ZURICH UNIVERSITY OF APPLIED SCIENCES
SCHOOL OF LIFE SCIENCES AND FACILITY MANAGEMENT
INSTITUTE OF NATURAL RESOURCE SCIENCES

Quantification of deforestation on Borneo in the last 20 years based on open source geodata

Bachelor Thesis

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by

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Abstract

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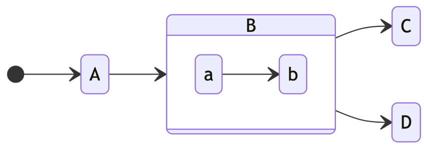
1 Introduction

Borneo, the third largest island in the world, is home to large tropical forests and peatlands. They have a vital ecological and climatic role on a global scale and are of great socioeconomic value on a national and regional level (Harrison et al., 2020). With an estimated 10,000 to 15,000 species of flowering plants, 37 endemic bird and 44 endemic mammal species (MacKinnon et al., 1997), Borneo is part of the Sundaland biodiversity hotspot (Myers et al., 2000). However, this vast flora and fauna is threatened by land use change, climate change and fire with the IUCN listing 415 species as threatened (Harrison et al., 2020). Among them is the humans closest relative, the critically endangered borneo orangutan [*Pongo pygmaeus*; IUCN (2016)]. In addition to biodiversity loss, these factors also have profound consequences at the regional and global levels. Among them are restrained water quality and quantity regulation services and greenhouse gases (GHGs Foley et al., 2011). Because of these far-reaching consequences, measures to halt, protect, or even reverse tropical deforestation have received increased attention. This, for example, through incorporating regulatory standards, corporate voluntary sustainability commitments, protected area networks, economic incentives, and demand-side interventions (Austin et al., 2019).

Vegetable oil producing crops such as canola, soybean, sunflower, and oil palm occupy ~7.5% of the world's agricultural land with a total annual production of 217 Mt (2020 - 2022 OECD, 2023). This demand is expected to increase to 310 Mt by mid-century (Byerlee et al., 2016), due to the increasing world population and as a renewable resource for biofuel (Abdul Majid et al., 2021). With a share of approximately one-third, palm oil is the most widely used vegetable oil (Kamyab, 2022; OECD, 2023). The island of Borneo, which is shared between the two largest palm oil producers in the world - Malaysia and Indonesia produce 85% of the world's palm oil - is a cultivation hotspot due to its tropical climate and high rainfalls (Kamyab, 2022).

Although many recent global datasets provide the basis for analyzing the key drivers of deforestation, the most recent study examining this for Borneo was conducted a decade ago (Gaveau et al., 2014). Considering the global importance of this region, this paper aims to fill this gap.

Building on open source geodata, this thesis investigates deforestation and its drivers. The spatial extent is the island of Borneo, and its temporal scope spans the past two decades. More precise, the following questions are addressed: (i) what is the yearly extent of deforestation, (ii) which influence did the introduction of the Roundtable for Sustainable Palm Oil (RSPO) have on deforestation rates, (iii) how much existing cropland was converted into oil palm plantations and (iv) how does proximity to infrastructure impact deforestation rates? Annex ii provides a list of the in-depth questions that help to answer these guiding questions.



Please see Figure @ref(fig:your-label) for the state diagram.

2 Literature review

2.1 Deforestation

2.2 Infrastructure

2.3 State of the art analysis

2.4 Oil palm *(Elaeis guineensis)* (Kamyab, 2022)

Originating from West Africa, the oil palm *(Elaeis guineensis)* is the most efficient and important oil-producing crop worldwide. It has the highest yield in tropical climates with high rainfall, hence it is successfully cultivated in Malaysia and Indonesia. These two countries produce 85% of the world's palm oil. Between 10 and 35 tons of fresh fruit bunch (FFB) are harvested on one hectare. Oil extraction rates (OER) have stagnated between 19 - 21% over the past 40 years (Chang et al., 2003; Chew et al., 2021). While the massive expansion of production capacities is associated with economic growth and rapid development, the ecological impact of giant oil palm monocultures and the environmental pollution caused by large quantities of by-products during oil extraction pose major problems. Palm oil is used in a

2.5 RSPO (Abdul Majid et al., 2021)

(Chapman et al. (2020); Descals et al. (2021)).

3 Method

3.1 Data acquisition and selection

Initially, databases such as Web of Knowledge or Google Scholar were searched for GIS and remote sensing studies covering Borneo, Southeast Asia or even a global extent. QGIS (Version 3.30) was used for initial data exploration. This led to the manual selection of data shown in Figure 3.1 for further analysis. Hereafter, the datasets are referred to by the names specified in the Content column. The research area included the landmass of Borneo, explicitly excluding the smaller surrounding islands. This delineation was obtained through the OSMnx python package, which accesses the Open Street Maps (OSM) database (**boeingOSMnxPythonPackage2017?**).

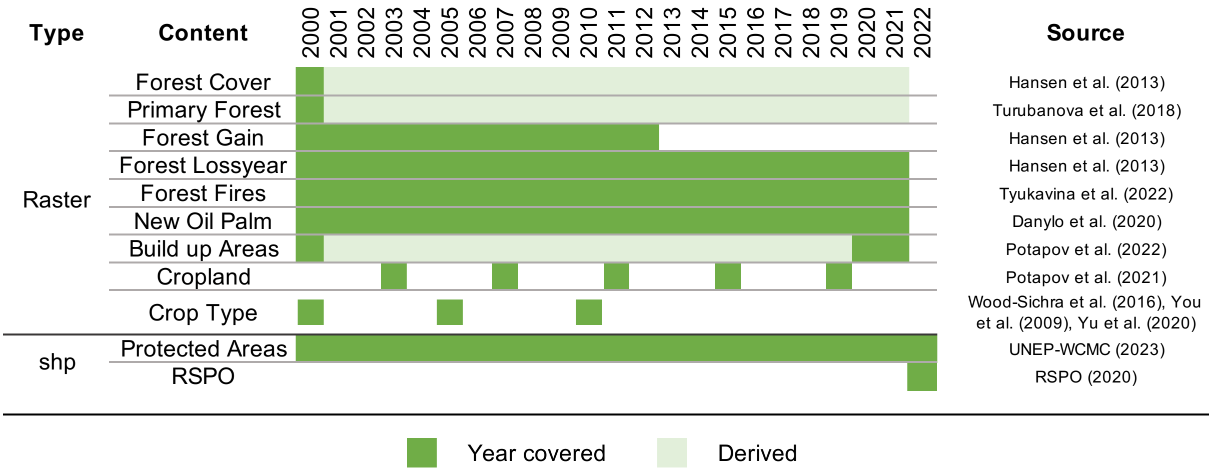


Figure 3.1: Example Picture 2

3.2 Data preparation

All datasets, which existed in several segments, were merged to cover at least the extent of Borneo.

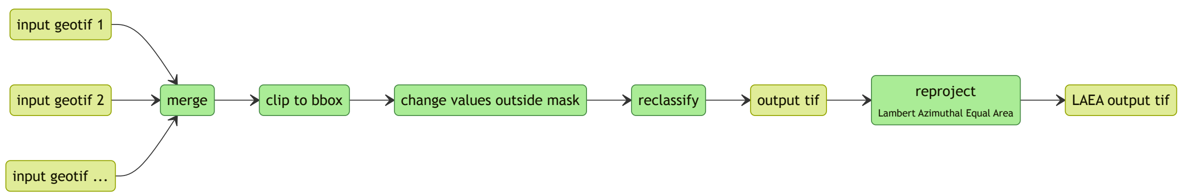


Figure 3.2: Flowchart

3.3 Data processing

For further analysis, a value of >50% tree cover was considered as forest (Hansen et al., 2013).

Aggregated plants and perennial woody plants such as coconut and oil palm were manually removed from subsequent analysis due to the cropland definition in the used dataset (Potapov et al., 2021), as well as crops with total physical harvest area lower than 10000 ha within the project extent in any of the three datasets.

Please see Figure 3.1 for the table.

Figure 3.2

Table 3.1: Demonstration of pipe table syntax 1

Default	Left	Right	Center
12	12	12	12
123	123	123	123
1	1	1	Hansen et al. (2013)

3.4 Data Collection

3.4.1 Data Source

4 Results

4.0.0.1 Questions

4.0.0.2 General Forest loss

1. How much forest area was lost yearly and in total?
2. How much forest area was lost due to forest fires yearly and in total?
3. How much new build up areas was created on forest loss areas (2020 compared to 2000)?
4. How much new build up areas was created on forest-fire loss areas (2020 compared to 2000)?
5. How much forest gain (area) occured on forest fire areas (2001 - 2012)?
6. How much forest was lost in protected areas yearly? –> carry out all of them with primary forests as well

4.0.0.3 Oil Palm related

1. How much new oil palm plantation area occured yearly on forest fire areas?
2. How much new oil palm plantation area occured yearly on non-forest deforested areas?
3. How much new oil palm plantation area occured yearly on deforested areas?
4. How much new oil palm plantation area occured in protected ares?
5. How much new oil palm plantation areo occured on non-forest area? (compared to year 2000 forest cover)
6. How much new oil palm plantation area occured on previos cropland (and other way around)?
7. How much forest area was ganied on previous oil palm plantation area yearly (2000 - 2012)?
8. How much area was used for other crops prior to oil palm plantation, and which?
9. How much area was used for oil palm plantation prior to other crops, and which?

4.0.0.4 Build up areas

1. How much new build up area occured in forest covered area (2020 compared to 2000)?
2. How much new build up area occured in non-forest covered area (2020 compared to 2000)?
3. How much new build up area occured in forest fire area (2020 compared to 2000)?
4. How much new oil palm plantation area occured within 1, 2, 5, 10, and 20 km of newly buld up areas?
5. How much forest area was lost to forest fires within 1, 2, 5, 10, and 20 km of newly buld up areas?
6. How much forest area was lost to non-forest fires deforested areas within 1, 2, 5, 10, and 20 km of newly buld up areas?
7. How much forest area was lost to cropland areas within 1, 2, 5, 10, and 20 km of newly buld up areas?

4.0.0.5 RSPO

???

For more information, refer to the literature review (Chapman et al. (2020); Descals et al. (2021)).

5 Discussion

However, the data showing forest gain in the span of 2001 - 2012 is inaccurate. Analysis showed that 32% of the alleged forest gain represents newly established palm oil plantations. Thus, all new palm oil cultivation areas established between 2001 and 2012 have been removed from the forest gain dataset.

5.1 Data selection

5.1.1 Crop harvest area

Existing mapping of cropland all take a similar approach. They disaggregate national and sub-national statistics and estimate their allocation to low-resolution grid cells of 5 arcminutes (Wood-Sichra et al. (2016); You et al. (2009); Yu et al. (2020); Grogan et al. (2022)). Among them, the Spatial Production Allocation Model (SPAM) takes the most factors into account rendering it the most comprehensive data. (You & Sun (2022)) Additionally, the dataset family currently contains data for the years 2000, 2005 and 2010, which makes it the most suited choice for the present work (Wood-Sichra et al. (2016); You et al. (2009); Yu et al. (2020)). However, due to improvements in the method of creating the datasets, the more recent ones are a more accurate representation of the physical harvest area and are more finely broken down into distinct crops. (Wood-Sichra et al. (2016); Yu et al. (2020)). This is why coconut is missing in the year 2000 even though it was an important crop for both Indonesia and Malaysia at that time (*FAOSTAT* (n.d.)).

Although a more recent dataset called Global Agro-ecological Zones (GAEZ v4.0) was available for harvested crops in 2015, no analysis was conducted with it because the data lacked the necessary quality and therefore could not be compared to the SPAM datasets. Just like the SPAM dataset, FAO statistics complemented with national data on FAO gaps, were used to calculate crop yield in a 5 arcminute resolution grid. However, the pixel values in the GAEZ 2015 dataset are based upon the GAEZ 2010 (GAEZ v3.0) dataset, whose download portal does not work anymore (FAO/IIASA (2010)). It was calculated by multiplying the year GAEZ 2010 pixel value by the countries' change in the given crop over the last 5 years. As a result, any spatial displacement in the harvest area of a given crop to another region is incorrectly mapped rendering the intended analysis inadequate.

Another available dataset for 2000 was neglected because the SPAM datasets were all created using the same method, which reduces inconsistency when comparing spatiotemporal differences. In addition, only the harvested area was available in the alternative dataset. This means that areas that were harvested several times per year were also counted multiple times, biasing the total physically cultivated area.

Nevertheless, SPAM data is also subject to non-negligible drawbacks, since ### !!!NOCH ERGÄNZEN!!! ### (Joglekar et al. (2019)).

5.2 Processing

As indicated before, merging data from different sources is challenging. This is especially true for the croplands in higher resolution (~30 m) with the physical harvest area for the individual crops in lower resolution (5 arcminutes). Especially because the two datasets were created with fundamentally different methods. While the dataset of the cultivated areas was created by analysis of satellite data time-series and showing their precise extent (Potapov et al. (2021)), the physical harvested area maps of the different crops were compiled by a complex model based on statistics and estimates (Wood-Sichra et al. (2016); You et al. (2009); Yu et al. (2020)). Even though a method to aggregate these datasets was developed, the main reason why crops were not further analyzed was that the intersection area of newly detected oil palm plantations was below a total of 80 km^2 for all of Borneo over the span from 2000 to 2017. Since this represents only such a small fraction of the total cropland (~2000 - ~3500 km^2) and

5.3 Oil Palm

Whilst this thesis allocates ~4 Mha to newly detected oil palm plantations, another paper states a higher number with ~ 5.5 Mha (Gaveau et al. (2019)). –> different crs (crs not given), falsely classified to pulp wood as difficult to distinguish.

5.4 Biodiversity

If the deforestation drivers are not addressed, biodiversity will continue to decline, as examined in a case study of the Borneo orangutan (Voigt et al. (2022)).

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Annex

I Plagiarism declaration

Statement of Authorship for Student Work at the School of Life Sciences and Facility Management

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☐ Course work
☐ Minor paper
☒ Bachelor’s thesis
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II Plagiarism declaration