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Interactive comment on "Managing fire risk during drought: the influence of certification and El Niño on fire-driven forest conversion for oil palm in Southeast Asia" *by* Praveen Noojipady et al.

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General Comments: -I would like to see more information on how the area for the buffer analysis was selected. Why were the buffer areas around certified and non-certified plantations combined together? Or would it have made more sense to consider the plantation boundaries vs. plantations+buffers, while also keeping certified and non-certified separate? I'm not sure if you might expect differences in fire activity between buffers around each type of plantation.

We appreciate the Reviewer's suggestion to provide additional information regarding the buffer areas and our analysis of deforestation and fire activity adjacent to oil palm plantations. Reviewer #1 also asked for clarification of the buffer analysis, and raised

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several similar questions regarding the potential for differences in buffers for certified and non-certified plantations.

The characteristics of buffer areas around certified and non-certified plantation boundaries were similar (see Figure R1, below), including the patterns of remaining forested area, forest loss, and fire-driven forest loss. In addition, oil palm plantations in Southeast Asia are frequently adjacent to other oil palm plantations (Figure 1), meaning that it is difficult to attribute buffer activities to only certified or non-certified neighbors. As a result, we analyzed fire activity and forest loss for a single set of buffer areas surrounding certified and non-certified plantations.

In the revised manuscript, we would clarify the characteristics of buffer landscapes in Section 2.1, including the fact that nearly 12% of the area within the 5km buffer was mapped as planted oil palm in 2010 (Gunarso et al., 2013; Carlson et al., 2013). Thus, the buffer region may reflect differences in management, in addition to differences in land use and land cover, based on the abundance of planted palm oil outside of large plantations.

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Please also see specific comments below on this topic. -Could there be differences in characteristics besides certification that are influencing the results? It's not clear to me as written if the authors considered other potential variables such as the level of access to plantations, size, whether part of the concession was previously developed, differences in specific provinces, etc. This might also help to address the statistical significance of the results.

We agree that certification is only one of the factors that may account for observed differences in forest loss and fire activity across certified and noncertified plantations. A large literature suggests that when it comes to certification, the producers with the lowest cost of entrance (e.g., the best environmental performance, large producers with sufficient capital) are typically those who become certified (e.g., Garrett et al., 2016).

By not controlling for these factors, we cannot attribute observed lower fire rates to certification. However, our study does not attempt to discern the cause of observed results. Many consumers of palm oil are looking for a commodity with certain attributes (zero-fire, zero-deforestation). Our work informs these conversations because it suggests that RSPO certification is a good signal for such embodied characteristics. Additional studies that control for attributes such as plantation age, size, isolation, and governance are expected to provide further insights regarding the direct influence of certification on environmental outcomes. In our revised manuscript, we will clarify the goal of our study (to measure attributes of certified and not certified palm oil, rather than attributing causality to RSPO certification).

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-Can the authors clarify in the text when they are discussing fires within a year of deforestation (fire-driven deforestation) vs. fires for plantation management/escaped fires? Sometimes it's not clear to me which fire type is being discussed and the description in the methods section does not make this aspect clear.

Our study specifically identifies fires that are spatially and temporally coincident with forest loss, and we describe these fires as contributing to fire-driven deforestation. These fires are distinct from burning for plantation management (e.g., during oil palm replanting), accidental fires either man-made or due to lightening, or fires that occur in non-forest areas. In a revised manuscript, we would revise any wording that might be ambiguous in the description of the fire results.

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Specific Comments:

-Pg. 2, Line 24: What about the % certified within Southeast Asia?

In a revised manuscript, we would clarify that most certified plantations are within Southeast Asia: "By 2016, the RSPO had certified 2.83 Mha of oil palm that produced

10.8 million tons of palm oil, or approximately 17% of global palm oil production, with >90% of certified areas in Southeast Asia (RSPO, 2016)."

-Pg. 3, Line 31: Do you have the date of certification for each plantation or is it only known to have occurred between 2009-2015?

In our original manuscript, the analysis considered the time series of annual fire activity and deforestation for certified and non-certified plantations, based on the extent of certified plantations as of April, 2015. This ever/never treatment of certification did not specifically consider the date of certification for each plantation. The RSPO Principles & Criteria prohibit deforestation of primary or HCV forest after Nov. 2005 and all fire activity, in accordance with laws in Indonesia, PNG, and Malaysia. As a result, our analysis captures the full range of company commitments to sustainable palm oil production covered by the Principles & Criteria, rather than only the actions following the receipt of the RSPO certificate.

However, the date of certification is known for each plantation in our database. In a revised manuscript, we propose to include estimates of the total forest loss, fire-driven forest loss, and total fire activity that occurs on the subset of certified plantations that have already received their RSPO certificate (See tables B2, B3, and B4, below). This detailed breakdown provides a more robust basis for evaluating forest loss and fire activity in certified plantations.

-Pg. 4, Line 4: Was each individual plantation owned by a separate company, or was there overlap in ownership?

RSPO member companies typically have more than one oil palm plantation, although member companies may have both certified and non-certified plantations, as not all plantations must be certified upon joining the RSPO. In our revised manuscript, we will clarify this nested structure.

-Pg. 4, Line 10: Can you give more details on how planted oil palm was detected and if there were any differences between the three studies?

The three data sources for planted oil palm (i.e., Gunarso et al., 2013; Carlson et al., 2013; TW, 2015) identified oil palm using visual interpretation based Landsat and other high-resolution datasets (i.e., Quickbird). Differences in the date of Landsat or other imagery, including cloud cover, may contribute to potential differences in the estimated extent of oil palm. When multiple estimates were available for the same epoch, we used the combined area from all sources as a more conservative estimate of the extent of planted oil palm.

-Pg. 4, Line 29: How was the 5km buffer selected? Were any differences considered between small vs. large plantations?

We selected a single buffer size (5 km) to evaluate the patterns of fire-driven deforestation, forest loss, and total fire activity adjacent to palm oil plantations. This buffer was calculated for all plantations combined, given that certified and non-certified plantations are frequently adjacent to one another. In general, palm oil plantations in this study were large; in Indonesia, the average size certified plantations (10,700 ha) was comparable to that of non-certified plantations (7,300 ha).

-Pg. 5, Line 12: Could there be any effects of having a 5 year time step for the oil palm datasets vs. the annual deforestation datasets?

The extent of planted palm oil was used to exclude forest loss likely associated with replanting of existing palm oil plantations, rather than clearing of remaining forest area to establish new plantations. Given this approach, estimates of annual forest loss outside of mapped oil palm were considered new forest loss (ie, we assumed that it would be unlikely for planted areas to be established and re-cleared within a single 5-year time step).

-Pg. 5, Line 23: Can you clarify if the certification timing was similar for all of these plantations (2009?) or if it varied across the study area? Could some of the plantations in the certified category have only been certified towards the end of the study period? If the dates are not known, I would appreciate a discussion at some point in the paper on how this could impact results.

Please see answer above. As noted, the dates of certification vary between 2008 and 2015 for individual plantations. The revised tables (B2, B3, B4) now provide a breakdown of forest loss and fire activity associated with plantations that have already received their RSPO certification, because certification itself (rather than intent to certify) may also impact fire and deforestation dynamics since it includes on the ground visits by auditors.

-Pg. 5, Lines 23-24: Can you comment here or in the discussion on why this could be higher? Were these plantations easier to access or were there other factors that lead to higher deforestation pre-certification? Are these results statistically significant?

Higher rates of forest loss prior to a specific cutoff date (i.e., 2006 or 2009) may indicate an effort to strategically clear forests before restrictions associated with certification begin. The question of statistical significance for differences in clearing rates would necessitate a detailed look at individual plantation characteristics, rather than all certified plantations as a group, in order to control for selection bias of certification. In a separate study (Carlson et al., under review), we evaluate rates of forest loss and total fire activity for matched certified and non-certified concessions.

-Pg 6, Line 1: What do you mean by management classes? Certified, non-certified, and buffers?

Yes, this reference was to certified plantations, non-certified plantations, and buffer areas. In a revised manuscript, we would change this terminology to clarify that this result applied to all three categories of land management.

-Pg. 6, Line 1: Can you mark el nino years on the figure for reference? Any differences depending on the strength of the el nino?

In a revised manuscript, we would mark the El Niño years in Figure 2, as suggested. As the reviewer points out, the strength and duration of El Niño events are somewhat variable (see Figure R2, below). Such differences do influence the total fire activity in different El Niño years (e.g., van der Werf et al., 2008, Field et al., 2016). However, the goal of this work was to compare fire activity across land management classes (certified plantations, non-certified plantations, and buffer areas) in each year, rather than the absolute amount of fire, since oil palm plantations account for a small proportion of total burning in Southeast Asia during El Niño events (e.g., certified plantations in Indonesia account for only 0.5% of all MODIS fire detections in 2015).

-Pg. 6, Line 6: Were the number of dry years consistent between the two periods of comparison?

This particular reference (Pg 6, Line 6) refers to deforestation rates, not fire activity. As a result, we would not expect the number of dry years to influence observed rates of forest loss.

-Pg. 6, Line 15: Again, I'm wondering if you know about differences in certification timing among the three areas?

Yes, as described above, the date of certification is known for all certified plantations in this study. The timing of certification differs among plantations. However, all companies that are members of RSPO agree to the Principles & Criteria of certification and commit to eventually certify all of their mills. The P&C specify reductions in deforestation and fire use that predate the receipt of the RSPO certificate. For example, certification dates for plantations in this study span the period between 2008 to 2015, yet companies with certified plantations joined RSPO as early as 2004. In a revised manuscript, we would clarify the sequence of events that predate certification, including the timing of membership as opposed to certification for member-held plantations.

-Pg. 6: Line 28: Can you give a comparison of the strength of these different El Nino events?

As shown in Figure R2, above, the strength of recent El Niño events is somewhat variable, as documented in a recent studies (e.g., Field et al., 2016). A full exploration of the evolution and duration of El Niño events is beyond the scope of this study (see Figure 5 in Field et al. (2016) for an analysis of precipitation, fire density, and other characteristics of previous El Niño events. The analysis in this study compares fire activity across plantation and buffer classes in each year, but does not compare absolute fire activity across El Niño events where it would be necessary to control for the strength of El Niño events and time-varying aspects of plantation management, including certification.

-Pg. 6, Line 35: I'm not sure I understand exactly what you did here. For the annual fire detections, did you address the difference in temporal sampling between the different datasets? What detection differences might you expect between the different sensors and how could this influence comparisons?

Figure 6 provides an indication of the degree of consistency between MODIS and new high-resolution active fire detections from VIIRS and OLI for 2014 and 2015. The accompanying map panels highlight the additional detail available from higher-resolution observationsâĂŤkey advances to support routine monitoring of environmental compliance under RSPO or other certification approaches. The goal was not a validation of current algorithmsâĂŤthese questions have been addressed in previous research (e.g., Schroeder et al., 2014). Instead, Figure 6 documents how data from new sensors are consistent with the long-term observations from MODIS and also offer new potential for transparency in monitoring environmental compliance under RSPO or other certification efforts.

-Pg. 7, Line 10: I thought that the Cattau study was focused on concessions that were previously cleared or planted, so wouldn't you expect differences between that study vs. fires used for deforestation as examined here? Or are you considering management fires (see general comment #3)? Not sure if I'm missing something here, so a clarification would be appreciated.

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Cattau et al. visually inspected a small number of oil palm concessions (n=53) using data in Google Earth and did not identify evidence of additional palm oil expansion during the period of their study (2012-2015). In contrast, we used satellite-based estimates of forest loss and planted oil palm to separate forest loss and fire activity associated with remaining forest areas from fire detections on existing cleared or planted palm. By reporting both fire-driven forest loss and total fire activity, we are able to separate the fire detections associated with expanding production from other fire types, including intentional management or accidental burning. We are therefore able to address somewhat different questions from Cattau et al., based on the larger sample size of plantations across three countries, longer study period (2002-2015), and separation of fire-driven deforestation from other fire types. Interannual variability in fires associated with forest loss and residual fires related to management or accidental burning (see figure 5) specifically investigates the degree to which fire-driven deforestation occurs on certified plantations, non-certified plantations, and surrounding landscapes in comparison with other fire types. Cattau et al. do not address the question of how fire is used during forest conversion, either as a component of the emissions embodied in certified palm oil or as a source of fires on the landscape during drought years.

-Discussion: If you feel it's warranted, could you comment on whether your work relates to the findings by Gaveau et al. (2016) on the timing of deforestation for oil palm plantations? Gaveau, D. L. A. et al. Rapid conversions and avoided deforestation: examining four decades of industrial plantation expansion in Borneo. Sci. Rep. 1–13 (2016). doi:10.1038/srep32017

Gaveau et al. argue that much of the oil palm expansion in Indonesian Borneo was on previously cleared lands, rather than intact forests. Our study differs from this previous work in several respects. First, we quantified forest loss, fire-driven forest loss, and total fire activity within oil palm plantations. We used existing maps of planted oil palm to isolate changes to remaining forest cover within plantations, and we therefore assume that all forest conversion is for palm oil expansion. In contrast, Gaveau et al. visually interpreted satellite data to identify planted oil palm for different epochs, similar to data products in our study (e.g., Gunarso et al., 2013; Carlson et al., 2013; TW, 2015). We do not attempt to identify the year of planting relative to the year of forest loss. Second, our study only examines certified plantations in Malaysia, not non-certified plantations. In our study, a higher proportion of new planted palm came from forest in Indonesia (59%) than Malaysia (20%) between 2001-2010. Some differences may be expected in our results based on the extent of plantation areas. In a revised manuscript, we would comment on the difference between our results and the findings from Gaveau et al., while clarifying that different results may reflect the difference in geographic domains and plantation datasets between studies.

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Technical Comments:

-Pg. 3, Line 25: Should it be section 2.1? (Also the rest of the subheadings in this section)

We have changed the section numbers accordingly.

-Pg. 5, Line 1: The VIIRS definition just repeats the first part of the sentence?

We have removed the repeated definition sentence.

-Pg, 5: Line 14: Can you add a supplementary figure show the distribution of peatlands? We only have the subsets from Figure 1.

In a revised manuscript, we would include the full peatland map as a supplemental figure (see figure R3 below).

-Pg. 5, Line 22: Missing %.

We have included %.

-Pg. 6, Line 29: What were the peak burning months?

August, September, and October. We have added the months in the main text, based on the analysis presented in Figure A3.

-Figure 1: Is it possible to color code the zoomed in subsets by certified vs. non certified? Perhaps with some shading of the peatlands instead? This might make the figure too busy but it would be nice to see the spatial details.

We are unable to provide the information on the location of certified plantations.

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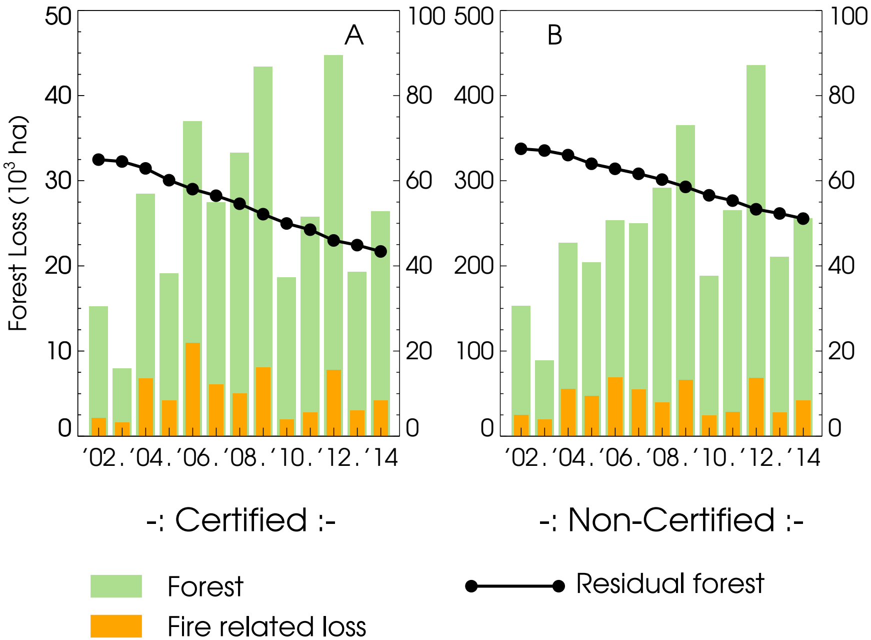

Figure R1: Forest (green) and fire-driven (orange) forest loss within the buffer (5km) areas of certified and non-certified oil palm plantation boundaries. Solid black lines indicate residual forest cover as a percentage of the buffer area adjacent to certified and non-certified plantations.

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Table B2: Total and fire-driven forest loss for oil palm expansion in Indonesia from 2002-2014 within the certified and non-certified plantations.

Year	Certified				Non-Certified		Buffer 5km	
	Total loss (ha)	Post-Certification loss (%)	Fire-driven loss (ha)	Post-Certification loss (%)	Total loss (ha)	Fire-driven loss (ha))	Total loss (ha)	Fire-driven loss (ha)
2002	12,646		4,961		86,179	21,890	184,140	29,713
2003	7,043		2,552		53,578	18,693	104,882	23,135
2004	32,885		12,587		158,904	62,232	288,634	71,538
2005	33,795		9,170		140,345	42,260	244,178	56,281
2006	54,313		12,023		224,249	85,081	320,690	88,869
2007	34,218		6,905		203,990	61,875	303,782	67,606
2008	27,376		876		252,538	31,337	355,449	47,793
2009	29,229	(1)	2,543	(0)	335,246	62,356	446,635	79,842
2010	6,267	(8)	306	(0)	120,598	14,330	228,111	28,634
2011	7,105	(23)	308	(42)	240,864	22,776	316,644	34,771
2012	9,163	(25)	495	(25)	334,453	45,787	512,886	80,585
2013	6,628	(50)	480	(82)	176,080	21,815	245,738	32,635
2014	7,264	(82)	774	(96)	195,885	31,298	302,012	48,848

Fig. 2.

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Table B3: Total and fire-driven forest loss for oil palm expansion in certified plantations in Malaysia and Papua New Guinea during 2002-2014. All areas are given in hectares (ha).

Year	Malaysia				Papua New Guinea			
	Total loss (ha)	Post-Certification loss (%)	Fire-driven loss (ha)	Post-Certification loss (%)	Total loss (ha)	Post-Certification loss (%)	Fire-driven loss (ha)	Post-Certification loss (%)
2002	14,870		912		3,959		1,244	
2003	6,563		791		1,645		301	
2004	13,522		1,912		3,279		721	
2005	6,410		506		1,242		252	
2006	12,312		465		2,893		718	
2007	12,045		15		2,099		479	
2008	7,381	(2)	91	(0)	1,188	(34)	116	(7)
2009	15,467	(8)	69	(0)	938	(71)	3	(0)
2010	10,378	(19)	155	(8)	716	(85)	14	(96)
2011	8,222	(35)	120	(65)	1,065	(85)	4	(98)
2012	7,432	(48)	235	(63)	1,235	(79)	3	(77)
2013	3,261	(50)	85	(78)	756	(100)	0	(100)
2014	4,096	(82)	114	(81)	477	(100)	3	(100)

Fig. 3.

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Table B4: Total MODIS fire detections for certified plantations, including post-certification fire detections.

	Indonesia		Malaysia		Papua New Guinea	
Year	Total fire detections	Post-Certification fire detections (%)	Total fire detections	Post-Certification fire detections (%)	Total fire detections	Post-Certification fire detections (%)
2001	169		124		37	
2002	1782		87		130	
2003	716		71		64	
2004	1821		87		130	
2005	1008		128		39	
2006	2712		17		83	
2007	197		12		61	
2008	87		9	(0)	43	(7)
2009	483	(0)	22	(0)	31	(0)
2010	72	(8)	18	(28)	44	(95)
2011	196	(29)	12	(50)	18	(67)
2012	191	(39)	21	(33)	44	(84)
2013	128	(55)	11	(55)	54	(100)
2014	361	(73)	35	(69)	52	(100)
2015	656	(100)	26	(100)	136	(100)

Fig. 4.

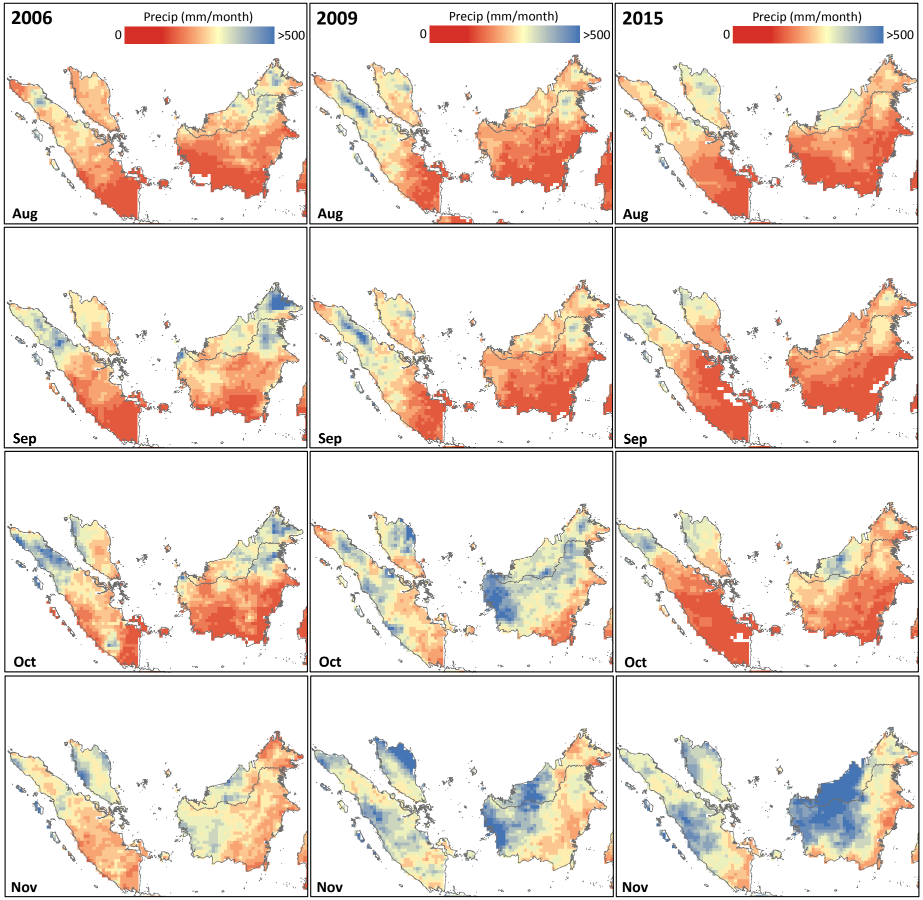

Fig. 5. Figure R2: Monthly precipitation for Indonesia and Malaysia from the Tropical Rainfall Measuring Mission (TRMM, 3B43v7) during peak fire months for El Niño years (2006, 2009, and 2015). The spatial di

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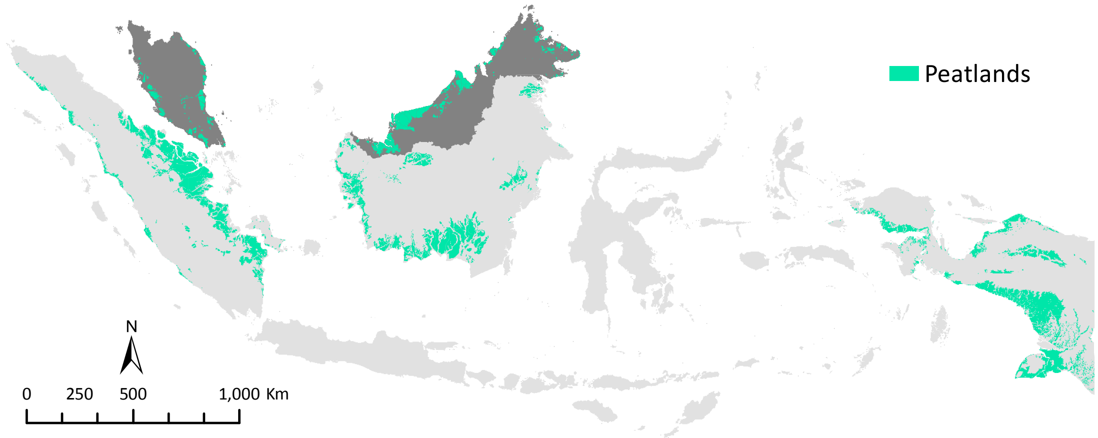

Fig. 6. Figure R3: Extent of peatlands in Indonesia and Malaysia (Wahyunto et al., 2003; 2004;2006 and WI, 2016).

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