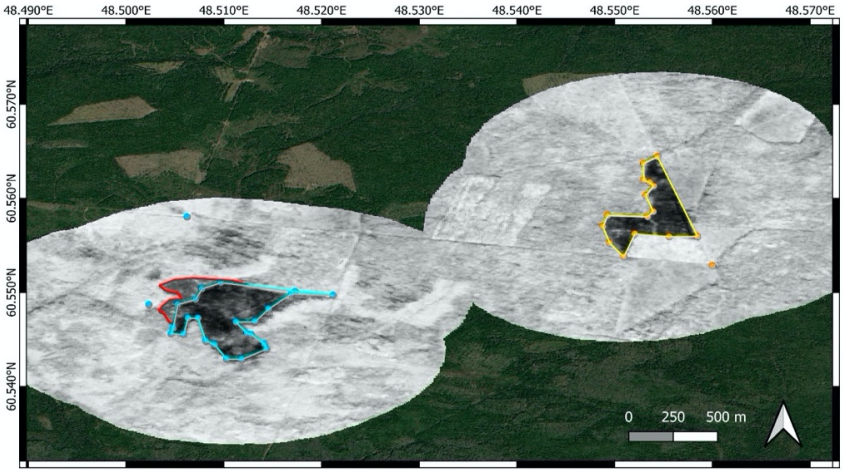

The use of satellite imagery in the context of due-diligence procedures to prevent illegal timber imports, deforestation and forest degradation.

Angelo Mariano[1], Michele Munafò[2], Chiara Cassandro[1], Alice Cavalli[3], Luca Congedo[2], Simonetta Della Rosa[1], Pasquale Dichicco[4], Chiara Giuliani[2]
[1] Consorzio Servizi Legno Sughero (Conlegno). angelo.mariano@conlegno.eu; chiara.cassandro@conlegno.eu; simonetta.dellarosa@conlegno.eu
[2] Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Roma. michele.munafo@isprambiente.it; luca.congedo@isprambiente.it; chiara.giuliani@isprambiente.it
[3] Università della Tuscia, Dipartimento per la Innovazione nei Sistemi Biologici, Agroalimentari e Forestali (DIBAF), Viterbo. alice.cavalli@studenti.unitus.it
[4] Laboratorio di Geomatica, Dipartimento di Scienze e Tecnologie Agrarie, Alimentari, Ambientali e Forestali (DAGRI), Università di Firenze, Firenze, Italy. pasquale.dichicco@unifi.it

Keywords: *due-diligence, legality, risk, deforestation, satellite images, wood, geolocation*

Abstract: *The role of due diligence (understood as the collection, verification and evaluation of the information necessary to ensure the legality and sustainability) is becoming increasingly relevant in EU legislation concerning agroforestry products to be placed on the market. The EU Timber Regulation (EUTR) obliges importers to carry out due diligence to accertain the legal origin of timber and timber products. The main requirement is to comply with the limits imposed by the legislation of the country of production and therefore to comply with the timber harvesting carried out on the basis of authorisations from the local authorities. Recently, increased interest in environmental protection has led the European Union to formulate the incoming deforestation-free products Regulation, which also requires due diligence for certain food products and introduces the obligation to geolocate production areas. This paper shows how the interpretation of satellite imagery is functional in the preparation of the due diligence required by the above-mentioned EU regulations and provides practical examples concerning wood from three high risk countries in EUTR terms.*

Introduction

In order to tackle forest crime and the marketing of illegally sourced timber, the European Union has adopted the FLEGT[1] Regulation (Forest Law Enforcement Governance and Trade of 2005, which is based on bilateral agreements between the EU and timber exporting countries) and EUTR[2] (European Union Timber Regulation of 2010, which obliges EU importers to conduct preliminary legality

checks on timber and timber products). Furthermore, the European institutions have recently approved the final text of the new deforestation-free products Regulation[3] with the intention of counteracting the placing on the market of soya, beef, cocoa, coffee, palm oil, rubber and wood products characterised by embedded deforestation, i.e. goods that have led to the destruction or degradation of forests in the countries of production (N.B.: *This paragraph has been updated from the original text published in October 2022 -* https://www.rivistasherwood.it/t/gestione/immagini-satellitari-contrasto-deforestazione-degrado-forestale.html *- due to the conclusion of the legislative process of the new Regulation*).

The EUTR and the new deforestation-free products Regulation - which, when fully implemented, will replace it - are based on the mandatory assessment of the specific risk of illegality or deforestation associated with the products to be placed on the market, and to this end, require importers and producers in the Member States to adopt appropriate due diligence procedures. The first step in doing so is to collect documents and any other information necessary to demonstrate the conformity of the supply that operators are about to undertake. Key information includes the description and quantity of the goods to be placed on the market, identification of the supplier and country of origin, indication of the species of origin, and proof of compliance with the laws in force in the area of production. Evidently, this is composite and heterogeneous information, the reliability of which must first be verified and then the adequacy and sufficiency of which must be determined for the purposes of the required ideal reconstruction of supply chains.

Tern years after the EUTR came into force, it is now clear that in some cases it is particularly difficult to effectively minimise the risk of illegality of products and to prove that the initial timber harvest (logging) is not only known and authorised, but also carried out in full compliance with locally applicable forest legislation. These difficulties particularly affect products with a highly articulated supply chain (paper, furniture, etc.) and countries characterised by high rates of corruption, low forest governance and unstable or undemocratic political regimes. This has led the European Commission to identify, among the possible risk mitigation measures, the consultation of satellite images of logging areas, attributing to this assessment an objective validity, far superior to that of the paper documentation commonly acquired by the operator in the initial phase of access to assessable information.

The use of satellite imagery to support due diligence, already recommended[4] (within the EUTR) for wood imports from Brazil, the Russian Federation and Ukraine, is more widely recognised by the deforestation-free products Regulation, which requires the mandatory geolocation of each forest,

agricultural or livestock territorial unit (plot) where the basic materials of the goods to be placed on the common market were produced.

In this paper, some concrete examples are given of the interpretation of satellite images aimed at assessing, for EUTR purposes, the regularity of timber harvests in Brazil, the Republic of Congo and the Russian Federation. With regard to the latter, it should be noted that the supplies under study (dating back to 2021) were outside the scope of the sanctions imposed in 2022 by the Council of the European Union, which prohibit the import of wood and wood products of Russian origin[5].

The choice of the four cases considered is detailed in the following section, but it should be noted that similar analyses could be conducted for any forest in the world, including those of the European Union and Italy. This is without prejudice to the fact that demonstrating the legality and complete conformity (in EUTR terms) of national or EU-origin timber - generally characterised by simple and well-documented supply chains - is much easier than what needs to be done for material imported from remote areas and, above all, penalised by insufficient or inadequate forestry controls. For the time being, the investigations described here are to be understood as possible risk mitigation measures to be undertaken as a proper complement to the due diligence procedures that precede the import of regulated products of non-EU origin.

Description of case studies

The cases analysed were selected according to various parameters including, first and foremost, the high risk commonly attributed to the above-mentioned countries by the most common international reference indicators (CPI[6], FIW[7], FSI[8], RLI[9], WRI[10]) and by the Legnok due diligence system of Conlegno[11] - Monitoring Organisation EUTR recognised by the European Commission in 2013[12]. Another selection criterion concerns the appropriateness of referring to fundamentally different forest types and related forms of sylvicultural treatment, in order to better explore the capabilities and limitations of the aforementioned interpretation techniques.

As a corollary, it is worth mentioning that the Russian Federation is the world leader in terms of forestry resources[13] (20% of the global total) and timber exports[14] and that, although imports (Italian and EU) of tropical wood are on average decreasing[15], Brazil (the second largest country in the world in terms of forestry extension - with 12% of the global total - and an important reality in terms of arboriculture[16]) remains among the most interesting trade partners for the EU. Furthermore, these two large countries are the subject of assiduous attention by environmental investigation NGOs, which frequently publish alarming reports[17,18,19] focusing on their poor forest governance and the high

incidence of destructive phenomena. Specifically, it can be summarised that Russia's forests are endangered by massive illegal felling aimed at mobilising large volumes of wood for export, while Brazil's forests are endangered mainly by continuous deforestation aimed at creating new areas for industrial agriculture and cattle breeding. Lastly, Congo has been considered for its belonging to the African continent (a priority in terms of nature conservation), due to the high deforestation rate characteristic of the country[20,21].

The following box contains a summary description of the forest felling authorising procedures in force in the three selected countries.

Russian Federation: all forests belong to the State and are regulated by the specific law of 2006[22,23]. Timber harvesting by private individuals is subject to a multi-year "forest lease" contract (varying from 10 to 49 years) or an annual "forest plot sale" contract, to be stipulated with the relevant public administration. Every year, the contract holder sends a 'forest declaration' to the relevant authority, indicating areas, volumes and wood species to be used. In 2015, the electronic system 'LESEGAIS'[24] was set up to record the quantity and type of timber harvested in the forest and subsequently traded. Prior to EU sanctions, the system was freely accessible to EUTR operators and provided useful information for due diligence.

Brazil: the 2012 Forestry Code[25, 26, 27] stipulates that the felling of native wood species must be part of 'sustainable forest management plans' duly compiled by the forestry company concerned and approved by the competent public administration of the federated state. The company is also obliged to submit an annual harvest operational plan which, if accepted, is followed by the final authorisation defining the permitted harvest in terms of species and volume.
Since 2011, permits and timber transport documents have been recorded by an electronic system[28] that is continuously updated.

Congo: Law No 33-2020 of 8 July 2020[29,30] regulates the forestry sector and sets the rules for the harvesting and trade of forest products. The State defines the management and conservation policies for public forests, which are the responsibility of the Ministère de l'Economie Forestière - MEF[31]. In the country there are 48 management units (Unitès Forestières d'Aménagement - UFA) with different forestry designations: production, protection, conservation or functional restoration. The State grants timber harvesting rights to private organisations (national or international) that win the relevant tenders. The competent ministry, depending on the case, issues four different types of permits called: Industrial Transformation Convention (CTI), Development and Transformation Convention (CAT), Plantation Cutting Permit (PCBP) and Special Permits (PS).

Materials and methods

The location of the timber harvests examined derives from the analysis of the cutting permits forming part of the documentation collected by the importers with the aim of setting up compulsory due

diligence, prior to the procurement of wood and wood derivatives. Below are the forestry characteristics and other information contained in the above documentation and considered for the purposes of this work.

Russian Federation - clear-cutting carried out in two different areas of a conifer-dominated coetaneous boreal forest undergoing artificial deferred regeneration. The vertices of the perimeter of the concession areas are indicated by a list of geographical coordinates.
Brazil - Selection cutting in uneven-aged tropical broadleaf forest. The authorisation shows the geographical coordinates of the point where the logs are concentrated and the overall image of the cutting area.
Congo - Selection cutting in tropical deciduous uneven-aged forest. The authorisation shows the coordinates of the vertices of the area covered by the concession.
Below is a summary table with all the information extracted from the documentation, useful for the due diligence analysis (Table 1.).

Table 1. Data extracted from documentation

Country	**Region**	**Cutting area (ha)**	**Cutting type**	**Authorised removal (m^3)**	**Concession start**	**Concession end**
Federazione Russa	Kirov	23	Clear	--	27/01/2021	31/12/2021
Federazione Russa	Kirov	32.2	Clear	--	02/02/2021	31/12/2021
Brasile	Matogrosso	2 976	Selection	38 343	10/06/2018	11/08/2019
Congo	Kabo	4 425	Selection	71 389	01/01/2018	31/12/2018

The methodology developed for the analysis is based on the use of freely accessible data and processing platforms.
The data concern the Sentinel-2 and Sentinel-1 missions developed by the European Space Agency (ESA) within the Copernicus programme for Earth monitoring[32].
The Sentinel-2 satellites through their optical sensor provide high spatial resolution (10 metres) multispectral images, at a global scale, of all land and coastal waters (and the entire Mediterranean Sea). Every point on the earth's surface is imaged, at the same viewing angle, every five days. The revisit time is reduced at higher latitudes by considering different acquisition angles. The Sentinel-1 satellites provide synthetic aperture radar (SAR) data, globally, with a time resolution of 6 days at equatorial latitudes (N.B*: as of 23 December 2021, Sentinel-1B is no longer providing data due to an unresolved anomaly; without the availability of this satellite, the temporal resolution of SAR data drops to 12 days*). SAR data is little affected by atmospheric conditions and allows the acquisition of

information in any meteorological situation. Geocoded Sentinel-1 GRD data with radar signal amplitude information were used for this study.

The platform on which the data processing methodology was developed is Google Earth Engine (GEE)[33]. This allows geospatial analyses to be carried out in the cloud, making a large amount of data, including those from the Sentinel missions, directly available, making it possible to optimise time and resources and to carry out multi-temporal analyses, over large and small areas, in a very short time. The results from cloud processing were then analysed on QGIS, an open source software that allows the visualisation and analysis of geospatial data.

The procedure followed for the analysis is summarised in Figure 1.. After extracting all the information necessary for the analysis from the documentation collected by the importers (Table 1.), the coordinates of the polygons of the concession areas are automatically extracted using optical character recognition methods. Automatic extraction is especially necessary in the presence of lists with hundreds of points. The next step involves the use of the cloud-based processing platform. The code developed on GEE, in the JavaScript language, allows the import of the polygons of the cut areas and on them the processing of vegetation indices (NDVI) or the selection of SAR images.

All processing is restricted to images with low cloudiness, trying to photograph the period immediately before the start of the cutting concession and the period after its expiry. Finally, the results are analysed using GIS software, into which the outputs of the automatic process are imported and interpreted to verify, through photo-interpretation, the correspondence with the cutting concession documents.

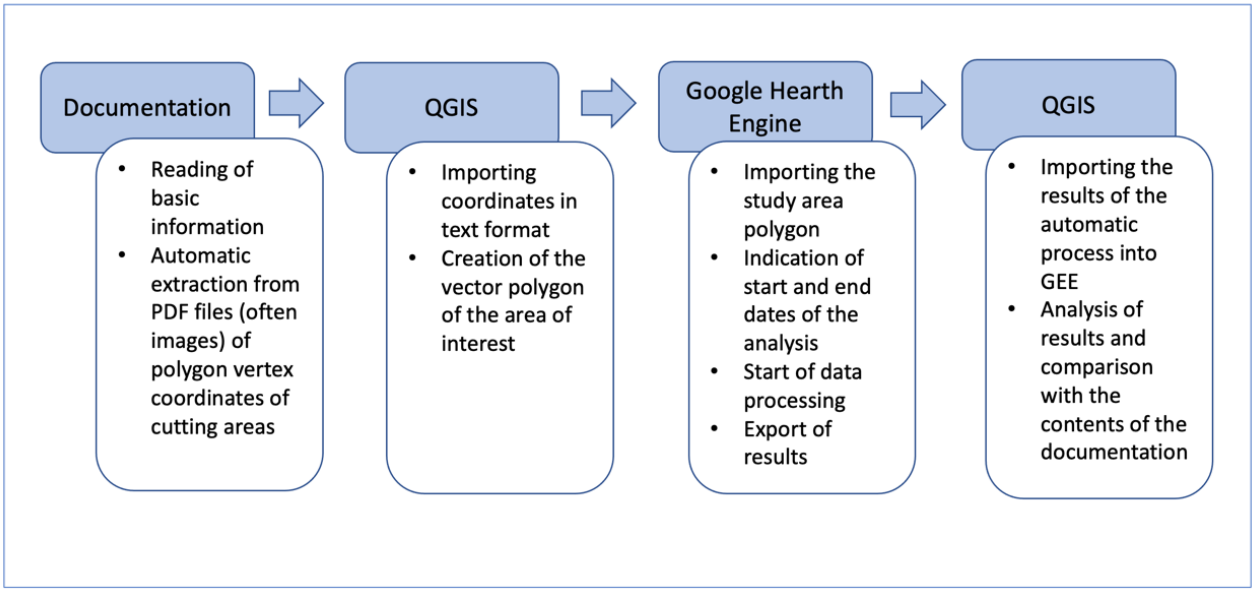

Figure 1. Outline of the procedure

Results and discussions

Russian Federation - The cuts covered two separate areas, the first of 23 hectares and the second of 32.2 hectares. Following the coordinates contained in the documentation, the construction of the polygons involved the exclusion of some points outside the cut areas. The first pair of coordinates of area 1 and the first two pairs of coordinates of area 2 were not taken into account as they corresponded to points taken erroneously, falling on roads and not connectable to the perimeter of the areas (Figure 2.). The area circumscribed by the polygons obtained coincides with that indicated in the concession. For both cutting areas the end of the concession was scheduled for 31 December 2021, the start for the first area (right in Figures 2. and 3.) was 27 January and for the second area (left in Figures 2. and 3.) 2 February 2021. Analysing the satellite images prior to the start dates shows the presence of uniform vegetation cover within the polygons indicated in the documentation. In Figure 2., in fact, high NDVI values can be seen within both polygons.

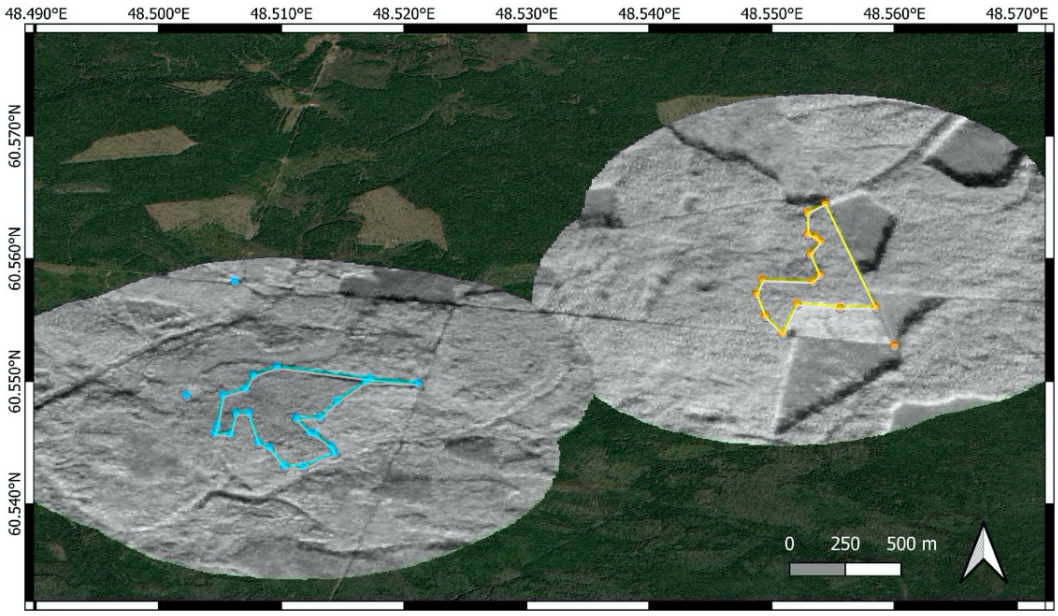

Figure 2. NDVI prior to the start of the concession. The yellow polygon, on the right in the image, represents area 1 of 23 hectares. The blue polygon, on the left in the image, represents area 2 of 32.2 hectares. Outside the polygons are the excluded points.

At the end of the concession, both areas were completely cut and characterised by very low NDVI values (Figure 3.).

By investigating other dates in between the concession period, it could be seen that the 23 hectares of the first area were cut and exfoliated in approximately two weeks from the start of the concession. On 19 February, the 32 hectares of the second plot were also completely cut.

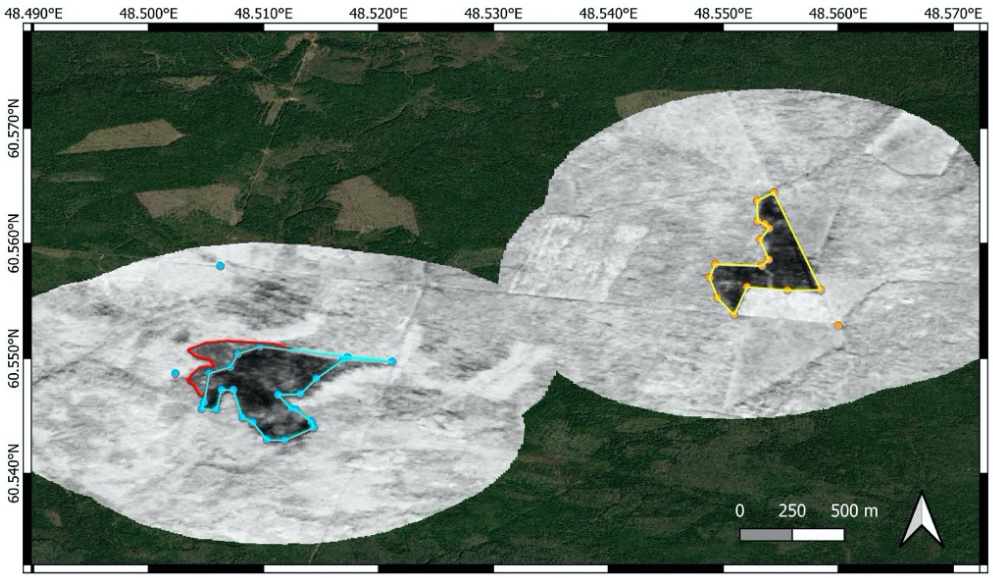

Figure 3. NDVI following the end of the cutting concession. Near zone 2, on the left in the image, a cutting area outside the concession polygon is circled in red.

As far as area 2 is concerned, the images relating to the end of the concession period revealed the presence of cuts that had taken place (most probably as a result of another authorisation) even beyond the limits indicated by the polygon, over an area of approximately 7.4 hectares (Figure 3). A thorough examination of the available documentation shows that the average timber production per hectare is approximately 218 cubic metres. Taking this value into account, it can be estimated that the mass removed from the area outside the concession is approximately 1 600 m^3 of timber.

The monitoring of area 1 was carried out using Sentinel-1 SAR GRD images in addition to optical images. This technique provided satisfactory results in terms of surveying clearcuts even in the presence of cloud cover, thus overcoming the problems associated with data from optical sensors that could limit monitoring activities especially in those areas that are seasonally covered by clouds for long periods. Observing Figure 4, one can see a decrease in the amplitude values of the radar signal after tree cutting.

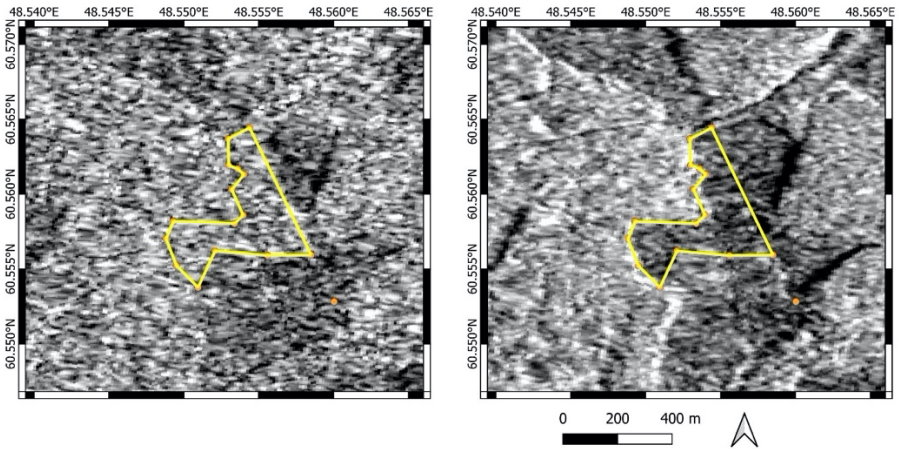

Figure 4. Sentinel-1 GRD images acquired before (left) and after (right) the concession period.

Brazil - The logging area in the Matogrosso region is approximately 3 000 hectares. The concession, which lasts more than a year, includes more than 38 000 cubic metres of removable timber. Although the coordinates of only one point adjoining the area were given, it was possible to trace the perimeter of the entire area by photo-interpreting an image attached to the documentation. The concession in question also specifies that only half of the area may be cut during the period indicated, while the remaining part will require a new concession (Figure 5).

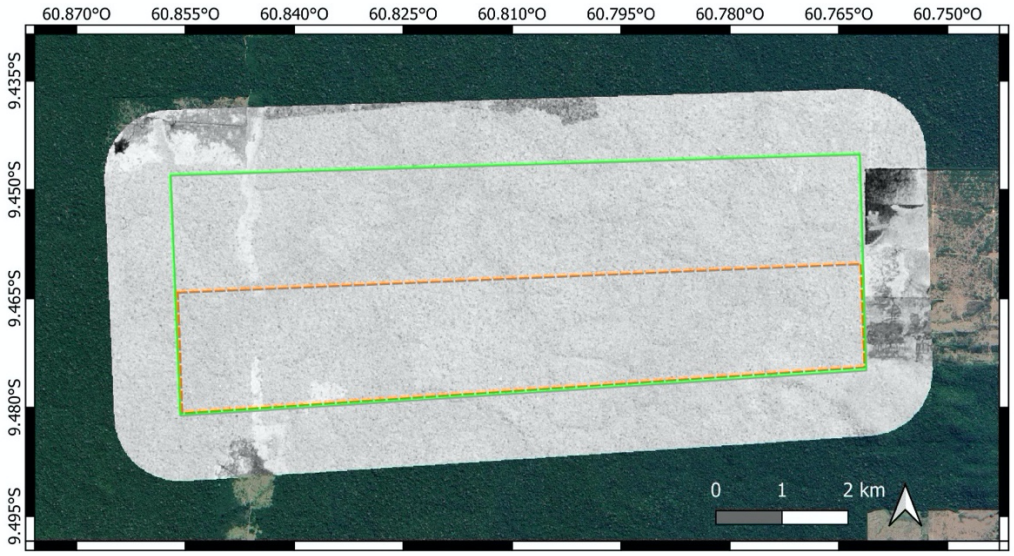

Figure 5. NDVI prior to the start of the concession. The entire area covered by the concession is identified in green. The dashed polygon identifies the half that can be cut immediately.

Comparing the NDVI, calculated before and after the concession period, one notices the appearance of darker patches, distributed in the lower half, which can be assimilated to a selective cut (Figure 6.). The darker patches are due to very low NDVI values that signify a lack of vegetation, in particular a main path appears to emerge from which lateral branches branch off.

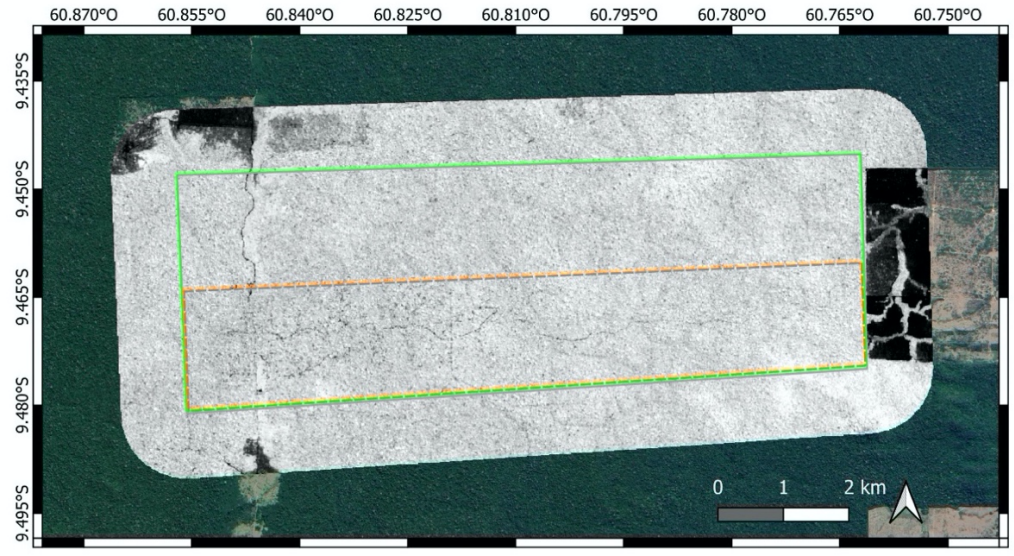

Figure 6. NDVI after the end of the cutting concession

Extending the analysis of the satellite images up to 2 months after the end of the concession, an increase in black spots with low NDVI can be seen towards the west in the middle of the cut area (Figure 7.). Since the due diligence information that the importer had access to was limited to the duration of the concession, it is not possible to determine whether the additional timber harvests carried out were the subject of a renewed authorisation or abusive cutting.

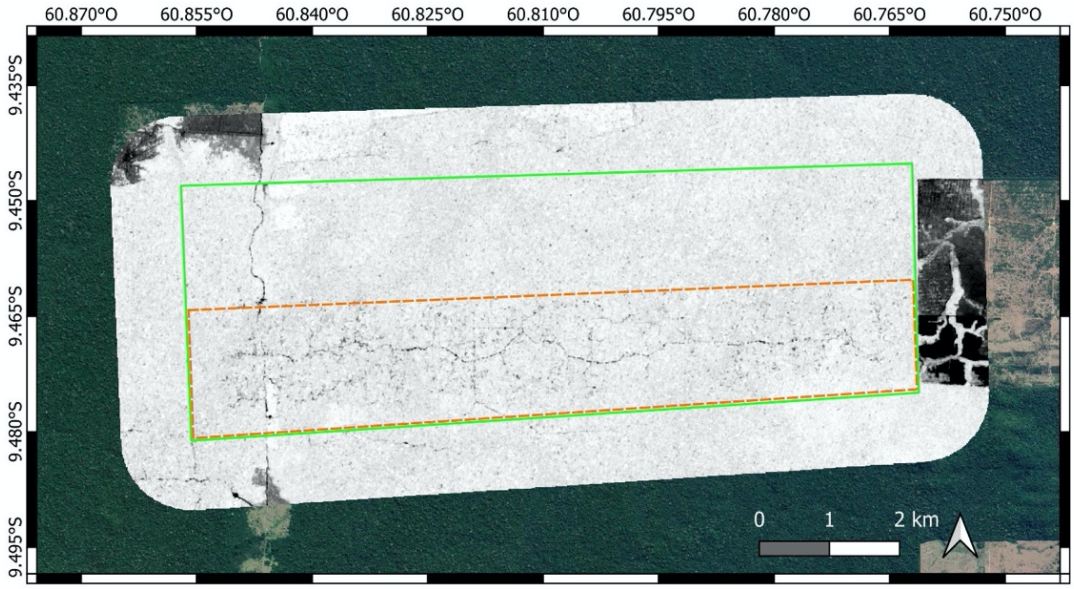

Figure 7. NDVI calculated 2 months after the end of the concession period.

Unlike clear cuts, selective cuts must comply with the limits of removable timber specified in the permit. In this case, the permit also indicates the volume allowed for each forest species. The estimation of the volume of timber removed, especially when broken down by forest species, is difficult to implement using the methodology implemented in this study and should be subject to more complex analysis and the availability of dendrometric information on the area.

Congo - The study area is located in the Kabo region and, according to the documentation provided to the importers, covers an area of over 4 400 hectares. Using the coordinates given in the same documentation, the area is smaller and amounts to 3 740 hectares. The type of cut is by choice and the period refers to the entire calendar year 2018.

An analysis of the NDVI pre- and post-concession vegetation index shows that the area shows a start of cutting prior to the concession, linked to a cut previously carried out on the adjacent area to the south (Figure 8.).

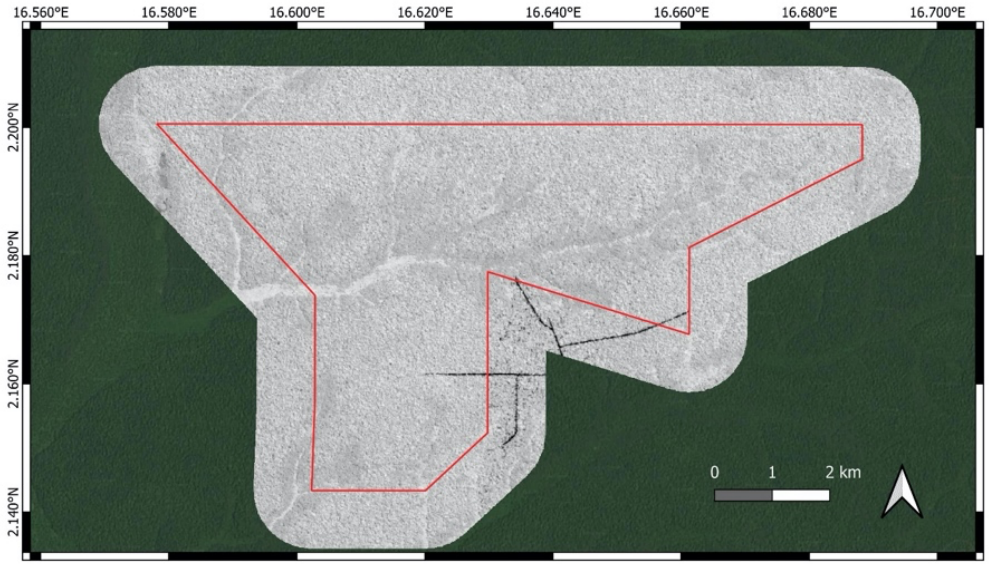

Figure 8. Pre-concession NDVI.

The dark lines branching off towards the polygon of interest represent areas devoid of vegetation, probably the logging paths onto which all the timber cut in the neighbouring areas flows. In fact, in the same image, small black spots can be seen to the left and right of each black line.

Analysing the image relating to the end of the concession, it can be seen that the branching of the black lines continued inside the entire polygon, expanding outwards as well (Figure 9.) and this proves the woodland utilisations actually carried out. Evidently, even in this case, the totality of the available information does not make it possible to determine whether the cuts carried out before 2018 were conducted legally (authorised under another logging permit) or abusively.

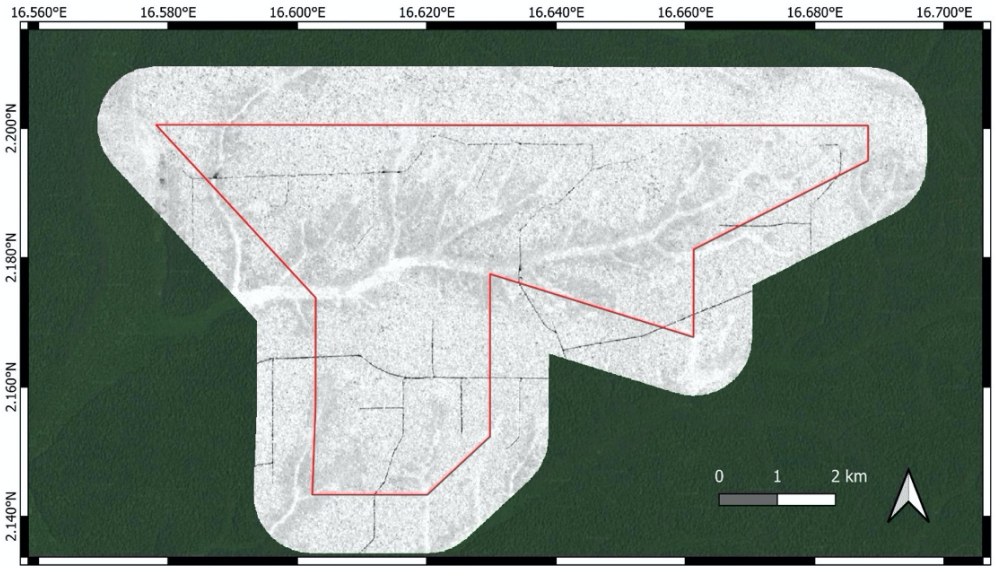

Figure 2. Post-concession NDVI

Conclusions

The main objective of the analysis conducted in this study was to explore the potential of satellite monitoring in the context of due diligence to prevent illegal timber imports, deforestation and forest degradation. The results of the analysis demonstrated the great potential of satellite monitoring and specifically, the possibilities offered by Copernicus Sentinel imagery.

Sentinel images represent an excellent tool for the investigations described in this study due to their characteristics related to spectral, spatial, temporal and radiometric resolutions. Furthermore, the joint use of optical data (Sentinel-2) and RADAR data (Sentinel-1) makes it possible to exploit the potential of multispectral data, which is useful for processing vegetation indices. This, without suffering the characteristic limitations of monitoring by optical sensors, mainly linked to the possible presence of cloud cover in certain storm scenarios, using when and where necessary the RADAR processed data.

The elaborations presented for the case studies under consideration show good results in the case of selective cuts and above all in the monitoring of clear-cuts, for which it is possible to delineate with great accuracy the areas affected by the removals and where, in the possession of ancillary information, it would be possible to estimate the quantity of wood mass removed.

The wide availability of satellite images over the same area throughout the year and the free access to them thanks to the Copernicus programme make it possible to monitor the time period covered by the concessions with great care and, where necessary, to extend the monitoring period beyond the term of the authorisation. This opportunity would make it possible to carry out further investigations and verifications aimed not only at ascertaining the legality of individual cuts (and thus of the supplies originating from them), but also at assessing their environmental compatibility over longer periods that are more consistent with the timeframe of normal forest management. If these more in-depth investigations go beyond the strict context of EUTR due diligence, it is evident how they represent the tools of choice in the case in which the real and overall impact of utilisations and other anthropic activities on forests is to be evaluated.

This last consideration acquires particular significance in virtue of the changed paradigm introduced by the EU legislator with the deforestation-free products Regulation in which the two assumptions of Legality and Sustainability, not only converge at the general purpose level, but constitute the founding aspects of the obligations conferred on those who market wood and its derivatives, coffee, cocoa, soya, palm oil, cattle, rubber and related products.

References

1 https://eur-lex.europa.eu/legal-content/IT/TXT/HTML/?uri=CELEX:32005R2173&from=IT

2 https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32010R0995&from=EN

3 https://data.consilium.europa.eu/doc/document/PE-82-2022-INIT/en/pdf

4 https://ec.europa.eu/transparency/expert-groups-register/screen/meetings/consult?lang=en&meetingId=23097&fromExpertGroups=true

5 https://www.consilium.europa.eu/it/policies/sanctions/restrictive-measures-against-russia-over-ukraine/

6 https://www.transparency.org/en/cpi/2021

7 https://freedomhouse.org/report/freedom-world/2021/democracy-under-siege

8 https://fragilestatesindex.org/

9 https://worldjusticeproject.org/rule-of-law-index/

10 https://www.wri.org/initiatives/environmental-democracy-index

11 https://legnok.conlegno.eu/

12 https://ec.europa.eu/environment/forests/pdf/Conlegno.pdf

13 https://www.fao.org/forest-resources-assessment/2020/en/

14 https://internationalforestindustries.com/2020/02/07/softwood-lumber/

15 https://www.idhsustainabletrade.com/uploaded/2021/12/Timber-11.0.pdf

16 https://pubsonline.informs.org/do/10.1287/orms.2020.02.03/full/

17 https://eia-global.org/subinitiatives/russia

18 https://news.mongabay.com/2021/09/illegal-logging-reaches-amazons-untouched-core-terrifying-research-shows/

19 https://www.wwf.org.uk/press-release/illegal-deforestation-report-brazil

20 http://www.commodafrica.com/01-07-2021-la-deforestation-en-cote-divoire-est-la-plus-forte-dafrique-avec-90-de-la-foret-disparue

21 https://www.lemonde.fr/afrique/article/2021/06/23/en-cote-d-ivoire-une-armee-verte-lutte-contre-la-deforestation_6085397_3212.html

22 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC068489

23 https://ec.europa.eu/environment/forests/pdf/Country_overview_Russian_Federation_03_10_2018.pdf

24 https://lesegais.ru/open-area/deal.

25 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC113357

26 https://ec.europa.eu/environment/forests/pdf/Country_overview_Brazil_03_10_2018.pdf

27https://ec.europa.eu/environment/forests/pdf/201209%20EUTR%20EG%20Country%20conclusions_Brazil_final.pdf

28 https://dados.gov.br/dataset/documento-de-origem-florestal-dof-autorizacoes-de-exploracao-florestal-autex

29 The Forest Code (Law no. 2019-675 of 23 July 2019) (repeals Forest Code of 2014, Law No. 2014-427 of July 14, 2014) https://www.fao.org/faolex/results/details/es/c/LEX-FAOC189532/

30https://ec.europa.eu/environment/forests/pdf/EUTR%20county%20overview_Republic%20of%20Congo%20_November%202020_EN.pdf

31 https://www.eauxetforets.gouv.ci/

32 https://sentinel.esa.int/web/sentinel/missions

33 Gorelick N, Hancher M, Dixon M, Ilyuschenko S, Thau D, Moore R (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 2020: 18-27. https://doi.org/10.1016/j.rse.2017.06.031