MAPPING THE EXTENT AND TYPE OF DEFORESTATION, CAMPO MA'AN CAMEROON

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Introduction

The recent approval of a large palm oil concession in SW Cameroun (Camvert) is raising concern about the impact on tropical forest ecosystems and local communities in the region. This concern requires evidence about the timing and extent of forest clearance. A combination of optical (Sentinel –2) and radar (Sentinel –1) satellite data from the European Space Agency (ESA) were used to map the timing and extent of forest clearance from 2016 to the present.

The type of forest in terms of carbon stocks and conservation value was also mapped, based on the High Carbon Stock Approach (HCSA) [1]. The key objectives, both before and after forest clearance, therefore, were to:

- map the location and extent of deforestation;
- track the timing of each stage of deforestation;
- map the quality of High Carbon Stock (HCS) and High Conservation Value (HCV) forest within the concession.

Although a 2km buffer was applied around the boundary of the concession to ensure that analysis of High Conservation Forest included patches of forest that extended beyond the concession boundary, all land cover data (ha and percent) are presented for the area of the concession only.

Sentinel -2 (optical)	Sentinel -1 (SAR)
16 April 2016	April 2016
15 February 2022	May 2022
	September 2022
	November 2022

Table 1. Satellite image data sources and acquisition dates

Land cover classification

Pre-clearance: April 2016

The first objective was to map land cover within the concession pre-clearance. The only available optical data were acquired by Sentinel -2 [https://sentinel.esa.int/web/sentinel/missions/sentinel-2] in April 2016 (Table 1). However, as this image is covered with extensive cloud and haze, Synthetic Aperture Radar (SAR) imagery (April 2016) from the Sentinel – 1 mission [https://sentinel.esa.int/web/sentinel/missions/sentinel-1] was integrated into the dataset prior to land cover classification. The advantage of an active sensor such as Sentinel -1 is the all-weather capability, which enables image scenes to be acquired even under conditions of dense cloud cover.

The multi-polarisation Sentinel –1 SAR data were pre-processed (calibrated and terrain-corrected) using the ESA SNAP (Sentinel Application Platform) software (https://earth.esa.int/eogateway/tools/snap) and

integrated with the optical bands from Sentinel –2. A maximum-likelihood classification was performed using the Semi-automated Classification (SCP) plugin available for QGIS.

False Colour Composite image (FCC)

A False Colour Composite (FCC) image was produced from three Sentinel –2 input bands (near-IR #6; visible red #5 & visible green #4). The contrast stretched Sentinel – 2 FCC for the April 2016 image with the boundary of the Camvert concession and roads[1] overlain, is shown in Figure 1.

An apparent area of early forest clearance is shown between the northern and southern blocks of the concession, showing as a mottled grey-blue pattern on the imagery (Table 2). Without further analysis it cannot be confirmed that this clearance was previously Dense forest, although this is probable given that most of the surrounding area is still Dense forest. Apart from this early clearance, mostly *outside* the concession boundary, there is no obvious evidence of agriculture or extensive clearance within the concession at the time of image acquisition in April 2016 (see Land Cover Classification, below). Extensive areas of haze (north-west) and cloud (west) are evident.

Land cover class	Typical colour/pattern
Dense forest (closed canopy)	Dark orange
Medium forest	Light orange
Disturbed forest	Dark blue
Cleared forest	Slate blue (areas of burn)/road network visible
Palm oil	Deep orange with tree cultivation rows visible
Cropland	Bright red/orange (uniform)
River	Dark blue
Cloud	Includes both cloud tops (bright white) and shadow (very dark)

Table 2. Typical colours and patterns of the different land cover types within the concession

[1] The alignment of roads was interpreted visually from a combination of Sentinel -2 FCC imagery, ESRI satellite Earth and Google Earth. Alignment, type, and extent of the road network is approximate.

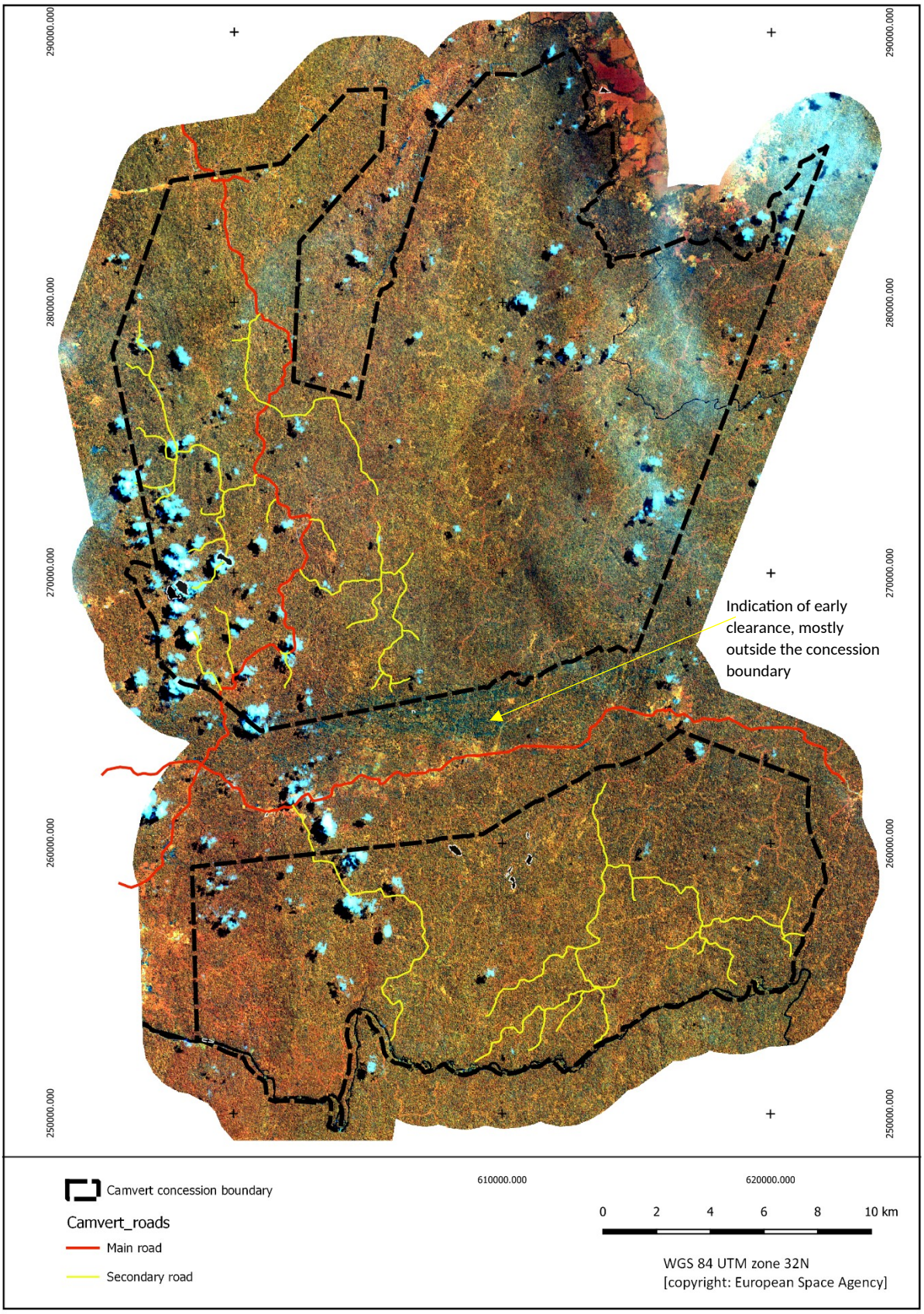

Figure 1. Sentinel -2 FCC image (#654), April 2016

Land cover classification

Training areas were selected based on the range of land cover types visible on the FCC image (Figure 1). Spectral signatures were calculated for each land cover type using selected Sentinel –2 bands and the VV & HV Sentinel –1 multi-polarised SAR bands [1] and input into the computer-assisted classification using the SCP plugin for QGIS [2]. The results of the land cover classification[2] are shown in Figure 2, with the area (ha & percent) of each land cover category shown in Table 3. There is only minimal evidence of forest clearance within the concession in April 2016.

[2] The accuracy of the land cover classification has not been validated with field survey data; the presence of cloud and haze results in large areas of unclassified land making it impossible to directly compare land cover totals between April 2016 and February 2022 (Figure 4).

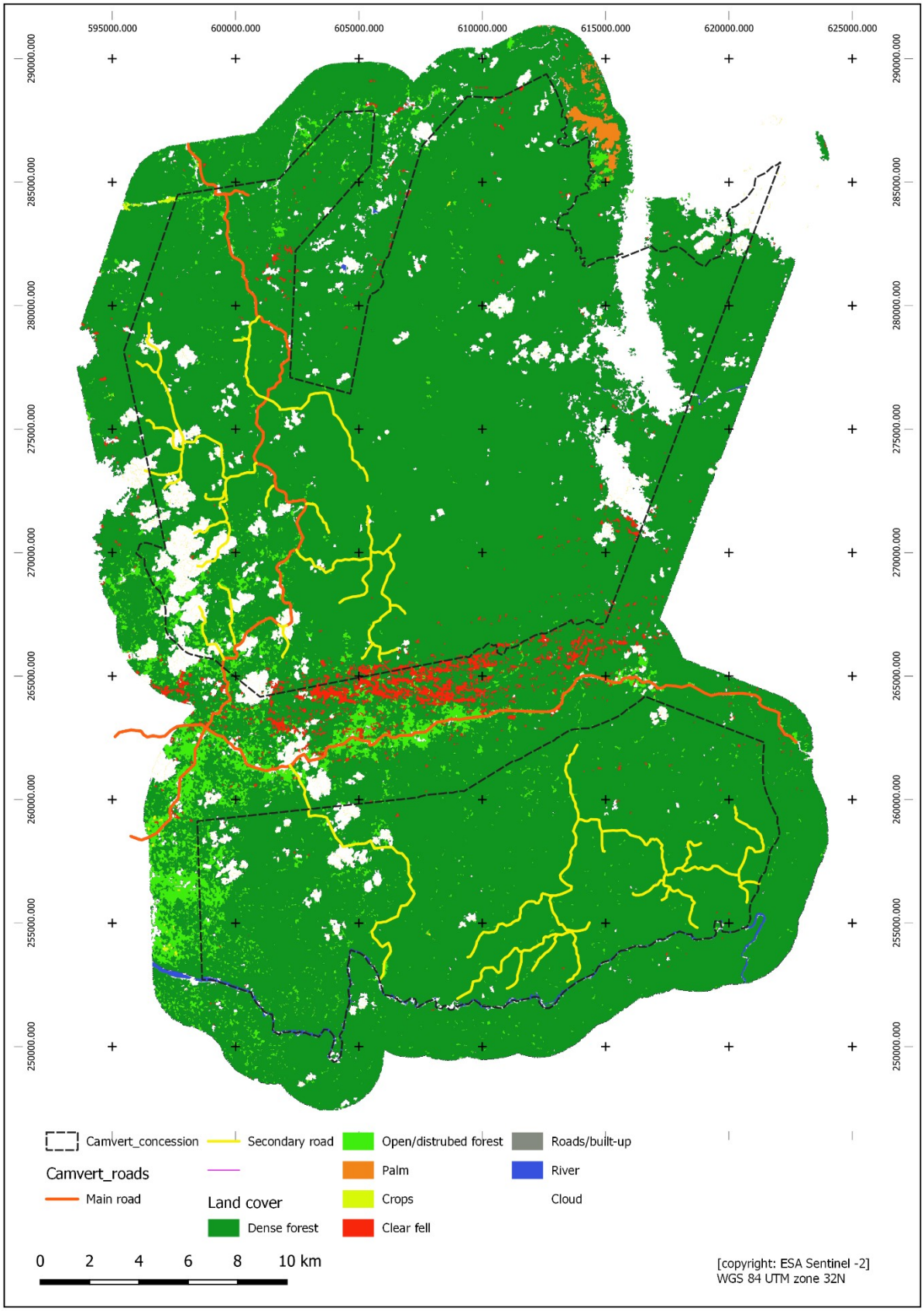

Figure 2. Land cover, 2016

	Ha	Percent
Unclassified	3914.70	6.51
Dense forest	53293.05	88.59
Open/disturbed forest	1335.78	2.22
Clear fell	277.95	0.46
Palm	1.66	0.00
Cropland	4.85	0.01
Developed (roads/built up)	2.41	0.00
River	135.97	0.23
Clouds	1193.05	1.98
	60159.43	100.00

Table 3. Land cover area, 2016

Post-clearance: 2022

The only recent cloud-free imagery was acquired in February 2022 (Figure 3). The image is cloud-free across the central and southern part of the concession, but significant cloud cover is evident to the north with areas of haze to the south-west. Land cover was classified from the Sentinel -2 multispectral satellite imagery (Table 1) acquired in February 2022. At this date, the area of the concession cleared for palm oil, is clearly visible to the centre-left of the image. The results of the land cover classification are shown in Figure 4, with totals (ha & percent) for each land cover category in Table 4.

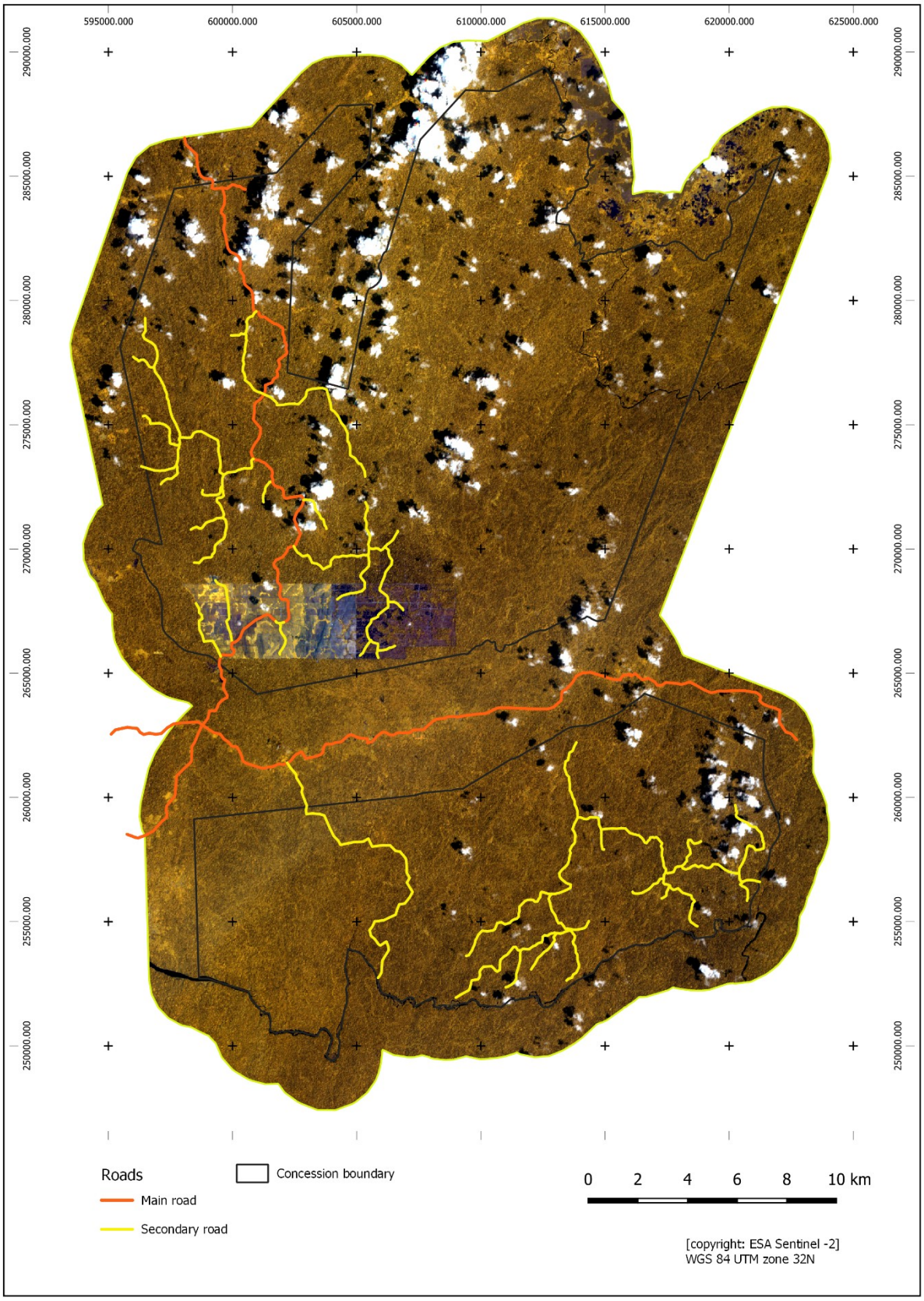

Figure 3. Sentinel -2 False colour composite (#654), acquired February 2022

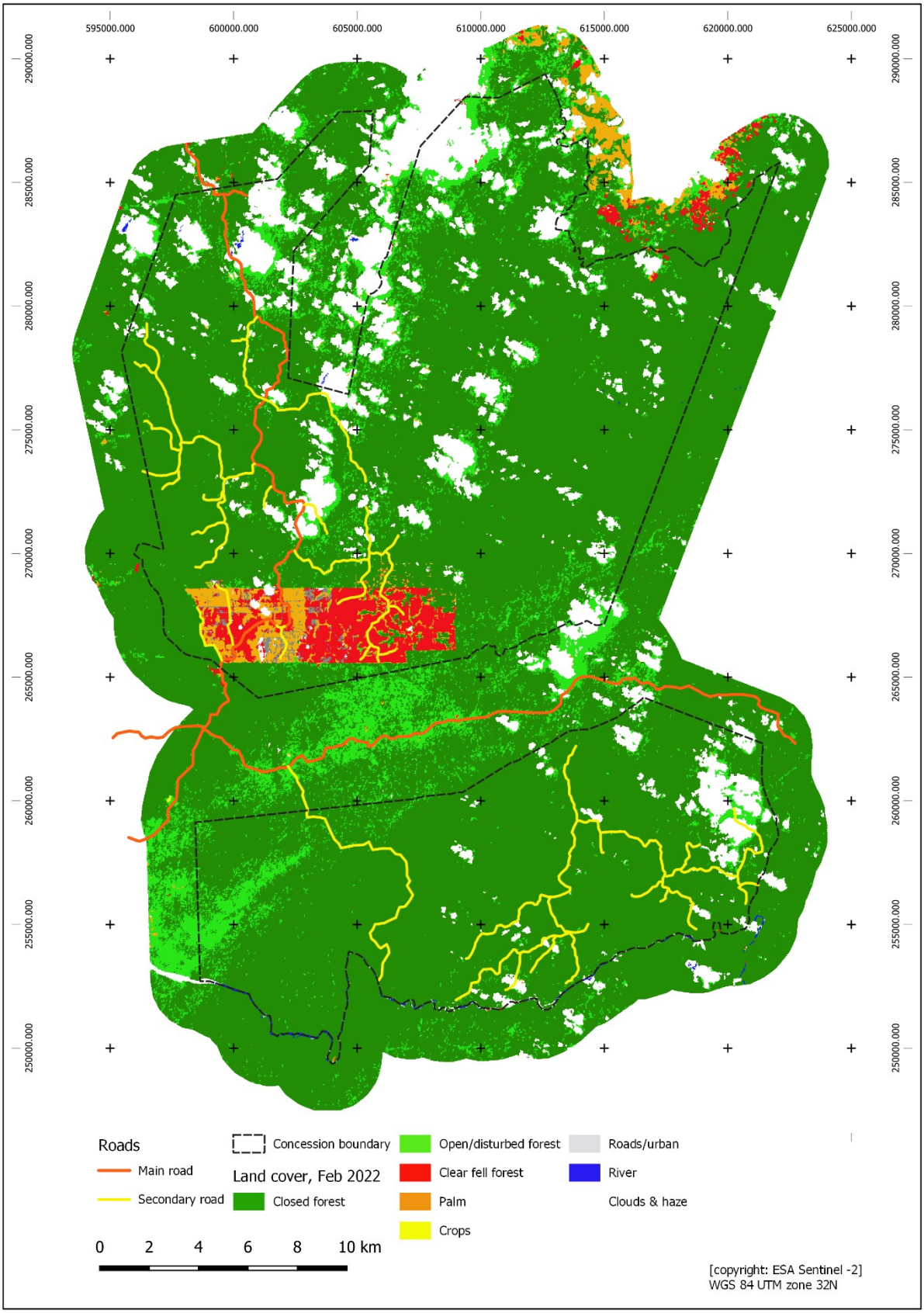

Figure 4. Land cover, February 2022

Land cover	Ha	Percent
Dense forest	47441.53	78.87
Open/disturbed forest	3430.58	5.70
Clear fell forest	1768.49	2.94
Palm	959.11	1.59
Crops	2.54	0.00
Developed: roads/built-up	229.09	0.38
River	108.2	0.18
Clouds	6214.14	10.33
Total	60153.68	99.99

Table 4. Land cover area, February 2022

Only a few ground-control points (GCPs) were collected during a short field survey visit to the concession in July 2022 (APPENDIX A). Many of these transects covered the same location, collected as part of a training exercise with participants attending the 'Forest Mapping & Monitoring' training course. Google Earth and ESRI satellite imagery, therefore, were also used as ground reference data to assign a land cover label to each class. The presence of cloud and haze, and the wide range of reflectance values associated with forest cover containing many species, combined with the complex mosaic of land cover types, compromised the accuracy of the land cover classification at both dates (April 2016 and February 2022). In particular, accurate discrimination between Dense (closed canopy) forest and Open/disturbed forest would require more extensive field survey. Roads and rivers were digitised visually from a combination of Google Earth imagery and ESRI global satellite imagery, although alignment and coverage are only approximate due to significant areas of cloud cover.

Mapping change: deforestation

The Sentinel -2 image acquired in April 2016 (Figure 1), shows clear evidence of forest clearance, mostly outside the present concession boundary. Only a limited area of clearance is visible within the concession boundary. Info Congo (https://infocongo.org/en/about/) analysed clearance for the Camvert plantation and stated that"Info Congo analysed PLANET satellite imagery before and after the attribution of the tender regarding the sale by auction of timber, signed by the Minister of Forestry and Wildlife of Cameroon for a 2500 hectare plot of the declassified portion of FMU (Forest Management Unit) 09 025. In December 2019, satellite imagery from PLANET showed that this 2500 hectare plot was still covered by forest." Info Congo

finds that by December 2021 '1,850 hectares of forest had already been cleared in Campo for the creation of the Camvert industrial oil palm plantation.'[3]

Several organisations and media reported that clearing of forest areas had already started in September 2019 for the nursery[4], at least May 2020 for the plantation[5] and planting started on September 12, 2020.[6] However, satellite images did not pick up on the deforestation in time: Landsat scenes between Jan 2019 and Dec 2020 were not cloud free and did not pick up the first stage of Camvert clearance. Sentinel-2 did not spot the clearance until December 2020. RADD alerts on Global Forest Watch show persistent deforestation since 11 October 2020 (starting time of the integration of the alerts into GFW).

Since the acquisition of a relatively cloud-free Sentinel -2 image in February 2022, further areas of forest have been cleared. Neither cloud-free Landsat nor Sentinel imagery was available to update the mapping beyond February 2022 so Synthetic Aperture Radar (SAR) imagery was used from the Sentinel -1 satellite. The European Space Agency (ESA) SNAP (SentiNel Applications Platform; https://www.esa.int/ESA_Multimedia/Images/2020/04/SNAP_desktop) software was used to process the SAR data, including radiometric calibration, terrain correction and speckle filtering. Figure 5 shows an extract of this image, centred on the area of clearance to show forest clearance to September 2022 and beyond, to November 2022 (interpreted visually from a composite of the multi-polarised SAR image).

The results show that the area of the concession cleared by September 2022 was 2876 ha (4.8 percent of the total area of the concession), but by Nov 2022 the area of clearance had doubled to 4978 ha (8.3 percent).

[3]https://infocongo.org/en/an-opaque-agro-industry-razes-cameroons-forests-with-impunity/

[4]https://www.greenpeace.org/africa/en/press/50150/camvert-a-recurring-nightmare/, https://news.mongabay.com/2019/12/ngos-reject-new-oil-palm-plantation-in-southern-cameroon/, https://www.forestpeoples.org/sites/default/files/documents/EWUAP%20submission%20UNCERD%20Re%20Cameroon%20CamVert%20October%202020_final.pdf

[5]https://infocongo.org/en/an-opaque-agro-industry-razes-cameroons-forests-with-impunity/

[6]https://www.greenpeace.org/africa/en/press/12227/illegal-giant-palm-oil-plantation-flattening-indigenous-peoples-rainforest-and-threatening-endangered-wildlife-in-cameroon/

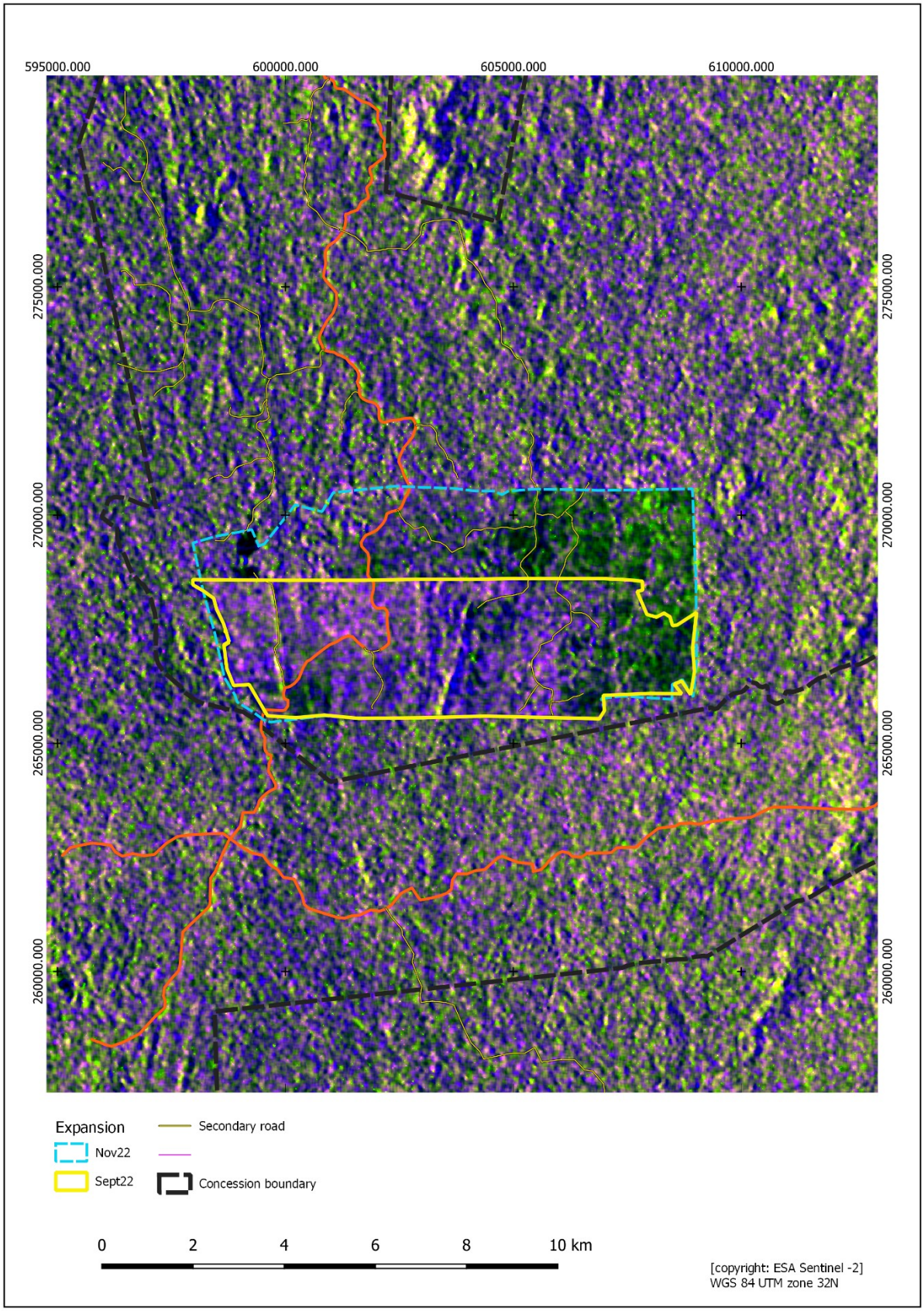

Figure 5. Sentinel -1 SAR composite image (VV, VH, VV/VH) for November 2022 showing expansion of forest clearance to November 2022.

High Conservation Value (HCV) Forest

The High Carbon Stock Approach (HCSA) [3] approach was used to identify HCV forest covering the concession and a 2km buffer zone. Dense and Open/disturbed forest was treated as a single land cover class, given the difficulty to discriminate accurately between the two types. Each 'patch' of forest was buffered internally (100m) to account for edge effects and identify the core area of each patch. The area of each buffered patch was calculated, and each patch was assigned to one of the following categories:

- Patches >100ha were designated as *High Priority Patches* (HPPs) (Figure 6).
- Patches between 10ha – 100ha as *Medium Priority Patches* (MPPs).
- Patches < 10ha as *Low Priority Patches* (LPPs)[7].

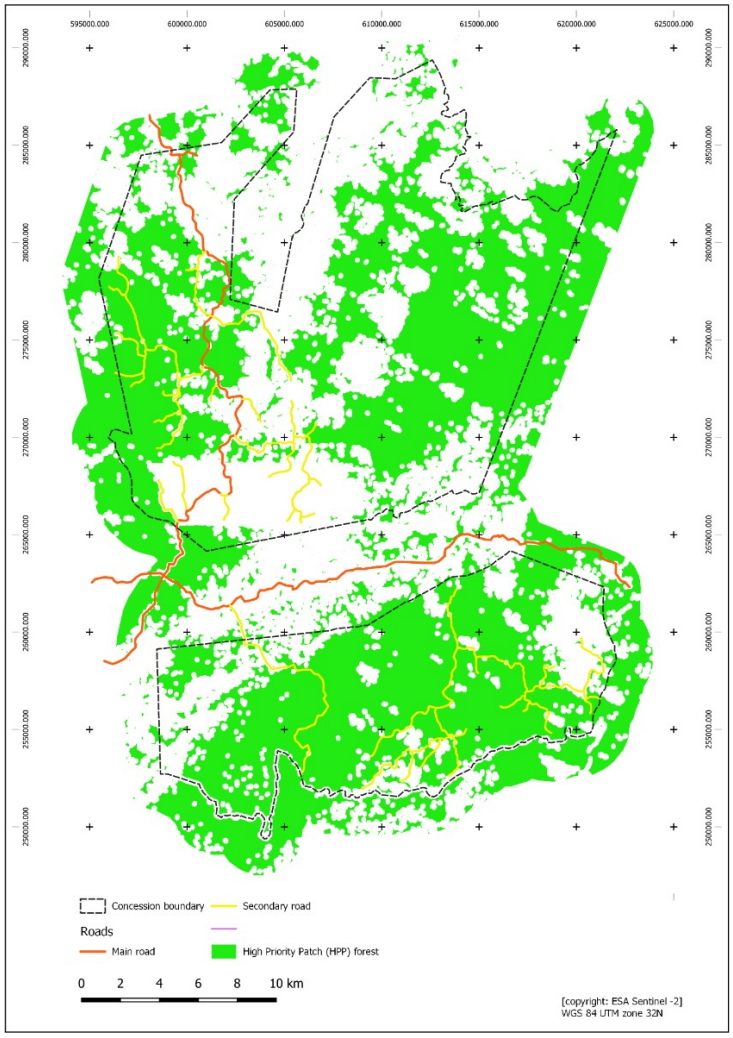

Figure 6. HPP forest

Where LPPs (<10ha core area) or MPPs (10 – 100ha core area) were either *connected to* (within 200m) or provided *connectivity between* (within 200m) a mapped HPP, the patch was 'retained' for further analysis. There are a range of options available for these important 'connected' patches. The following are possible options, rather than recommendations, as part of a longer-term land use plan for the region:

[7] Patches < 1 ha area were mostly the result of classification error and removed.

1. MPPs connected to HPPs, could be recategorized as HPP. Otherwise, unconnected MPPs could be protected only when within a riparian zone or as part of a linking wildlife corridor.
2. LPPs could be labelled as 'indicative conservation'. For example, where an LPP is located close to a water course, it could be retained in 'exchange' for the loss of other LPP cleared for planting elsewhere in the concession.

In fact, given the high percent of continuous Dense Forest within the concession, the majority of the concession is designated as HPP (Table 5; Figure 6). By contrast, the area of LPP and MPP forest is low (Figure 7), although this situation will change as more forest is cleared and fragmented as the concession is planted.

Patch type	Ha	Percent
HPP	32346.8	53.74383
MPP	688.88	1.144566
LPP	1149.76	1.910313

Table 5. Area (ha & percent) of different HCV patch types within the Camvert concession

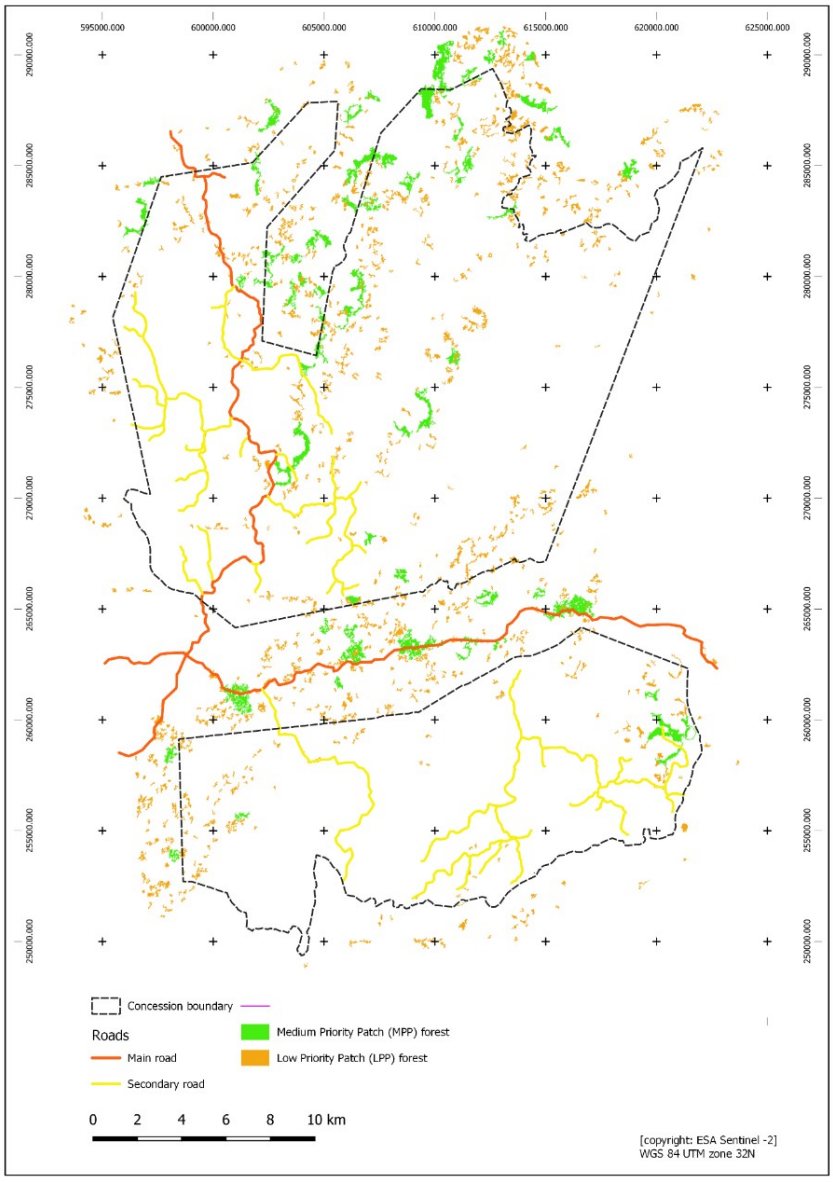

Figure 7. LPP & MPP forest

High Carbon Stock Forest

High Carbon Stock Forest (HCS) forest was mapped from existing global datasets. There are several datasets available globally, but one commonly used source is from The Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) (https://daac.ornl.gov/get_data/) [4]. The data (2010 only) provide maps of both aboveground and belowground biomass (Mg/C/ha) at a 300m spatial resolution. In this case only the aboveground dataset was used to give an estimate for the area of remaining Dense forest within the concession. The mean is 1090 Mg/C/ha (1 SD ±226), well above the threshold used by the Round Table on Sustainable Palm Oil (RSPO) [5] of 35 Mg/C/ha.

Summary

1. Map the location and extent of deforestation. A combination of Sentinel – 2 (optical) and Sentinel – 1 (SAR) satellite imagery was used to map the area of clearance within the Camvert concession at

two dates, 2016 and 2022. There was very little evidence of forest clearance within the concession in 2016 but, by November 2022, over 8 percent of the concession had been cleared for planting.

- Track the timing of each stage of deforestation. SAR data proved useful to map the timing of forest clearance. Whilst only 3 dates (April 2016, September 2022 & November 2022) were analysed in this report, the analysis has demonstrated the potential of SAR for this type of forest monitoring
- Map the quality of High Carbon Stock (HCS) and High Conservation Value (HCV) forest within the concession. More than 50 percent of the concession was classified as High Priority Patches (HPP) and the mean aboveground biomass was relatively high across the concession with a mean value of 1090 Mg/C/ha.

Recommendations & Further work

1. **Land cover classification.** Whilst the land cover classification was based on the best available data, the high level of cloud cover and few ground control points (GCPs) surveyed in the field for both calibration and validation of the classification, meant that the accuracy of the land cover mapping cannot be assured. It is recommended that additional GCPs are field surveyed.
2. **HCV & HCS forest.** More work is required to identify areas of HCV forest, specifically the integration of existing records, where available, on species diversity and abundance. More accurate global datasets of biomass are increasingly available and these should be used to update maps of above and belowground biomass for the concession.
3. **SAR imagery.** The SAR data from Sentinel -1 proved useful for monitoring change (see also RADD forest disturbance alert from Wageningen University; https://nrtwur.users.earthengine.app/view/raddalert). However, there is also the opportunity to explore the potential benefit of the integration of SAR and optical imagery for improved land cover classification [1].

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[5] Golden Agri-Resources and SMART in collaboration with The Forest Trust and Greenpeace. *High Carbon Stock Forest Study Report: Defining and identifying high carbon stock forest areas for possible conservation*. June 2012.

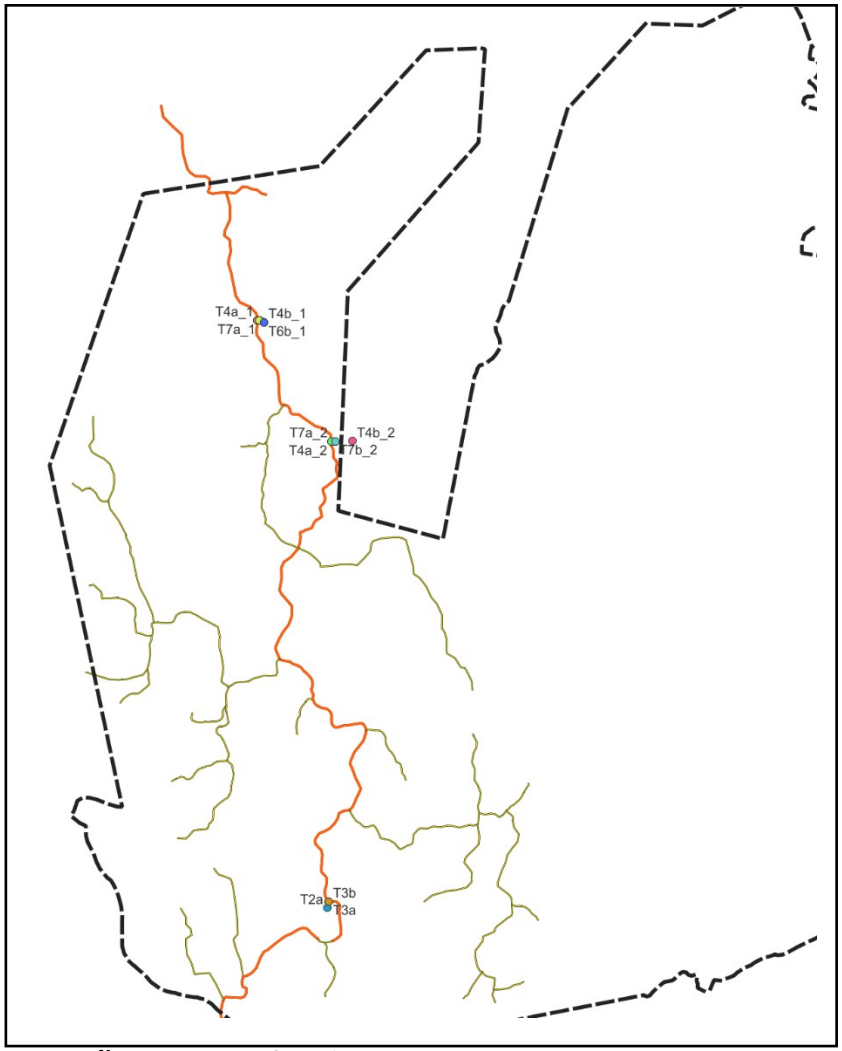
[6] Suggitt, A. J., Yeong, K. L., Lindhe, A., Agama, A., Hamer, K. C., Reynolds, G., Hill, J. K., & Lucey, J. M. (2021). Testing the effectiveness of the forest integrity assessment: A field-based tool for estimating the condition of tropical forest. *Ecol Solut Evidence*, 2: e12067. https://doi.org/10.1002/2688-8319.12067

APPENDIX A

Field survey data collected using the Forest Integrity Assessment (FIA) method [6] during the training course, Forest Mapping & Monitoring (Aug 2022). The location of each of the transects is shown in the figure, below.

Transect	T1_1	T2_1	T2_2	T3_1	T4_1	T4_2	T5	T6_1	T6_2	T7_1	T7_2	T8_1	T8_2
STRUCTURE & COMPOSITION													
Naturally fallen tree >40cm	0	0	1	1	0	1	0	1	0	0	1	0	1
Naturally fallen tree >60cm	0	0	0	1	0	0	1	0	0	0	0	0	0
Several trees >10cm	1	1	1	1	0	1	1	1	1	1	1	1	1
Several trees >20cm	1	1	1	1	0	1	0	1	1	1	1	1	1
Tree >40cm	1	1	0	1	1	1	0	1	0	1	1	0	1
Several trees > 40cm	1	1	1	1	1	1	0	1	0	1	1	1	1
Tree > 60 cm	1	0	2	1	1	1	1	0	0	0	1	1	1
Several trees > 60cm	1	1	1	1	1	1	0	0	0	0	1	1	1
Tree >80 cm	1	0	0	1	1	0	1	0	1	1	1	1	1
Several trees >80cm	1	0	0	0	0	0	1	0	0	0	0	1	0
Climber >10cm	0	0	1	1	0	1	1	1	0	0	0	1	1
Tree with epiphytes	1	1	1	1	1	1	1	0	0	1	1	0	0
Several trees with epiphytes	1	0	1	1	0	0	1	0	0	0	0	0	0
Tree with nesting hole	0	0	0	0	0	0	0	0	0	1	0	0	0
High tree crown with thick branches	0	0	0	1	0	1	1	0	0	0	0	1	1
Trees with marks from mammal, bird or lizard	0	0	0	0	0	0	0	0	0	0	0	1	1
Tree species important for wildlife > 20cm	1	0	0	1	0	0	1	0	0	1	0	1	0
Several trees of species important for wildlife > 20cm	1	1	1	1	1	1	1	0	0	1	0	1	1
Standing dead tree or snag > 20cm	0	0	0	0	0	0	0	0	0	0	1	0	0
Termite mound	0	1	1	1	1	1	1	1	0	1	1	0	1

Commercially valuable timber tree species	1	1	1	1	1	1	0	0	0	0	0	1	1
Commercially valuable timber tree species >20cm	0	1	1	1	1	1	0	0	0	0	0	1	1
Tree species felled for local use	0	0	0	0	0	0	0	0	0	0	0	1	0
Tree species felled for local use >20cm	0	0	0	0	1	1	0	0	0	0	0	1	0
Average visibility in forest >10m	1	1	0	1	1	0	1	0	0	1	0	0	1
Average visibility in forest >20m	0	0	1	0	0	0	0	0	1	0	1	1	1
No sign of invasive plant or animal species	0	0	1	1	1	1	0	0	1	0	0	0	0
No sign of hunting, traps or snares	0	0	0	0	1	1	0	0	1	1	0	0	1
No sign of burning	1	0	0	1	1	1	1	1	1	1	0	1	1
No sign of logging	0	1	1	1	0	1	0	1	0	1	0	1	1
No sigh of clearing for agriculture	1	1	1	1	1	1	0	1	0	1	1	1	1
No sign of domestic grazing	1	1	1	1	0	1	0	1	11	1	1	1	1
No waste or litter	1	0	1	0	1	1	0	1	0	1	1	1	1
Distance to road, track or river > 1km	0	0	0	0	0	0	0	0	1	0	0	0	0
Distance to road, track or river >5km	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL SCORE	18	14	20	24	17	22	14	12	19	17	15	22	23



Appendix A. Transect locations