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Short Communication

Certified "sustainable" palm oil took the place of endangered Bornean and Sumatran large mammals habitat and tropical forests in the last 30 years

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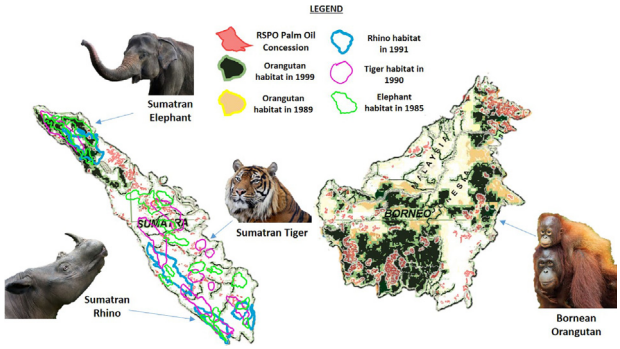
HIGHLIGHTS

- This study adopted an unprecedented historical perspective over a 30-year time series.
- Remotely sensed imagery (1984–2020) of Sumatra and Borneo were analysed.
- Deforestation showed a strong relation to the development of certified "sustainable" palm oil.
- Currently certified oil palm plantations are also located in the 1990s large mammals habitat.

GRAPHICAL ABSTRACT



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ABSTRACT

Tropical forests inhabited by endangered orangutans, rhinos, tigers, and elephants in South-east Asia are threatened by deforestation, including oil palm expansion. Certification has been proposed to label sustainable palm oil production. However, from a remotely sensed time-series and imagery analysis (1984–2020), we discovered that most of the currently certified grower supply bases and concessions in Sumatra and Borneo are located in the 1990s large mammals habitat and in areas that were biodiverse tropical forests less than 30 years ago. In light of this dramatic evidence, we suggest that certification schemes claim for the "sustainable" production of palm oil just because they neglect a very recent past of deforestation and habitat degradation.

1. Introduction

Tropical deforestation is largely driven by commodities supply, particularly from agriculture (cocoa, coffee, tea, timber, palm oil, etc.) (Curtis et al., 2018). In South-east Asia, in particular, besides a high forest loss mainly due to paper and pulp production (Abood et al., 2015), the recent establishment of extended industrial oil palm plantations has suddenly increased the clearing of tropical forests (Sodhi et al., 2004). Because international concerns raised around the "sustainability" of palm oil in terms of global exportation and the impact of local industry on the environment (Vijay et al., 2016), stakeholders from the

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different sectors of the palm oil industry including oil palm producers, processors, traders, consumers, manufacturers, retailers, banks, investors, nature conservation and developmental NGOs, formed in 2004 the Roundtable on Sustainable Palm Oil (RSPO). This multi-stakeholder representation has "the objective of promoting the growth and use of sustainable oil palm products through credible global standards and engagement of stakeholders" (RSPO, 2020). However, its capability to stop deforestation and forest degradation has been often challenged by several empirical research studies and investigations (Ruysschaert and Salles, 2014; Van der Ven et al., 2018). The criteria and indicators associated with the RSPO guidance document specifically mention biodiversity conservation and require growers to conserve rare species, habitats, and control hunting (RSPO, 2013). Moreover, there is a requirement that new plantings starting from November 2005 do not replace primary forest or High Conservation Value (HCV) areas for their importance for biodiversity conservation (RSPO 2013). In fact, large-scale oil palm plantations have a great impact on wild species and host 65% less biodiversity than natural forests (Ruysschaert and Salles, 2016).

Nonetheless, although some authors claimed that certification significantly reduced deforestation in plantations of RSPO members from 2001 to 2015 (Carlson et al., 2018), further analyses suggested that certified palm oil is not so sustainable as believed before (Cazzolla Gatti et al., 2019). This is because deforestation was usually evaluated in certified plantations that already contained little remaining forest at the start of the studies, after 2000. It seems trivial that there are no reasons to evaluate the sustainability in terms of forest conservation of an already heavily damaged area. In particular, if studies do not account for recent land changes, concession certification would appear beneficial for the environment. Instead, it was suggested that, in the last 15 years, about 40% of the area located in the current RSPO concessions suffered a significant degradation of the habitat (caused by deforestation, fires or other damage to trees) before being converted into oil palm plantations (Cazzolla Gatti et al., 2019). The discovery that tree cover loss occurred both before and after the start of the RSPO agreements (2004) and the Palm Oil Innovation Group (POIG) initiative (2013), raised a fervent debate on the actual sustainability of certified palm oil (Hinkes, 2019; Ruysschaert et al., 2019; Martens et al., 2020). These results suggested that certified concessions do not differ much from non-certified ones and led to the conclusion that any certified palm oil production cannot be completely deforestation-free. Furthermore, the impact of oil palm expansion on wildlife habitat reduction has rarely been considered from a time perspective and this has biased the evaluation of the actual sustainability of certified palm oil (Edwards et al., 2010). For instance, among some of the most charismatic and endangered animals, the habitats of the three orangutan species, and the Sumatran rhino, tiger, and elephant only occur in tropical forests of Indonesia and Malaysia (Sabah, Sarawak). Recently, the population of Bornean orangutan (*Pongo pygmaeus*) in the wild was estimated in ≈80 k individuals (Voigt et al., 2018; Santika et al., 2017), which would represent a huge decline from an estimated 288,500 individuals in 1973 and is projected to decline by more than 55% by 2025. Surveys conducted in Kalimantan showed that 2-3 k orangutans were killed every year in Indonesian Borneo during the last decades (Meijaard et al., 2011). The Bornean orangutan, as the two other species living in Sumatra, is listed as Critically Endangered by the IUCN and included in Appendix I of the CITES. For these species, the risk of extinction in the wild will be extremely high in the absence of effective protection of habitat (Marshall et al., 2009; Ferber, 2000; Santika et al., 2017). Yet, only less than 100 Sumatran rhinoceros (*Dicerorhinus sumatrensis*), which is the smallest of the living rhinos and the only Asian rhino with two horns, survive in small, fragmented non-viable populations, and with limited possibilities to find each other to breed (Kretzschmar et al., 2016). Likewise, the Sumatran tiger (*Panthera tigris sondaica*) is considered critically endangered because its population halved to 500 individuals from the 1980s (Wibisono and Pusparini, 2010) and the Sumatran elephant (*Elephas maximus sumatranus*) is largely threatened because of poaching for its tusks, deforestation, and habitat loss (Sitompul et al., 2013). Major threats to all these species have come from logging and forest fires, including those associated with the rapid spread of oil palm plantations in the last few decades. Many companies choose to use forested land to gain additional profits by logging the timber before oil palm cultivation (Abood et al., 2015).

There is, therefore, an urgent need to evaluate, with a historical perspective, the recent past of the effective impact of "sustainability" labels over certified palm oil production both in terms of its contribution to deforestation and habitat degradation. Here we analysed remotely sensed time-series of satellite images (from the oldest available of 1984 to the newest of 2020) of all 78 RSPO-certified grower supply bases in Indonesia and all 173 RSPO-certified concessions in the Malaysian Borneo (Supplementary Fig. 1) to understand the pattern from deforestation towards certification. We evaluated the overlapping between the currently certified supply basis and concessions on endangered large mammals distribution ranges (after 1984) and calculated the extent of tropical forest that was replaced by certified "sustainable" palm oil production (see Section 5 "Methods in Brief" for definitions and more details).

2. Certified plantations overlap with habitats of endangered large mammal species

Preliminary, we estimated that, in Borneo and Sumatra, more than 75% of all the current RSPO Members' Concessions took the place of the 1990s habitats of endangered large mammal species (Fig. 1). With a higher detail analysis, we detected that, of the current 27 RSPO certified supply bases in the Indonesian Borneo (Kalimantan), 23 are located in an area that was orangutans habitat up to 1999 (Table 1). Yet, 3 of these 27 RSPO certified supply bases were still fully covered by tropical forests up to 2003, 2005, and 2008 before being quickly logged, transformed in oil palm plantations, and then certified as "sustainable" (Table 1). Moreover, of the current 173 RSPO-certified concessions in the Malaysian Borneo, 131 are located in an area that was orangutans habitat up to 1989 and 35 in that up to 1999 (Table 1).

Although in Sumatra the 1999 habitats of the other two orangutan species were not replaced by the certified oil palm plantations (habitat ranges of 1989 were not available for analysis in Sumatra), we detected that of the current 51 RSPO certified supply bases on this island, 9 are located in Sumatran elephant 1985 habitat, 11 in Sumatran tiger 1990 habitat, and 3 are located in Sumatran rhinoceros 1991 habitat (Table 1).

3. Forest loss detected from time-series of high-resolution satellite images

Additionally, our time-series analysis of high-resolution satellite images revealed that the area covered by forest in 1984 in the current RSPO certified supply basis and concessions was significantly reduced up to 2020 both in Sumatra ($U = 181$; $p < 0.001$) and in Borneo ($U = 8$; $p < 0.001$) (Fig. 2a). Currently, only patched and highly disturbed forests remain in certified bases and concessions compared to 1984 tropical forest extension, which is just 3.6% and 9.8% of the total area assigned to certified oil palm plantations in Sumatra (15 k ha out of a total 414 k ha of concessions) and Kalimantan (41 k ha out of a total 417 k ha of concessions;), respectively (Table 1 and Fig. 2b). Moreover, we discovered that 49% of Sumatran and 99% of Bornean certified supply bases were completely covered by tropical forests still between 1984 and 1990, before being converted in oil palm plantations from 1990 to 2000 and, then, receive the "sustainability" label up to 2016, whereas almost no forest remains in 2020 (Fig. 2c; see Supplementary Figs. 2 and 3 for the high-resolution time-series images of land change in all certified supply bases of Indonesia).

Overall, certified "sustainable" oil palm plantations in Indonesia replaced 92.3% (666 k ha out of 722 ha) of 1984 tropical forests, which were mostly logged during just the last 30 years (on average, after

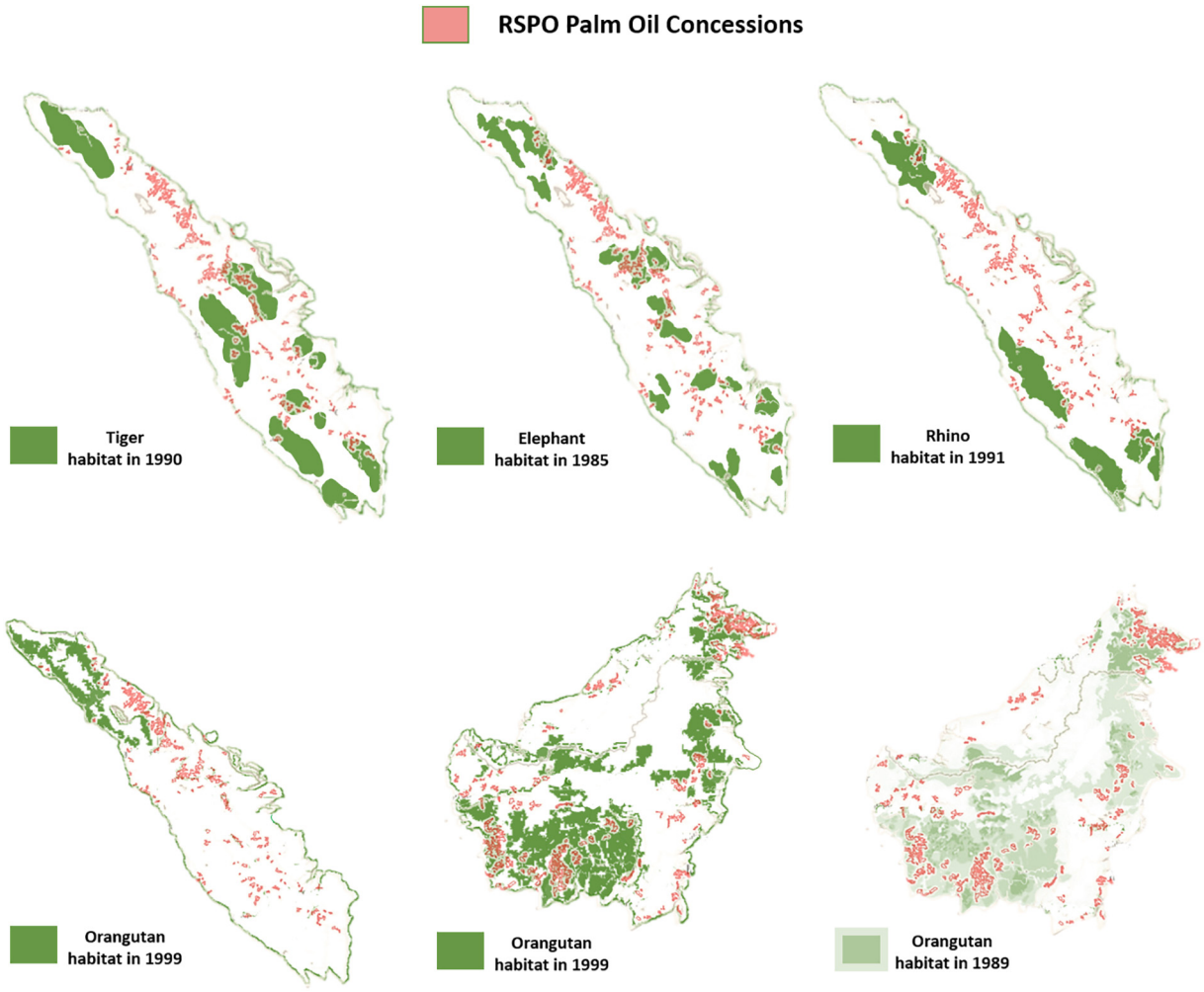

Fig. 1. The impact of sustainable palm oil on tropical forests and large mammals habitat. The maps show the overlap between all RSPO Members' Palm Oil Concessions (pink areas) and tiger, elephant, rhinoceros, and orangutan habitats in Sumatra and orangutan habitat in Borneo (green areas).

Table 1
Summary values detected from time-series of satellite images of only those supply bases (n°78) in Indonesia and concessions (n°173) in Malaysian Borneo that received a "sustainability" certification by RSPO (orangutan 1989 habitat map was not available for Sumatra; low resolution of satellite imagery for Malaysian Borneo before the 2000s made the year of plantation start undetectable; 0 values for Sumatran elephant, tiger and rhinoceros habitats in Borneo are due to the absence of these species in the island after 1984).

	Region	Number of areas	Total area (ha)	Forest cover 1984 (ha)	Forest cover 2020 (ha)	Year of plantation start (mean ± s.d.)	Palm oil plantations 2020 (ha)	N° of areas in orangutan habitat (1989)	N° of areas in orangutan habitat (1999)	N° of areas in elephant habitat (1985)	N° of areas in tiger habitat (1990)	N° of areas in rhino habitat (1991)
RSPO certified supply basis	Sumatra (Indonesia)	51	413,541.13	398,689.33	14,851.80	1989 ± 5	398,689.33	Data not available	0	9	11	3
RSPO certified supply basis	Borneo (Indonesia)	27	417,225.85	405,890.25	40,928.76	1996 ± 6	376,297.09	23	23	0	0	0
RSPO certified concessions	Borneo (Malaysia)	173	≈470,000	≈140,000	≈3,300	Data not available	≈466,700	131	36	0	0	0

1989 ± 5 in Sumatra and 1996 ± 6 in Borneo; Table 1 and Fig. 2b–c). Of these, 51 RSPO certified supply bases in Indonesia were still fully covered by forest up to 1990 and 5 of them were a rainforest up to 2000 (Supplementary Figs. 2 and 3). In the Malayan Borneo, although the satellite image resolution was lower than that of Indonesia, we were able to estimate that of the ≈470 k ha included in 173 RSPO-certified concessions, only ≈3,3 k ha of fragmented rainforests remain in 2020 (Table 1).

4. Certification does not ensure "environmental sustainability"

Our findings clearly show that certification does not ensure "environmental sustainability" of palm oil production. In fact, our analyses revealed that higher portions of endangered large mammals habitat (like that of Bornean orangutan and Sumatran tiger, rhino, and elephant) and almost intact tropical forests were depleted in very recent times (<30 years) to leave space for oil palm plantations. These, a few years

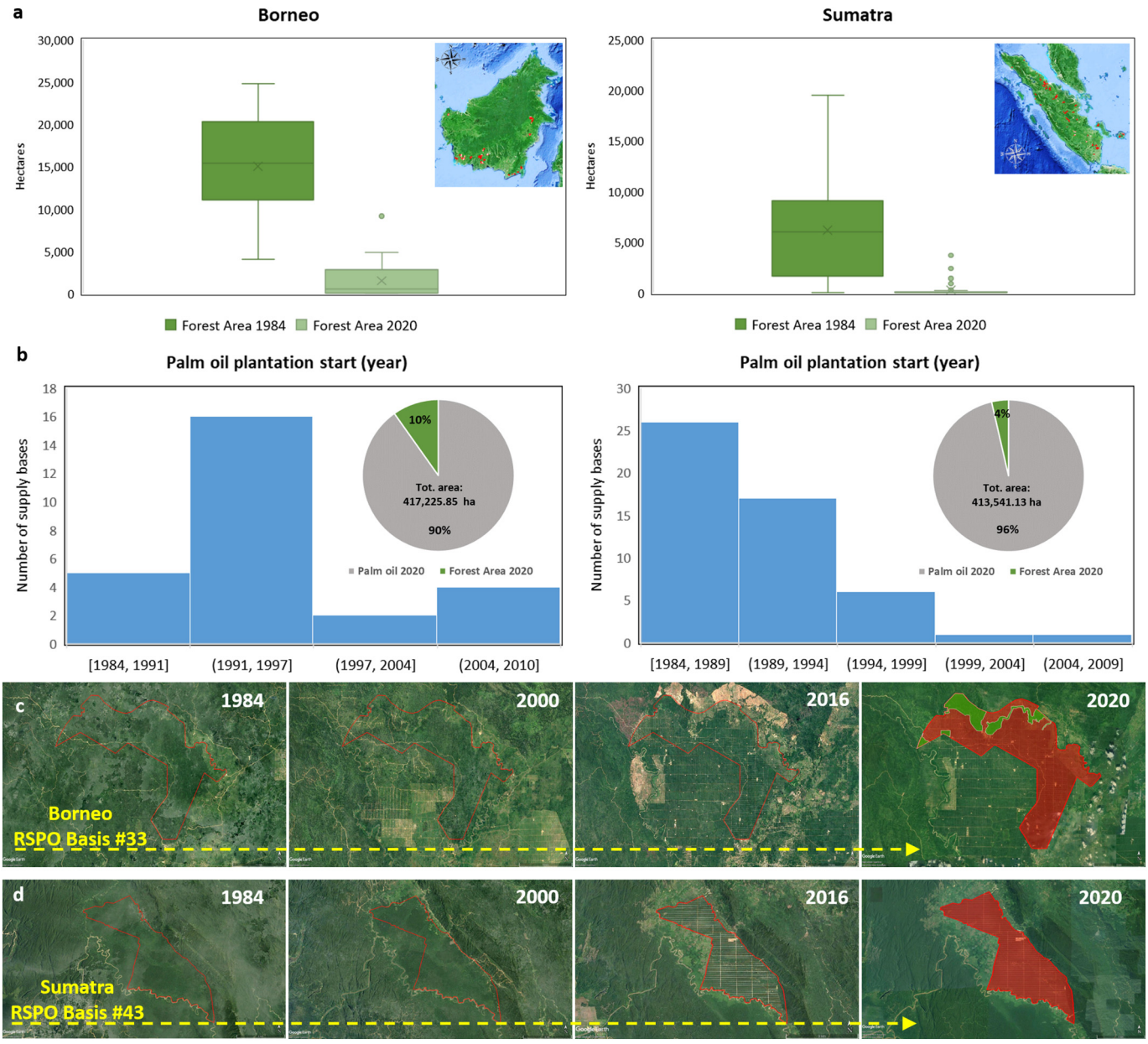

Fig. 2. A time-series analysis of satellite images reveals the pattern from deforestation to certification. a) a comparison between 1984 and 2020 forest areas in Bornean and Sumatran RSPO-certified supply bases (red areas in the upper-right panel; boxplots shows the distribution of forest areas between upper and lower quartiles, the mean as an X and outliers as points outside the "whiskers", which indicate the variability); b) the average period when oil palm plantation started (year) in certified bases and the percentage of the area currently occupied by oil palm and forests in 2020 (in the smaller pie charts) over the total; c) time series of high-resolution satellite images from 1984 to 2020 of two sample bases (see Supplementary Figs. 2 and 3 for the images of all the 78 certified bases) show the land change from tropical forests to plantations in the last 30 years (the red line marks the border of palm oil supply bases, the red area in 2020 image represent the oil palm plantation's current extent within the basis, and the light green area the remaining forest; satellite image for non-commercial use provided by Google Earth, Landsat/Copernicus).

later, were unreasonably certified as "sustainable". It seems meaningless to label as "sustainable" a plantation only considering what it is at the time of certification, ignoring recent-time impacts on wildlife and the environment. In this way, every area that was a forest just "yesterday", and is logged "today", can become a sustainable plantation "tomorrow or the day after", replacing habitats and forests that seem easy to forget and trace back to once disappeared.

Oil palm oil concessions in South-east Asia (mainly managed by a hundred of groups) cover already about 18 million hectares, whose more than 6 million hectares have been transformed in plantations only between 2001 and 2016 (Cazzolla Gatti et al., 2019). Of this, about 3 million hectares are RSPO-certified plantations, which include the supply bases and concessions analysed in this study. Yet, there are new controversies on oil palm plantations and development projects expanding in Africa (Ordway et al., 2019) and South America (Johnson, 2014). By taking an environmental perspective, our study meets the concerns of the studies that consider a social perspective on the term "sustainability" of palm oil (Ruysschaert et al., 2019). As for them and in the light of our results, we fear that the "sustainability" of palm oil is just an illusion that could facilitate, with certification, the expansion of oil palm plantations all over the tropical world and its global trade. Labelling part of palm oil production as "sustainable", against the evidence showed in this study, will just continue to reassure public opinion's concern and allow the certification of other areas that were naturally forested just a few years before as the demand increases. Therefore, due to its recent past of deforestation and habitat destruction,

we argue that the globally traded "palm oil" cannot be considered "environmentally sustainable" even if it comes from certified suppliers. We also suggest the need of further research to evaluate the impact of palm oil expansion and certification on other (less charismatic, but also important and threatened) species of South-East Asia and forest ecosystems of newly planted tropical areas in Africa and South America.

If we do not want to completely lose our close relative orangutans, the shrinking populations of endemic rhinoceros, elephants, and tigers, and irreplaceable areas of biodiverse tropical forest to supply of "non-reasonably sustainable" palm oil our junk food, biofuel, and cosmetic productions, we should stop supporting an unjustified claim of "sustainability". Just 30 years ago, when most of the currently certified plantations were rich rainforests inhabited by large mammals and many other wild species, the world did not know almost anything about palm oil, which slowly intruded the global market simply because of its cheapness. Do we want to continue to give wildlife and tropical forests a value lower than that of a cheap oil, which – even when certified – has, however, destroyed them?

5. Methods in brief

To evaluate the overlapping between certified palm oil supply bases and concessions and large mammals habitat, we used the first available species distribution maps after 1984 (the first year of satellite imagery analysis): the orangutan distribution map of 1999 produced by Davila Ross and Geissmann (2009) and that of 1989 produced by WWF Germany (https://www.wwf.de/themen-projekte/bedrohte-tier-und-pflanzenarten/orang-utans/); the Sumatran rhino distribution map of 1991 (Santiapillai and MacKinnon, 1991; Uryu, 2010); the Sumatran tiger distribution map of 1990 (Kitchener and Yamaguchi, 2010; Tilson and Nyhus, 2010); the Sumatran elephant distribution map of 1985 produced by WWF (https://wwf.panda.org/?65900%2FMapping-Sumatras-shrinking-elephant-habitat); the data set provided by the Roundtable on Sustainable Palm Oil (RSPO) on certified grower supply bases in Indonesia (Sumatra and Borneo) provided by the Global Forest Watch (http://data.globalforestwatch.org/datasets/rspo-certified-oil-palm-supply-bases-in-indonesia); and the RSPO members' concession maps of Malaysian Borneo (https://rspo.org/members/georspo).

In our study, we indicated as "RSPO Members" - following the RSPO official definition (https://rspo.org/members) – those entities that represent "all links along the palm oil supply chain and have committed to produce, finance, source and/or use RSPO certified sustainable palm oil". We also indicated as "certified palm oil" the palm oil production that comes from plantations that received a "sustainability label" by RSPO (i.e. all those concessions that were confirmed as "RSPO certified" at the time of our data collection in 2020). A supply base consists of all lands that produce or support the production of palm oil processed at an RSPO-certified mill and may include planted palm, nurseries, riparian buffers, HCV set-asides, palm oil mills and supporting infrastructure, certified smallholder oil palm lands, and roads. This dataset included 78 areas in Sumatra and Indonesian Borneo.

The Malaysian Borneo RSPO-certified concessions included 173 areas. For this database, we checked the RSPO certification status of each concession and we subset the data to only those concessions confirmed as "certified".

Then, we digitalized and analysed species distribution maps and certified oil palm plantations polygons with the software ArcGIS and Google Earth Pro.

We detected the deforestation rate and oil palm plantations expansion from the remotely sensed Landsat imagery provided by Google Earth Pro (https://www.google.com/earth/versions/) from 1984 to 2020. Then, we analysed, year-by-year, the historical land change in each certified supply base and concession, recording also the first year of the appearance of an oil palm plantation in each area (Fig. 2b). In this study, we avoided to use tree cover loss and gain estimations (Hansen et al., 2013) and preferred a direct photointerpretation of high-resolution satellite images (at a resolution of 200–1500 m altitude; Supplementary Fig. 4) to ensure that what we were measuring as "tropical forest" (with a conservative canopy cover >10%) and "oil palm plantations" was not confounded with other plantations or other non-forest tree covers. Our photointerpretation had an estimated (thematic and geometric) accuracy >99% for Indonesia (Sumatra and Kalimantan; from 1984) and >95% for Malaysian Borneo (from 2000). The satellite image resolution for Malaysian Borneo before the 2000s was not high enough to allow an estimation of the beginning of an oil palm plantation in the certified concessions.

To provide a visual comparison of the changes that happened in each certified location, we also collected three sample satellite images in 1984, 2000, and 2016 for Indonesian RSPO-certified supply bases. We displayed this comparison for a sample basis in Sumatra and one in Kalimantan in the main text (Fig. 2c) and for all the 78 bases in the Supplementary Figs. 2 and 3 (the low satellite image resolution for Malaysian Borneo before the 2000s impeded us to provide a more detailed analysis for this region). Moreover, we calculated the extent of certified plantations and remaining forests in each location on the most recent (2020) satellite image and showed the area covered by forest (green area) and plantations (red area) on the 2020 image of our time series (Fig. 2 and Supplementary Figs. 2 and 3) to provide an immediate visual comparison of the land cover type.

Finally, we analysed the statistical significance of the difference in average forest cover from 1984 to 2020 (Fig. 2a) with a non-parametric pairwise Mann-Whitney U test ($\alpha = 0.01$) and plot the graphs through the software R (R Core Team, 2013).

Data availability

The RSPO maps used to analyse the overlapping between supply basis and concessions with species habitats that informed our analysis are publicly available at https://rspo.org/members/georspo and http://data.globalforestwatch.org/. Remote-sensing data of the satellite images used to detect changes in forest cover towards plantation are publicly available at https://www.google.com/earth/.

Datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Roberto Cazzolla Gatti: Conceptualization, Methodology, Formal analysis, Resources, Writing - original draft, Writing - Review & Editing. **Alena Velichevskaya:** Formal analysis, Resources, Writing - original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.140712.

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