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Title: Use of high-resolution earth observation for large scale land acquisitions and land use change monitoring in Cameroon

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Introduction

Over the last decades, large areas in Africa have been experiencing extended land cover and land use changes triggered by population growth, changing diets and increased demand for agricultural products. For changes triggered by large scale land acquisitions (LSLA) in the agriculture and other sectors, low transparency, remoteness of the areas concerned and conflicts about tenure rights are often restricting the data available. This is particularly the case in Cameroon with its high levels of competition for land and looming land governance conflicts (Sonkoue and Nguiffo 2019).

Earth Observation (EO), thanks to the rapidly growing high-resolution data availability has emerged as one of the most promising means for mapping and monitoring land use change. More specifically, the recent Copernicus satellites Sentinel 1 (SAR) and Sentinel 2 (optical) satellites are providing a coverage of Africa every 5-days at a 10 m resolution. Such EO data can be used to develop practical tools to monitor land use changes, compliance of large-scale contractors and level of implementation of LSLA's. Earth observation can also be a baseline in research on the impact of improved land governance and security tenure system on land use change.

In the case of Cameroon, we are testing the potential of EO to support the monitoring of various land use change types with possible impact on local communities land rights. In the three cases explored, existing remote sensing product and recent S2 data are used to map the past and current situation. The potential of that information for informing land governance and conflict resolution is explored in the framework of the LandCam project¹. The LandCam project aims to help improve land governance in Cameroon by facilitating

¹ The LandCam project is funded by the European Union and implemented by a consortium of organisations led by the Centre for Environment and Development (CED), the Network to Fight Against Hunger (RELUF) and the International Institute for Environment and Development (IIED).

dialogue among actors at the local level in selected sites, and at the national level on options for the land law reform.

Study sites and EO data

The benefit of EO to monitor three land use change cases is explored in different areas of Cameroon:

- Mining activities in Eastern Cameroon
- Migration and Agriculture in Northern Cameroon
- Activities in and around agro-industrial plantations in Western Cameroon

A first study case focus on the impact of small-scale mining activities, mainly gold mining, on the forest cover. Those mining concessions, due to their small scale, are often not following the Environmental Impact Assessment (EIA) process. However, a cumulative impact of the different mining activities is to be expected. The study area is narrowed to three polygons (see polygons 1, 2 and 3 in Figure 1). Sites 1 (close to the city of Betare-Oya) and 2 (in the Meiganga department) are located in an environment dominated by savannah and gallery forests. Site 3 (in the Batouri department) includes some dense humid forest. The objective is to assess the extent and the increase of the mining activities in the last years.

A second case investigates how migration is causing agricultural intensification and encroachment in protected areas in the North of the country. Especially since the insurgency of Boko Haram started to affect Cameroon from 2012, an increase of migration from Nigeria has been observed causing some agricultural and population shifts. This also led to an increase of settlements close or inside protected areas. Three protected areas (Parc National de Faro, Parc National de Bouba Ndjida, Parc National de Bénoué) are in the vicinity of the study sites (see polygons 4 and 5 in Figure 1). The objective is to monitor the evolution of agricultural activities and to illustrate the impact of the installation of the people close or inside the Protected Areas, e.g. by the observation of the growth of villages.

Last, the implementation of rubber and oil palm plantations is assessed to detect possible anomalies as compared with the original contracts. In Cameroon, agro-industrial plantations are allocated to a specific owner and the information is registered by the government. There are four main plantations owners in the area of interest (see polygons 6 and 7 in Figure 1). The analysis is considering one example of each of those four companies: Sudcam, Biopalm, Socapalm and Hevecam. The general objective is to monitor the plantations activities and check for any expansion outside scope. A specific objective is to analyse the absence of implementation of the management plan in the Biopalm concession. A related objective is to report on community management and how the concessions were used beforehand by local people. Eventually, the analyses should feed the discussion on how concessions should be granted in the future.

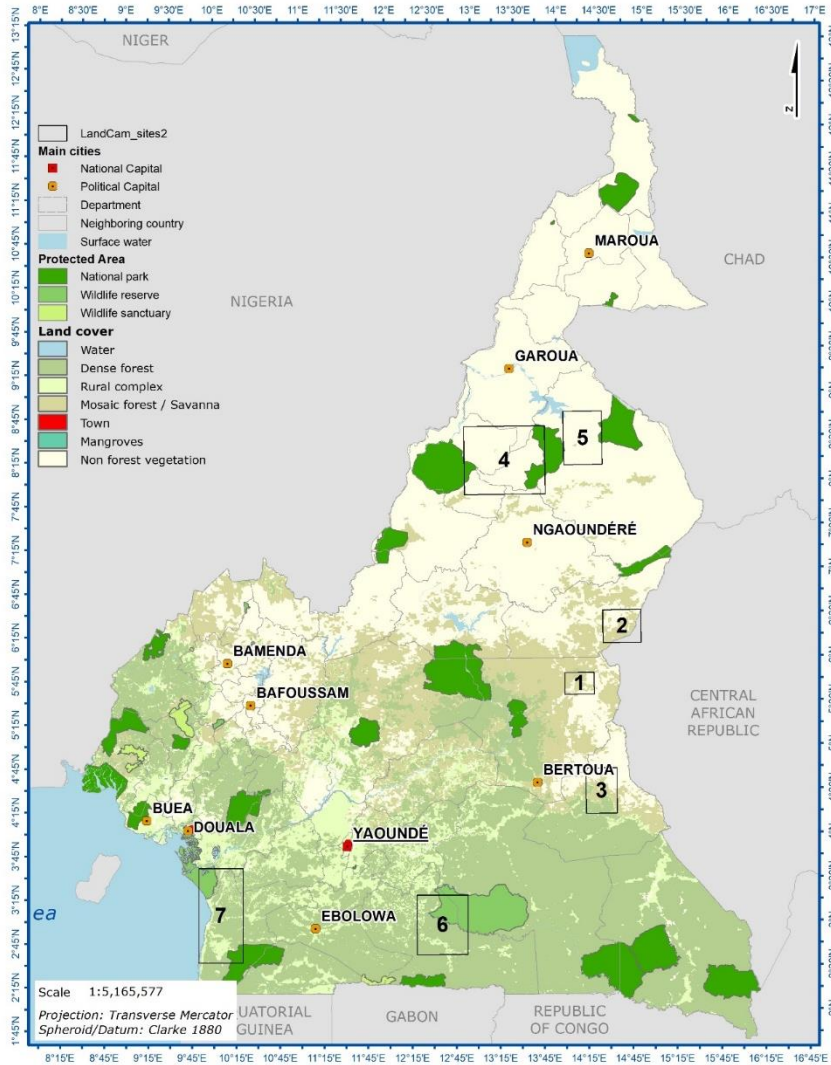


Figure 1: Location of the study sites in Cameroon

To produce meaningful maps of the land use change dynamics in the study sites, a combination of existing EO based products and recent satellite images is used.

To identify the change in the forest cover in the mining and agro-industrial areas, two existing product of tree cover loss are used. The first one is the Global forest change (GFC).

The second is the European Commission's Joint Research Centre (JRC) Roadless dataset². The GFC is the global dataset delivered by Hansen et al. (2013). Based on Landsat data, the product is available for the period 2000-2018 and gives a yearly information about new areas of tree cover loss. In addition, there is a binary layer informing about any regrowth identified during the period 2000-2012. To provide a full picture of the tree cover dynamic, the tree cover loss and gain information are combined with a layer representing the tree cover percentage in 2000. The JRC Roadless dataset from Vancutsem and Achard (2016) covers the period 1984-2018 and the tropical belt. The product gives, for any pixel, an information about the dynamic of tree cover change. The information is derived from any available single Landsat image. It is therefore very precise temporally. The tree cover loss or regrowth observations are classified in a number of classes informing the user about the timing and the duration of the disturbance. For the analysis, an added value is that the agro-industrial plantations are reported in specific classes of changes in the product. The two datasets are very similar as they are both derived from Landsat data and provide information at a resolution of 30 m. But they are produced with a different methodology and cover different periods.

To analyse the expansion of agricultural land in the North, the JRC Crop and Grassland masks are used. Those masks are two hybrid agricultural static maps at 250 m spatial resolution, one for cropland and another for grassland for the nominal year 2016 in Africa. We used it as an indicator of the agricultural land localization before 2016. For Cameroon, the cropland information is coming from the Copernicus Global Land Cover map (Smets et al. 2017). The grassland information is coming from the Congo Basin vegetation type map (Verhegghen et al. 2012).

Last, the multitemporal Global Human Settlement Layer (GHSL) built up grid is used to check the expansion of settlements close to the protected areas in the North. The grid contain a multitemporal information layer on built-up presence at four time periods: 1975-1990-2000-2014 . It is derived from Landsat data and has a resolution of 30 meter.

In addition to those products, S2 images from 2016 to 2019 are reviewed. For the mining and agri-industrial concessions, cloud-free images are selected at the beginning and end of each year. For the expansion of agricultural land, images falling at the beginning and during the growing season are selected. According to a review of NDVI profiles from different sensors, the growing season in that area is starting in May/June and is reaching a maximum in August/September. Images from later in the year present large burned areas, making the visual interpretation more complicated.

² The Roadless dataset is not publically available yet. We could access it in the framework of an institutional collaboration. The final product could present some modifications compared to the data presented here.

Nowadays, analysis of times series of EO images such as S2 is done on scientific cloud computing platforms. In this study, the Google Earth Engine (GEE) platform (Gorelick et al. 2017) was used, directly and through the ASAP (Anomaly Hotspots of Agricultural Production) High Resolution Viewer (Rembold et al. 2018). The ASAP is a platform for agricultural monitoring at field level based on high resolution EO data that does not require programming on the user's side. Through the interface, it is possible to retrieve high resolution imagery at a certain period of the year and to compare them with the same period in a previous year. It is as well possible to retrieve time series profiles.

Mining activities in Eastern Cameroon

In the three sites of interest, extended areas of tree cover loss are observed in both the GFC and the JRC Roadless products. The tree cover loss is not only related to mining activities. Patches of tree cover losses corresponding to small-scale agriculture activities, probably shifting cultivation, are also identified. In addition, in the patch of dense moist forest present in site 3, some patterns of tree cover loss specific of selective logging activities are visible.

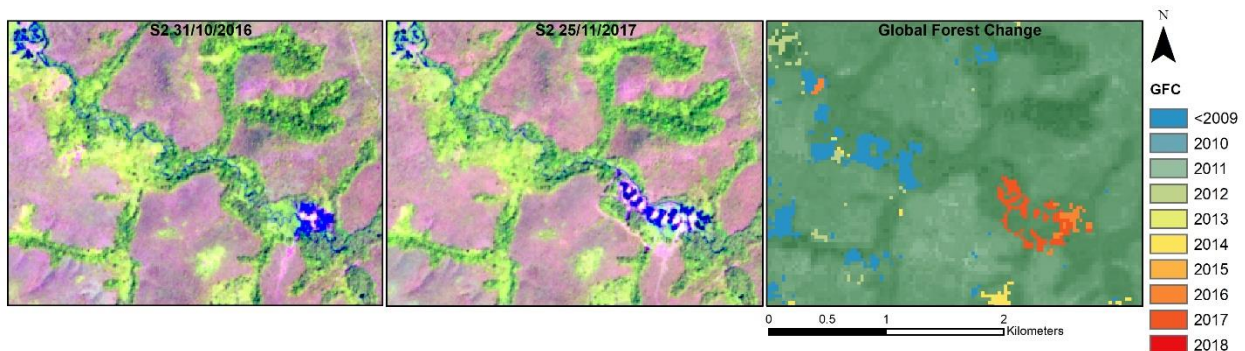


Figure 2 : Mining activity in a gallery forest. Sentinel 2 image for 31/10/2016 (left) and 25/11/2017 (right), (R: SWIR 1, G: NIR, B: RED). Tree cover loss from the Global Forest Change product.

The mining activities are recognizable as occurring along riverbeds. In the three sites, mining activities are spreading across the main river and their tributaries. A typical example is visible in Figure 2. In S2 data, mining activities are easily spotted as a series of pools of water along an existing river. In October 2016, the mining activity has already started. One year later, a series of small pools is visible along the river.

In the three sites, mining activities started in the year 2013 or 2014 and have increased each year since then. The activities related to agriculture were already observed beforehand. They are not restricted to riverbed areas.

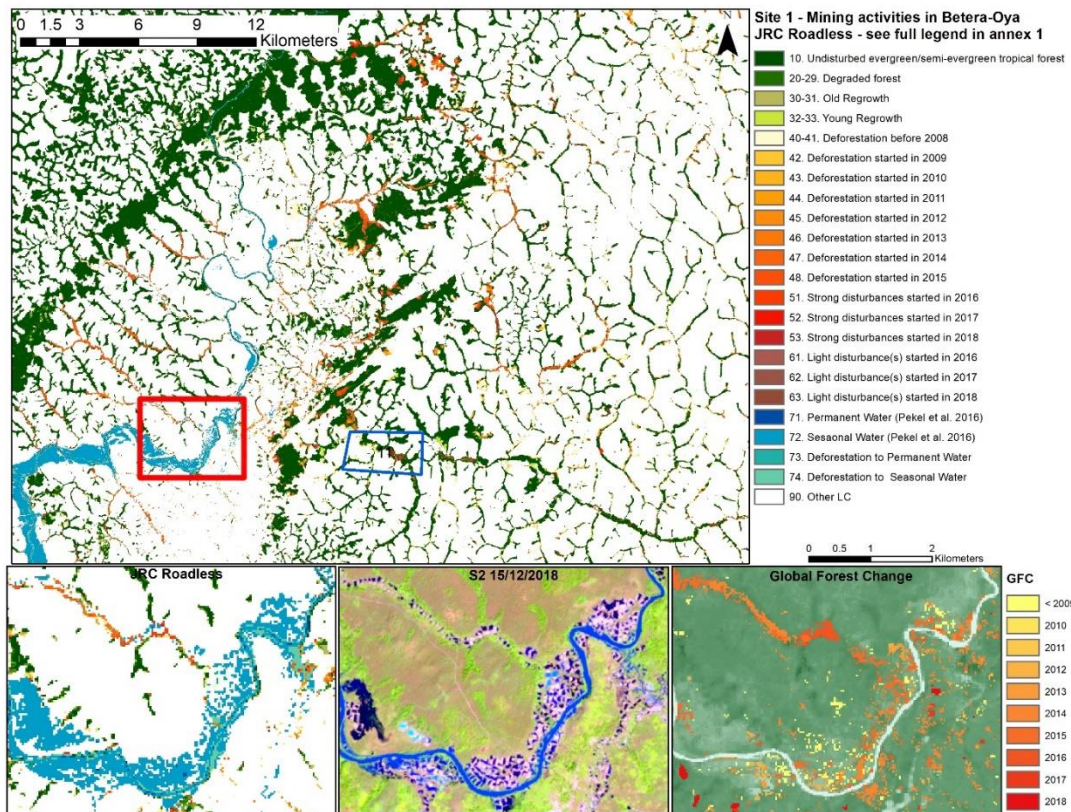


Figure 3 : Forest cover disturbances in the site 1 – Betare-Oya illustrated with the JRC Roadless product. Zoom: right- JRC Roadless, center - Sentinel 2 image (R: SWIR 1, G: NIR, B: RED), left – Global forest change

The intensity of mining activities is the highest in site 1, with a high concentration of mining sites along the Lom river (Figure 3). The site 2 presents extended mining activities in the centre of the area. The area with most tree cover loss, however, is located close to the border of the Republic of Congo and seems to be driven by agriculture activities. The site 3 only present limited mining activities. However, the mining activities are occurring along a river that is located at the fringe of the dense forest and not in a gallery forest or the savannah as for site 1 and 2. Further expansion of the mining activities could have a huge impact on the forest cover.

Agriculture and migration in Northern Cameroon

In the area delimited by polygon 4 and 5, we look for hotspot of land use changes (new cropland, new settlements) in the S2 images. Several areas already converted to cropland according to the JRC Crop mask expanded during the period 2016-2019. Those areas are delimited in Figure 4 by the blue polygons. In those remote areas, only small-scale farming type of agriculture is observed. No intensive (irrigated) infrastructure are visible. Figure 5

illustrates a cropland area that have been expanding rapidly from 2016 to 2019. Especially images from the beginning of the growing season, when crops are still bare soil, is illustrating clearly the increase in cropland areas.

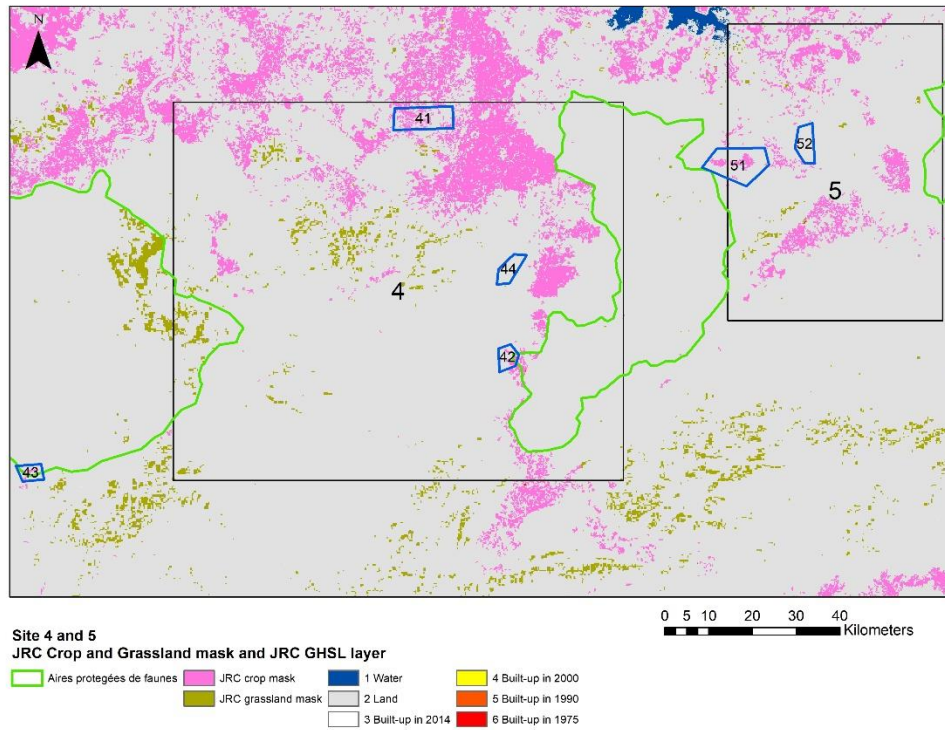


Figure 4 : Crop, Grassland and settlements in the North of Cameroon (polygon 4 and 5 of Figure 1)

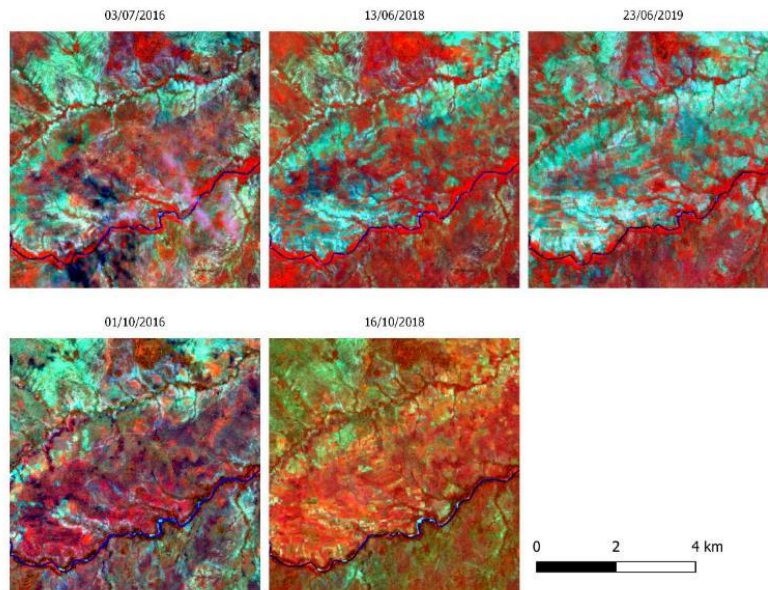


Figure 5 : Expansion of cropland areas as observed in S2 data for polygon 41 of Figure 4 (R: NIR, G: SWIR1, B: RED)

The national park boundaries seem to be respected in the area. Only one encroachment is clearly visible in the PN Bénoué (situated at the East of polygon 4). However, this could be a discrepancy in the delimitation of the shapefile downloaded³. Looking visually at the S2 data, no other encroachments zones (at least large ones) were identified. However, a site (polygon 51 in Figure 4) shows some cropland area expansion close to the North East border of the Bénoué National Park. As illustrated in Figure 6, the crops are expanding along a road. It is probably a place that is important to monitor due to its vicinity of the protected area.

Regarding new or expansion of existing settlements, unfortunately, the information of the JRC GHSL layer is not detailed enough to pick small settlements that would relate to migration. Only bigger urban areas are captured in Cameroon.

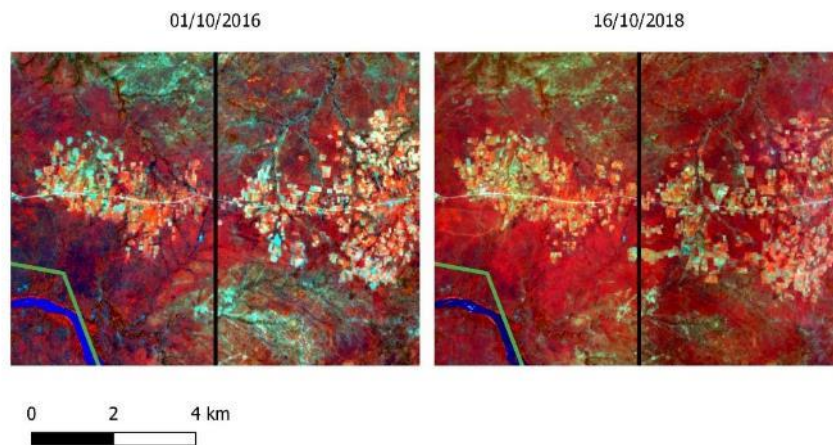


Figure 6 : Expansion of cropland areas as observed in S2 data for polygon 51 (R: NIR, G: SWIR1, B: RED)

Activities in and around agro-industrial plantations in Western Cameroon

We analysed the dynamic inside and close to the border of the four plantations for the 10 years period 2009-2018. We found the Roadless product and the GFC to be complementary. The analysis highlighted that the management activity is important in SudCam, Socapalm and Hevecam while it confirmed that the Bioplam present none or very little implementation (Figure 7). Outside the boundaries of the concessions, the four sites all present an important activity in term of forest disturbances. However, from the existing dataset of tree cover loss and the S2 images, it is difficult to determine the drivers of the tree cover disturbances observed outside the boundaries of the plantations. Very High Resolution (VHR) images and field knowledge would be needed to go further in the analysis.

³ Downloaded in May 2019 from <https://cmr.forest-atlas.org/?l=fr>

Inside the Biopalm concession, the only activity visible is located in the western and northeastern borders. According to the GFC map, the tree cover loss took place in the period 2015-2017. The area of loss seems quite extended for being encroachment by local community. It might be the start of some exploitation activities. However, this would need to be further investigated. On the other hand, the direct surroundings of the Biopalm plantation is very active in term of forest disturbances. Along the road, shifting cultivation and small-scale deforestation happened a lot in the last years.

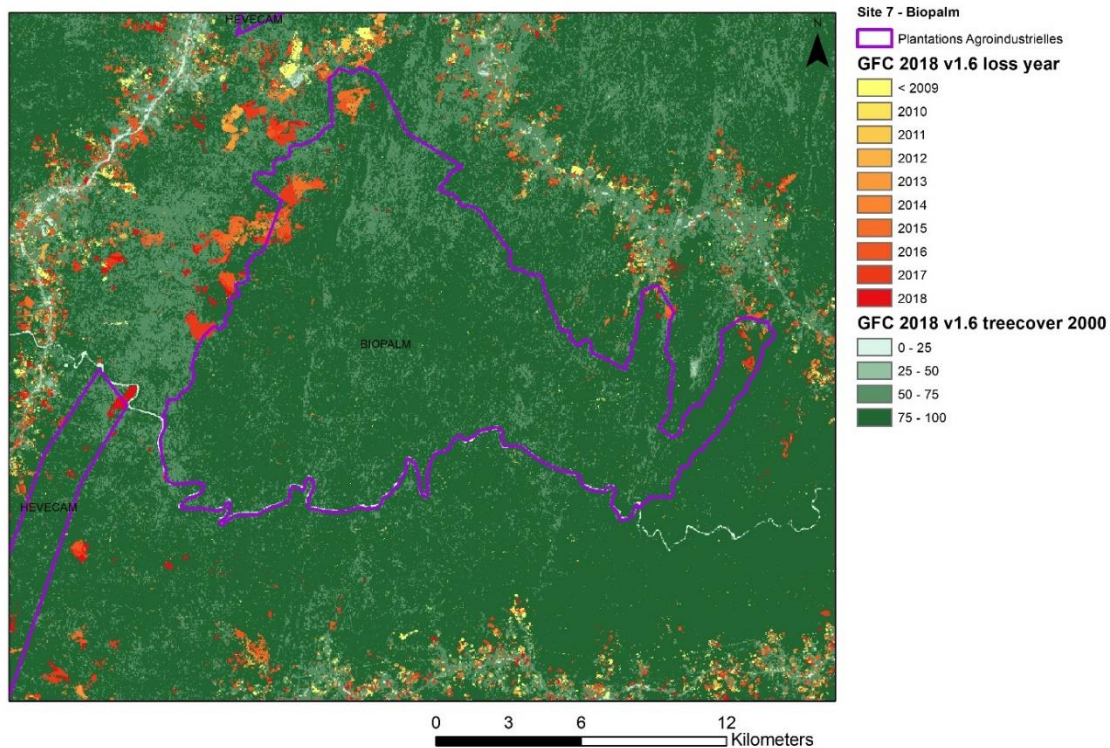


Figure 7 : Biopalm plantation – forest change dynamics illustrated with the Global Forest Change Product

The rubber plantation SudCam is a typical example of overlaps between the habitats of great apes, community lands and agro-industry interest as investigated by Sonkoue and Nguiffo (2019). The Dja Natural reserve is located in the immediate vicinity of the plantation. From the review of the tree cover loss products, the forest disturbance dynamic is quite important, both outside and inside the plantation. Along the roads, we observed small-scale disturbances linked to shifting cultivation activities. In the North West, polygons 61 and 62 are highlighting two patches of deforestation that present a dynamic and a pattern that would need more investigation (Figure 8). In the North of the polygon, a new dam is visible (flooded in 2017-2018). In the South, traces of old logging activities are visible (polygon 63).

Inside the boundaries of the plantation, the northern part of the plantation has been cleared in the period 2012-2015 and trees have been planted in the centre of that area (light green in Figure 8).

The southern part has been more recently cut and put under exploitation. A first part has been cut in 2017 while the very last part has been cut in 2018 (see zoom in Figure 8). It is interesting to note that before the cut, selective logging activities were taking place (S2 of February 2017 – zoom of Figure 8). It is important to note that our analysis doesn't reveal any encroachments inside the protected area.

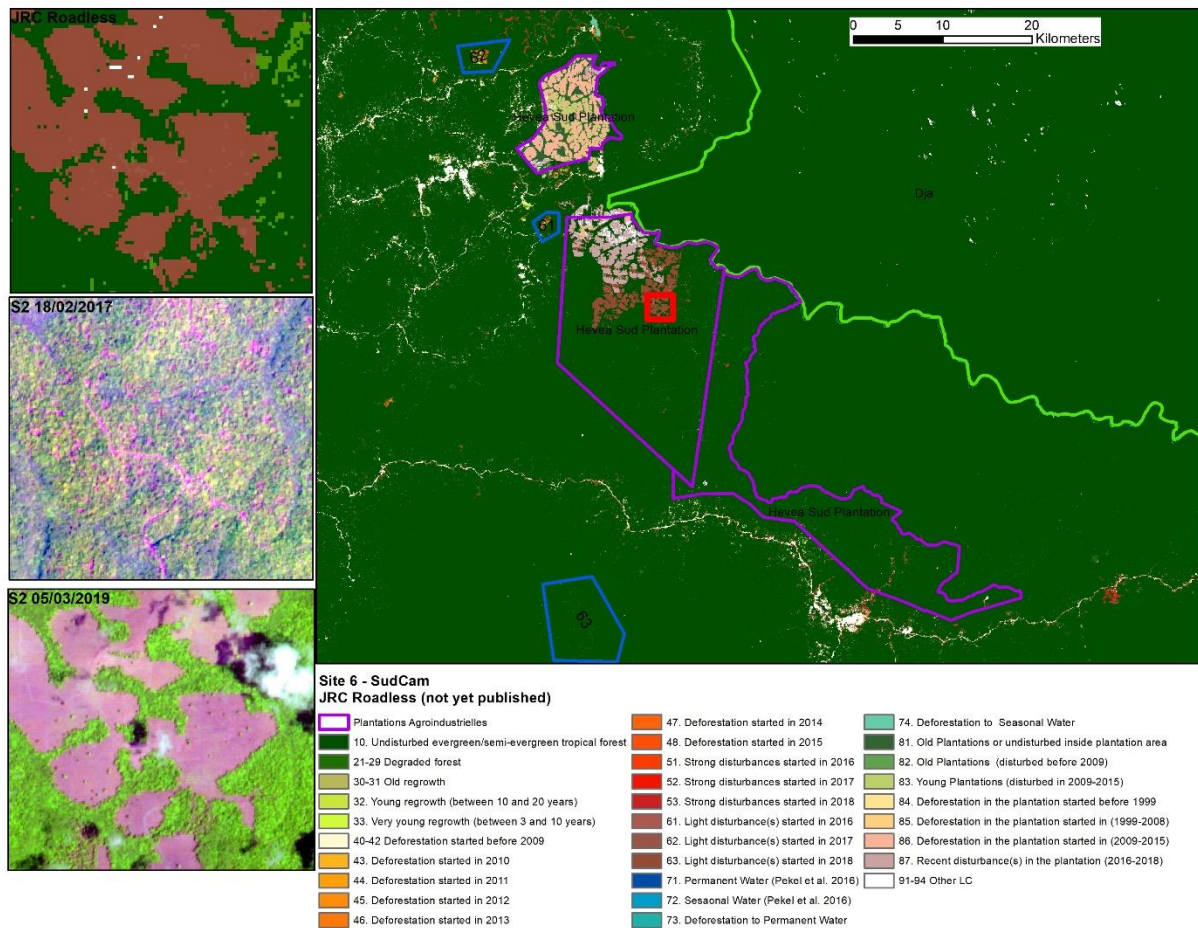


Figure 8 : SudCam plantation – forest change dynamics illustrated with the JRC Roadless map. Sentinel 2 images from 18/02/2017 and 05/03/2019 (R: SWIR 1, G: NIR, B: RED).

Conclusion and next steps

Existing remote sensing derived datasets of tree cover loss, extent of agricultural land and settlements have been used in combination with 10-m resolution recent satellite images. The combination of the two information provides a basic toolkit for identification of land use changes.

Our analysis confirmed an increase of small-scale mining activities in the eastern part of the country. The extent of the area affected by mining should be more precisely quantified to report on their common impact. And any future expansion of mining activities should be monitored, specifically in the dense forest.

Regarding migration and agricultural changes in the North, several area of agricultural land expansion in the last years have been identified. The area close to protected areas should receive particular attention in the future. For the monitoring of settlements however, another source of information should be explored (e.g. household surveys).

The tree cover loss products analysed provides valuable information to analyse the status of implementation of the agro-industrial concessions. However in order to report on community management (beforehand and actual), that information needs to be combined with community and field knowledge, e.g through participatory mapping exercise.

An added value of remote sensing data is its transparency. The products reviewed here are available publicly (or will be in the near future for the JRC Roadless) and the Copernicus satellite imageries are available to public. The different data can therefore be used by any institution or NGO as baseline or supporting documentation in land policy issues analysis or land laws reforms justification.

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