**

Inputs – 1. Current Landcover – The year 1992 was chosen as a current landcover year for analyzing changes in habitat quality. The number of classes, landuse codes and data sources are given in Appendix 1, table 3.

2. Future Landcover – The year 2015 was chosen as a future landcover year for analyzing changes in habitat quality. The number of classes, landuse codes and data sources are given in Appendix 1, table 3.

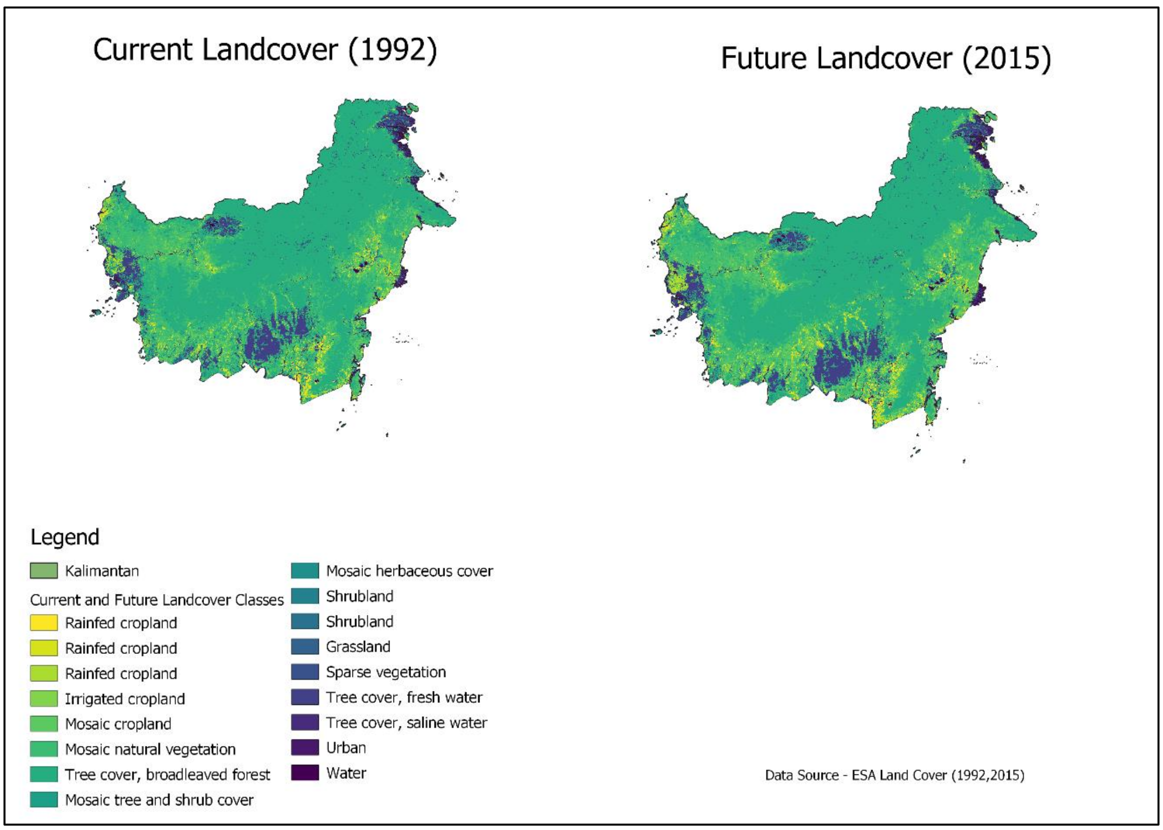


Fig. 4. Current and Future Landcover for Kalimantan.

3. Threats – The threats rasters were extracted from the landcover; and include cropland, urban areas and roads.

Each threat was weighed (between 0 -1) and given a maximum distance depending upon its impact (assumed) to the natural forest.

It was assumed that cropland was indicating Oil Palm plantations with the high threat value of 1, urban and primary roads were also considered as high threat to the habitat 1. This assigned weight was based on literature reviews which accounted that oil palm, roads and urban areas are the most important causes of forest decline in Kalimantan. Moreover, light roads, secondary roads and small plantations were given lesser threat values since they have a lesser impact. So, for example , , if urban area has a threat weight of 1 and the threat weight of secondary roads is set equal to 0.5 then the urban area causes twice the disturbance, all else equal, to all habitat types.

Moreover, the decay of each value was either linear or exponential depending on its distance from the habitat. Thus, the impact of a threat on habitat decreases as distance from the degradation source increases, so that grid cells that are more proximate to threats will experience higher impacts. For example, a grid is 3 km away from Oil Palm plantation field and 0.2 km from highway then, it is more likely to be impacted by the highway than the Oil Palm.

The threat table is given in Appendix 1, table 4.

4. Sensitivity of Land Cover Types to Each Threat – The relative sensitivity of each habitat type to each threat on the landscape is the final factor used when generating the total degradation in a cell with habitat. Sensitivity values between 0 and 1 indicate the sensitivity of LULC (habitat type) j to threat r where values closer to 1 indicate greater sensitivity.

Each landcover class was evaluated whether it has our habitat under study or not and relatively was assigned a value from 0 to 1. Next each landcover was given a sensitivity value to the threats defined above. This was based on how people reported the impact of above-mentioned threats on our chosen habitat i.e. our forests. Finally, the model assumes that the more sensitive a habitat type is to a threat, the more degraded the habitat type will be by that threat. (Appendix 1, table 5)

5. Saturation constant – The value of “k” was kept as 0.5

Assumptions – 1. It was assumed that cropland was indicating Oil Palm plantations in the chosen landcover scenarios.

2. It is also assumed that primary and secondary roads are a major threat than secondary roads, since these roads promote transport of resources from the forests.

2.b. **The Carbon Storage and Sequestration Model**

Inputs - 1. Landcovers – The landcover for Kalimantan (used above) was used.

2. Year of Landcovers – 1992, 2015

3. Carbon Pools – Each landcover class was assigned 4 values of carbon: above-ground biomass, below-ground biomass, soil carbon and dead organic matter.

The values of each carbon category were derived from various published sources and IPCC 2006 handbook (Appendix 1). For the landcovers where data was missing, the values were assigned based on IPCC guidelines, for example dead organic matter is one tenth of above ground biomass. Also, the values reported for root to shoot biomass (IPCC 2006) were assigned as below-ground biomass using the conversion factor for Tropical Rainforests.

The values for urban and water landcover classes were assigned based on relative values to mosaic tree cover and wetlands respectively. (Appendix 1, table 6)

4. Economic data – This was not clearly mentioned in published literature, hence the values from InVEST user guide was used (Appendix 1).

Assumptions - It was assumed that cropland was indicating Oil Palm plantations in the chosen landcover scenarios and that value of carbon store is lower in Oil Palm than in an intact forest.

Results

1. Habitat Quality Model

The following layers were generated as the output (along with intermediate output layers) deg_sum_c: relative level of habitat degradation on the current landscape (Fig 5)

deg_sum_f: relative level of habitat degradation on the future (Fig 5)

landscape quality_c: relative level of habitat quality on the current (Fig 6)

landscape quality_f: relative level of habitat quality on the future landscape (Fig 6)

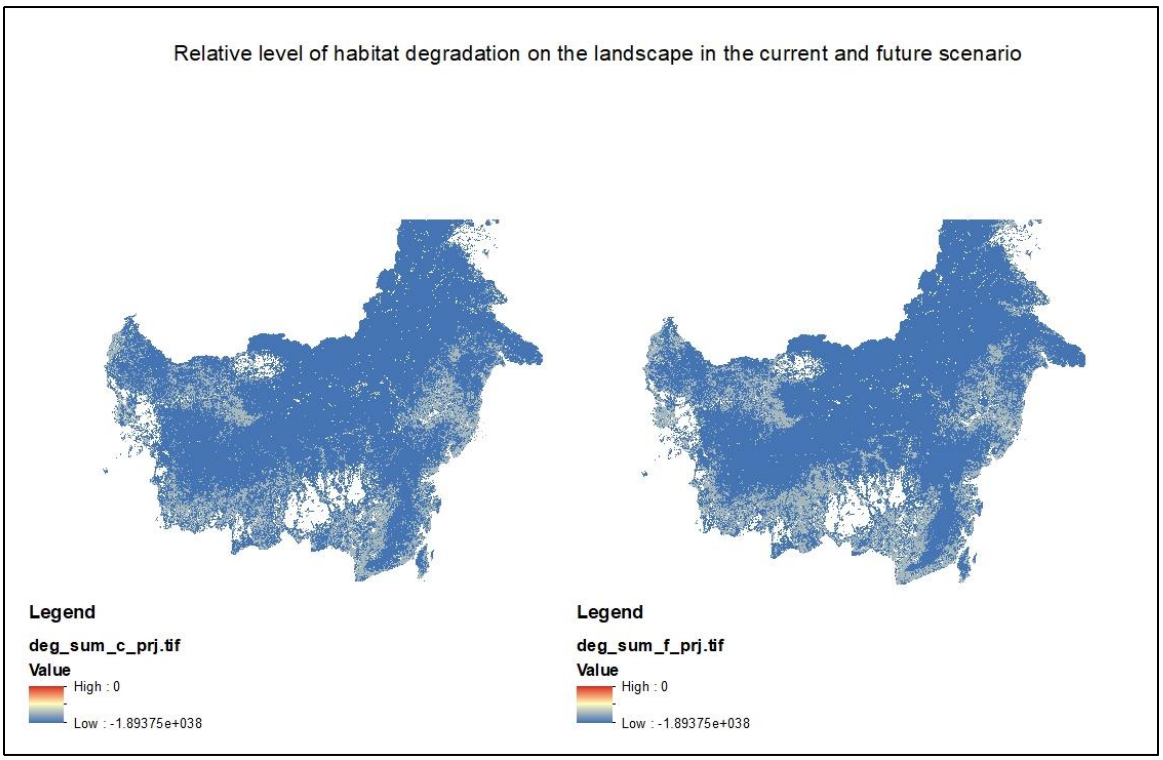


Fig 5. Relative level of habitat degradation on the Kalimantan landscape in current (1992) and future scenario (2015)

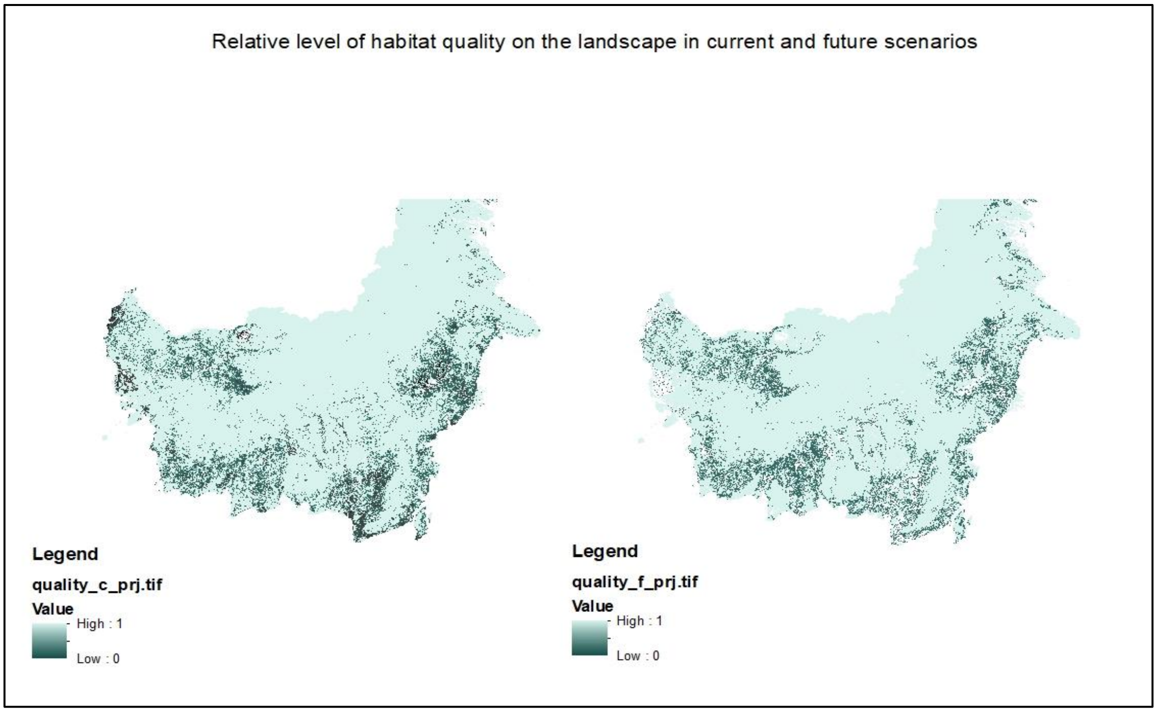


Fig 6. Relative level of habitat quality on the Kalimantan landscape in current (1992) and future scenario (2015)

Table 1. A comparison of scores for habitat quality layer of current and future landcover.

	Score for each category				
Habitat quality layer	**0**	**0.3**	**0.5**	**1**	**Sum**
Quality_current	5395926	680908	832	4532463	10,610,129
Quality_future	5465434	739436	408	4404851	10,610,129
Difference	**69,508**	**58,528**	**-424**	**-127,612**	**0**

2. **The Carbon Storage and Sequestration Model**

A lot of intermediate output files are generated and three new layers and one parameter log and one report on the model run:

delta_cur_fut – raster files showing the difference in carbon storage between two scenarios (units: Mg/pixel) – (+) values indicate sequestered carbon, (-) values indicate lost carbon (Fig 7) tot_c_cur (.tif): raster files with carbon storage (units: Mg) for current scenario – this is the sum of all carbon pools (Fig 8)

tot_c_fut (.tif): raster files with carbon storage (units: Mg) for future scenario – this is the sum of all carbon pools (Fig 9)

npv_fut (.tif): raster files showing the economic value of carbon sequestered between two scenarios (units: currency/pixel) (Fig 10)

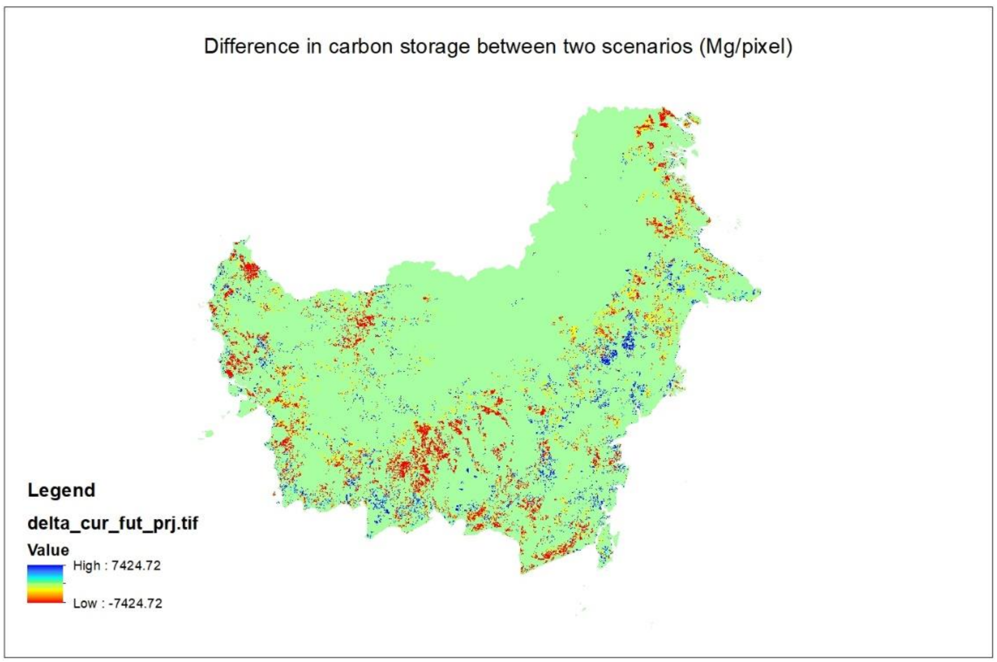


Fig 7. Difference in difference in carbon storage between two scenarios (units: Mg/pixel) – (+) values indicate sequestered carbon, (-) values indicate lost carbon

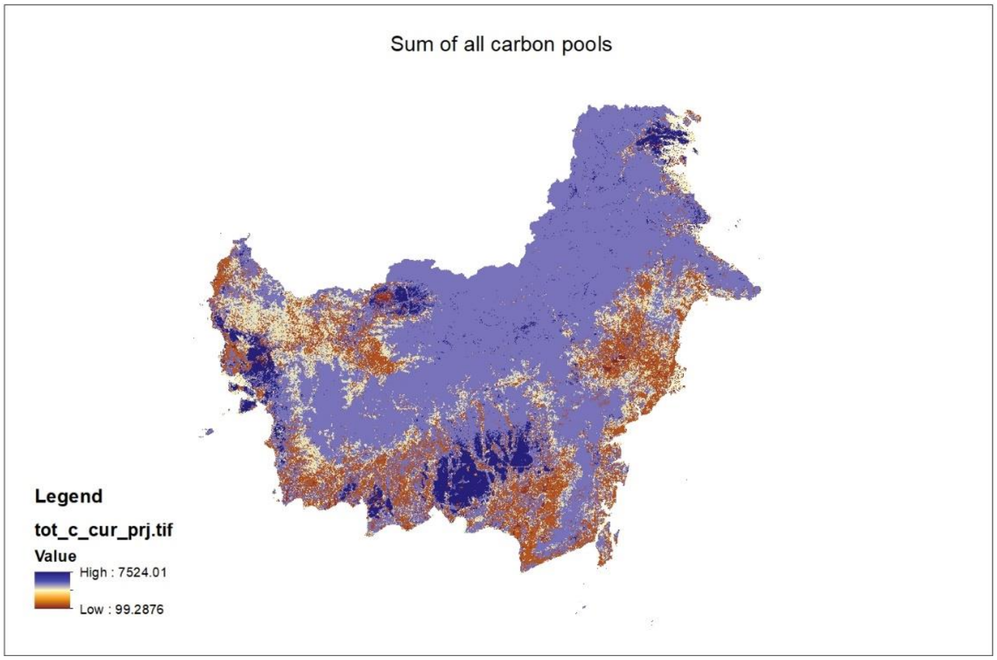


Fig 8. Total carbon storage (units: Mg) for current scenario – this is the sum of all carbon pools

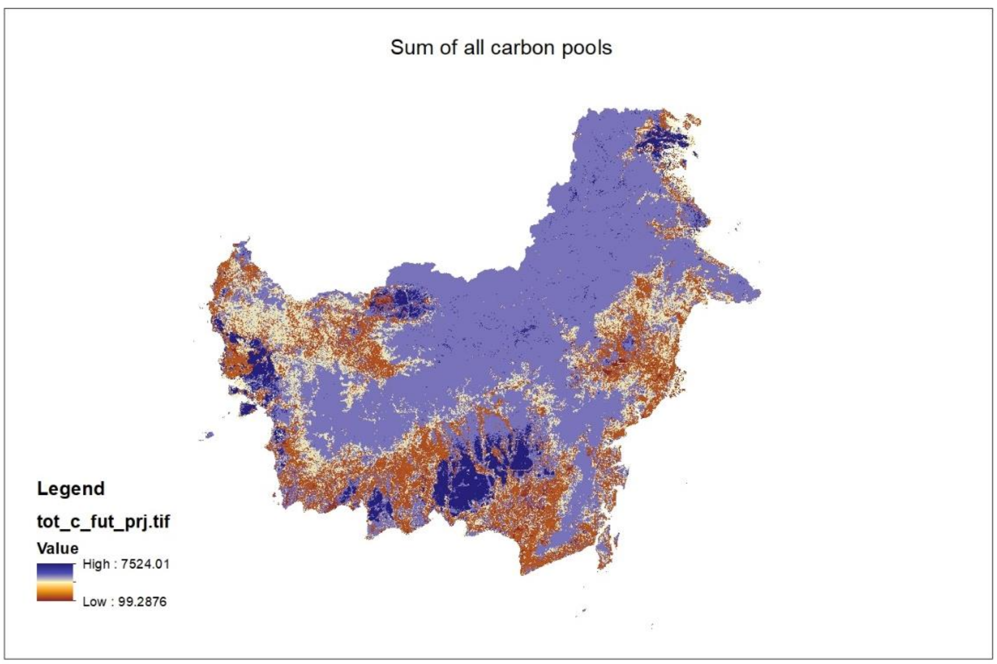


Fig 9. Total carbon storage (units: Mg) for current scenario – this is the sum of all carbon pools

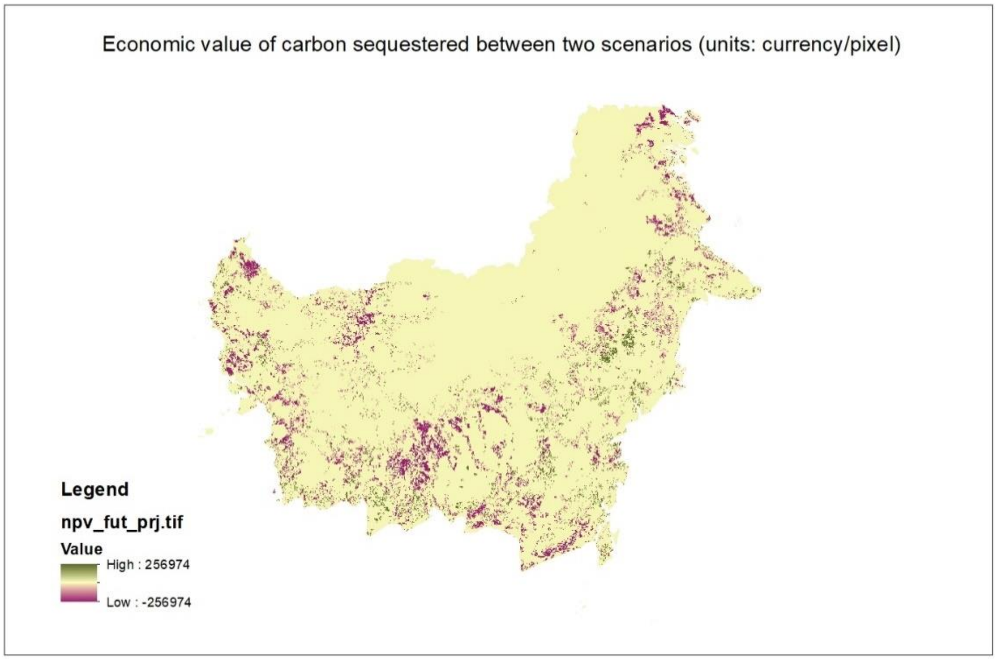


Fig 10. The economic value of carbon sequestered between two scenarios (units: currency/pixel)

Aggregate Results

Description	Value	Units
Total cur	24382610593.14	Mg of C
Total fut	23522660484.14	Mg of C
Change in C for fut	-859950097.52	Mg of C
Net present value from cur to fut	-29763315890.09	currency units

Fig 11. A summarized result of how values of carbon changes in future compared to the present scenario.

Discussion

1. Habitat Quality Model

There is a decrease in categorical score for higher habitat (0.5 and 1) value but there is an increase in lower habitat value (0 and 0.3) but the sum shows no difference. Re analysis using different K values of saturation produced same result, furthermore, increasing the relative values of threat produced the same result. However, upon analyzing the map in detail we see that there has been a change in number of pixels, for example , in western Kalimantan we can see that the habitat quality decreased from current(1992) to 2015. According to the user guide of InVEST model, it is mentioned that “if the amount of habitat across any two scenarios is approximately the same then a higher landscape quality score is indicative of better overall quality habitat”. But taking a note from all the published literature, the reality is different than what the model shows, there has been drastic decrease in the area of natural forest and a drastic increase in area of planted Oil Palm farms.

Furthermore, if we consider an overall higher landscape quality in the model, this undermines the development that has taken place across Kalimantan. The lack of getting a different value for habitat quality can also be attributed to the coarse nature of the used LULC data from European Space Agency (ESA). Thus, this is one of the limitations which might improve in future with development of regional LULC maps. Also, to get more specific results, the model needs more specific land cover classes indicating pixels with oil palm plantations as well as other plantations like rubber. Currently the criteria of forest in the ESA LULC map includes Oil Palm as a part of the forest.

Another limitation in the assessment was that road data was same for using as threats for current and future scenarios due to lack of spatial data on roads in the year 1992 and 2015. On the ground there has been increase in connectivity to different places across Kalimantan and this further poses a huge threat on the rainforest. If in future, such an assessment is carried, one must keep in mind the development of roads and infrastructure.

Finally, one unaddressed issue is the demand of Oil Palm from westernized countries. If one has a data on this, probably it could be included as an added threat i.e., the more the demand the greater the clearance of rainforests for Oil Palm.

2. Carbon Model

There is an overall carbon loss from the Kalimantan ecosystem, resulting in a negative currency value. Upon comparing figure 8 and 9, we see that in some parts, there is a clear increase in pixels showing lower values of total carbon. This is also highlighted in figure 10, where pixels of lower values of sequestered carbon increase from 1992 to 2015.

Furthermore, if you zoom in areas of lower habitat quality (Fig. 6), they overlap with areas of lower total carbon values (Fig 8 and 9). This is in support of the fact that replacing a highly diverse Tropical Rainforest to a monoculture Oil Palm plantation results in net loss of carbon.

This model could be made more robust if values of carbon stocks in all classes of landcover were available to analyze. Like, distinct values of carbon pools from the Oil Palm and natural rainforest cover only for Indonesia can further enhance the results. Currently, the values were based on the IPCC report which are a coarse representation of the rainforests, thus data from the forestry and agricultural departments of Kalimantan or Indonesia for that matter would be more useful for practitioners.

Also the current valuation in the model is given by InVEST, which may also can affect the model if region specific "payment for carbon value is available .Overall , from visual analysis of result we can observe a change in habitat quality , however the sum remains the same. On the other hand, there is a definite loss of carbon. Thus, more robust data can improve our results and help in correct assessment of ecosystem services.

Conclusion

InVEST models for Habitat Quality assessment and Carbon (sequestration) are an important tool for ecosystem service practitioners. In the Habitat Quality model, the most significant aspect is the ability to characterize the sensitivity of habitat types to various threats. Not all habitats are affected by all threats in the same way, and the InVEST model accounts for this variability. Further, the model allows users to estimate the relative impact of one threat over another so that threats that are more damaging to biodiversity persistence on the landscape can be represented as such.

In the Carbon model, the user gets a sense of how much carbon is lost based on changes in LULC, and can value it in economic terms. This gives decision makers a great edge to decide if certain development projects or certain Land Use activities will be economically and ecologically benefiting or not.

However, there are many intrinsic aspects in the model that needs to be developed further, with a rapid development of Ecosystem service sciences. The results in this study had some major limitations both in terms of available data, specifically differentiation between Oil Palm pixels and rainforest pixels in the LULC map. Moreover, lack of data on roads and carbon pools for the region, further limited the final output. In the model itself, there were limitations based on how threats were added in the Habitat quality model, but this limitation has been already mentioned in user guide of the model. Perhaps, in future there will be an update on this.

In all, better data availability in future, both spatial (resolution-wise) and economical(region-specific) and some updates in the model itself will be very benefitting to the land use managers.

Appendix 1

Table 3. Landcover codes with description (data source – ESA CCI Land Cover project)

Code	Description
10	Rainfed cropland
11	Rainfed cropland
12	Rainfed cropland
20	Irrigated cropland
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub,herbaceous cover) (<50%)
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
50	Tree cover, broadleaved, evergreen, closed to open (>15%)
100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%) grassland
120	Shrubland
121	Shrubland
130	Grassland
150	Sparse vegetation (tree, shrub, herbaceous cover)
160	Tree cover, flooded, fresh or brakish water
170	Tree cover, flooded, saline water
190	Urban
210	Water

Table 4. Threats

MAX_DIST	WEIGHT	THREAT	DECAY
20	1	crp	exponential
0.5	0.2	lrds	linear
3	1	prds	exponential
4	0.7	sagr	linear
1	0.7	srds	linear
10	1	urb	exponential

crp – cropland, lrds – light roads, prds – primary roads, sagr- small scale plantations, srds – secondary roads, urb - urban

Table 5. Sensitivity values for each threat

LULC	NAME	HABITAT	L_crp	L_lrds	L_prds	L_sagr	L_srds	L_urb
10	Rainfed cropland	0	0	0	1	0	0.5	1
11	Rainfed cropland	0	0	0	1	0	0.5	1
12	Rainfed cropland	0	0	0	1	0	0.5	1
20	Irrigated cropland	0	1	0	1	0	0.5	1
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub,herbaceous cover) (<50%)	0.3	0	0	1	0	0.5	1
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)	1	1	0.7	1	0.8	0.8	1
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	1	1	0.7	1	0.8	0.8	1
100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)	0.5	1	0.2	1	0.5	0.5	1
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%) grassland	0.3	1	0	1	0	0	1
120	Shrubland	0	0	0	1	0	0	1
121	Shrubland	0	0	0	1	0	0	1
130	Grassland	0.5	0	0	0	0	0	0
150	Sparse vegetation (tree, shrub, herbaceous cover)	1	0	0	0	0	0	0
160	Tree cover, flooded, fresh or brakish water	1	0	0	0	0	0	0
170	Tree cover, flooded, saline water	1	0	0	0	0	0	0
190	Urban	0	0	0	0	0	0	0
210	Water	0	0	0	0	0	0	0
255	Water	0	0	0	0	0	0	0

Table 6. Carbon pool values

C_above	C_below	C_soil	C_dead	lucode	LULC_Name
34.7	12.8	51.85	3.47	10	Rainfed cropland
34.7	12.8	51.85	3.47	11	Rainfed cropland
34.7	12.8	51.85	3.47	12	Rainfed cropland
34.7	12.8	51.85	3.47	20	Irrigated cropland
37.8	14	26	3.776	30	Mosaic cropland (>50%) / natural vegetation (tree, shrub,herbaceous cover) (<50%)
261	96.6	26	26.1	40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
312.7	115.7	66	31.27	50	Tree cover, broadleaved, evergreen, closed to open (>15%)
161	59.6	33	16.1	100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
54.8	20.3	33	5.48	110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%) grassland
54.8	20.3	0	5.48	120	Shrubland
40.7	15.1	0	4.07	121	Shrubland
54.8	20.3	0	5.48	130	Grassland
22	8.1	0	2.2	150	Sparse vegetation (tree, shrub, herbaceous cover)
457	169.1	86	45.7	160	Tree cover, flooded, fresh or brakish water
211.8	78.4	86	21.18	170	Tree cover, flooded, saline water
10	0	0	0	190	Urban
10	0	0	0	210	Water

Economic Value

1. Price / Metric ton Carbon – 66$

2. Market discount in price of carbon – 7%

3. Annual rate of change in price of carbon – 0

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