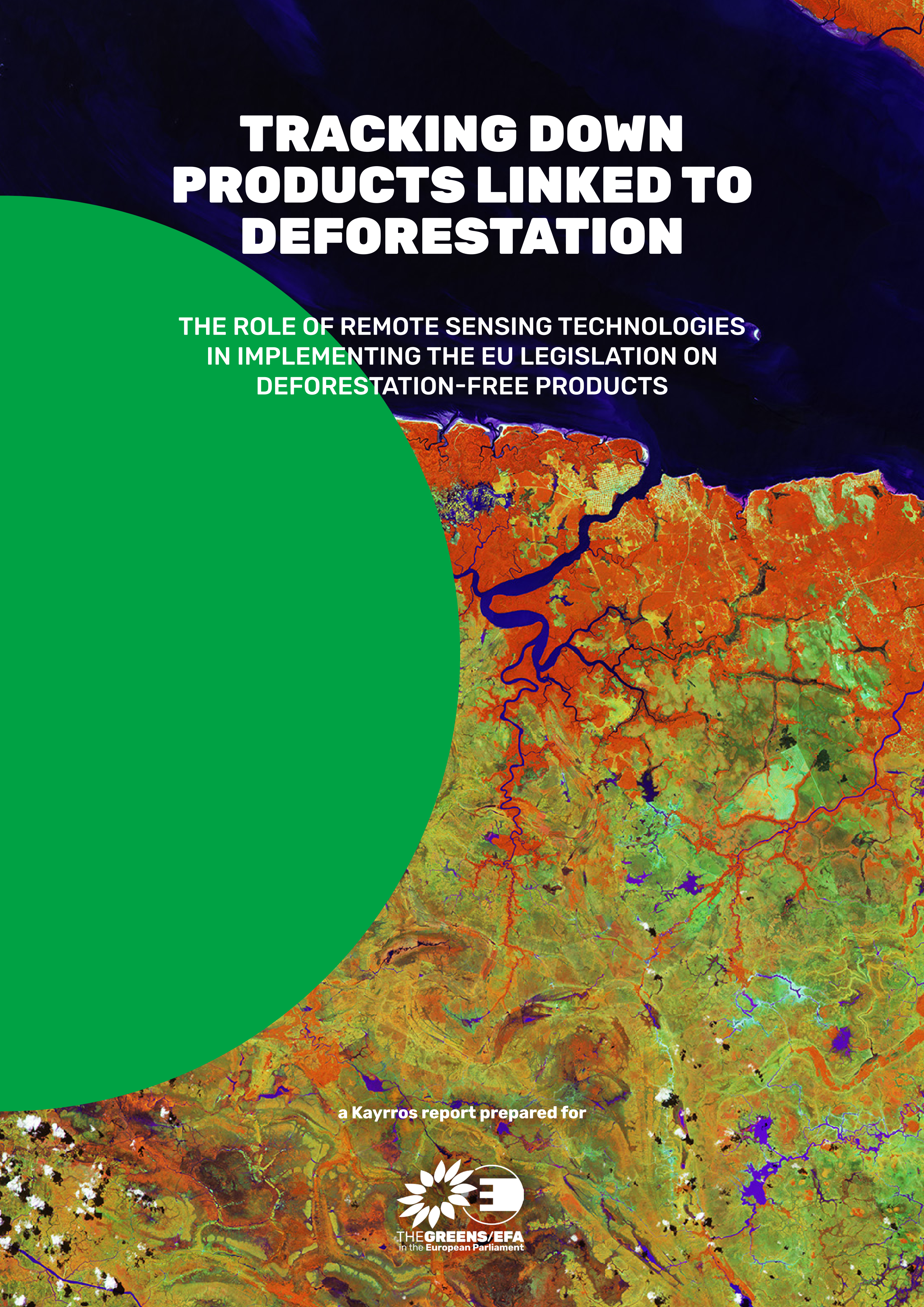
TRACKING DOWN PRODUCTS LINKED TO DEFORESTATION

THE ROLE OF REMOTE SENSING TECHNOLOGIES IN IMPLEMENTING THE EU LEGISLATION ON DEFORESTATION-FREE PRODUCTS



a Kayrros report prepared for

THE GREENS/EFA in the European Parliament

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About Kayrros

Kayrros is a leading geospatial analytics company that helps clients in the energy, finance and public sector make better decisions. Kayrros measures the environmental impact of economic activity and provides unique insights for the net zero transition by combining advanced algorithms with satellite imagery and other alternative data sources.

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TABLE OF CONTENTS

FOREWORD BY THE GREENS/EFA

The proposed EU regulation on deforestation-free products could be a game-changer in the fight against global deforestation and ecosystem destruction. It aims to ensure that EU consumption of agricultural commodities like soy, beef and palm oil has no direct negative impact on the world's forests. Companies will have to demonstrate that products sold in the EU have not been produced on land that has recently been cleared or degraded.

To this end, companies will have to put in place systems allowing them to trace their products and commodities back to the plot of land where they were first grown, harvested, raised, fed from or obtained. They will be required to identify the geolocation coordinates of those parcels, as well as the date or time range of production.

The trade associations representing these companies have claimed that traceability to the point of production is impossible, especially for soy and palm oil. They say that it could lead to supply shortages for "high-protein material".[1] They have also said that poor smallholder farmers would be negatively affected.[2] The palm oil industry has asked the EU to delay the traceability requirement for palm oil products until 2030. The EU should accept traceability to the mill rather than the plantation, they argue.[3]

Companies have claimed that traceability to the point of production is impossible, especially in soy and palm oil

However, the largest independent oil palm smallholders' association in Indonesia, SPKS, which represents 58,000 independent smallholders, has said its members "have the ability to provide their traceability data according to EU demands".[4] SPKS says it is "straightforward to do traceability from the plot of land or plantation" and there is "no excuse to delay".[5]

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[1] The Guardian, 2 March 2022, Agribusiness giants tried to thwart EU deforestation plan after Cop26 pledge

[2] COCERAL, FEDIOL, FEFAC, 15 February 2022, Joint Position on the Commission Proposal for a Regulation for Deforestation-free Supply Chains

[3] CABISCO et al, 18 May 2022, Joint Statement of Palm Oil Sector Organisations on the Proposal for a Regulation on Deforestation-free Products

[4] SPKS, 24 March 2022, Submission to the European Commission on the proposal for the regulation regarding commodities associated with deforestation and forest degradation

[5] Greenpeace Unearthed, 24 May 2022, Palm oil industry seeks delay to deforestation law

Groups representing more than 34,000 Ivorian cocoa farmers have also rejected the industry claims. They have expressed their support for the proposed traceability requirement and stated that: "The industry players who are trying to prevent a traceability system involving the geolocation of plots and the identification of each producer, are in reality campaigning for nothing to change."[6]

The case of GM-free and organic soybeans has shown that companies can still guarantee strict production standards for commodities that are usually bulked and aggregated along the supply chain. Big soy traders like Cargill, Bunge and ADM have committed to achieving full traceability including direct and indirect suppliers by 2025 and 2030, according to their no-deforestation policies and statements.

Experience with GM-free and organic soybean demonstrates that companies can still guarantee strict production standards for commodities that are usually bulked and aggregated along the supply chain

The requirement for full product traceability will necessitate far-reaching changes in some industries. However, this is exactly what the new legislation is aiming to achieve. It wants to change current practices, not document them. The proposed regulation will oblige all operators to request supply chain traceability from all their suppliers at the same time, providing a level playing field for those companies already investing in traceability along their entire supply chain.

This report shows that operators will be able to use available satellite imagery tools, among other options, to check the land-use history of their production areas, map their supply chains and verify information provided by their direct and indirect suppliers. Public authorities will be able to use these tools to check companies' compliance with the regulation.

It also shows that the objectives of the proposed legislation will not be achieved without greater supply chain transparency. Operators should be obliged to identify all the participants in their supply chain and to disclose that information in their due diligence statements and annual reports. Traders should be obliged to present this information to their buyers, so that goods are easily traceable as they make their way to the end consumer.

This information will serve operators, enforcement agencies and the public alike. It is the only way to reassure consumers that the products they buy are not linked to deforestation or human rights abuse.

Only if we know where products come from can we guarantee consumers that their purchase does not contribute to the destruction of forests and other precious ecosystems

The requirement to trace products to their point of origin is a cornerstone of the proposed legislation. Only if we know where products come from can we guarantee consumers that their purchase does not contribute to the destruction of forests and other precious ecosystems. This requirement should not be weakened under any circumstances.

The proposed EU regulation on deforestation-free products can be one of the essential tools to prevent environmental and human rights crimes and protect the climate. The case against Casino, brought by a coalition of NGOs and Indigenous peoples from the Brazilian and Colombian Amazon, shows just how badly such laws are needed.[7] We need to make them as effective as possible - for consumers, forest communities and our ecosystems.

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[6] ADDF et al, 28 February 2022, Support for the geolocation requirement in the draft EU regulation on deforestation free supply chains

[7] Mighty Earth, 3 March 2021, Amazon indigenous communities and international NGOs sue supermarket giant Casino/Pão de Açúcar/Éxito over deforestation and human rights violations

EXECUTIVE SUMMARY

Under the planned EU legislation on deforestation-free products, operators will have to demonstrate that certain commodities and products they wish to import to the EU, or export from the EU, are not associated with any deforestation or forest degradation.

To be able to do so, companies will have to link these commodities and products to the exact plots of land where they were produced, as well as the date of production. They must demonstrate that these plots have not been cleared or degraded after 31 December 2020, the cut-off-date proposed by the European Commission. Competent authorities must be able to verify this information. Satellite images and positioning stemming from the use of EU satellite systems can be part of authorities' compliance checks, according to the proposed legislation.

In this report, Kayrros, a geospatial analytics company from France, argues that satellite-based remote sensing technologies can support both operators and competent authorities in the implementation of the upcoming EU legislation on deforestation-free products. Operators can use these technologies to fulfil their due diligence obligation, and competent authorities can use them to verify the reported information.

Satellite-based remote sensing technologies can support both operators and competent authorities in the implementation of the upcoming EU legislation on deforestation-free products

The EU's Copernicus constellation of satellites provides a broad range of satellite imagery that, when combined with machine learning and other advanced algorithms, can effectively support the traceability of forest-risk commodities and products. Remote sensing data can be used to detect and analyse deforestation and forest degradation, as well as precursor events to deforestation and forest degradation (e.g. the construction of new roads). They can also be used to monitor the development of agricultural production areas and identify specific types of production such as permanent crops (e.g. palm oil), pastures and non-permanent crops (e.g. soybean). Whilst permanent crops are relatively easy to monitor, the identification and monitoring of non-permanent crops will require contextual analysis or ground-truth, i.e. data collected in the field by visual observation and/or ground sensors.

The information about deforestation and forest degradation, and global production areas, must then be associated with specific supply chains and companies in order to support the due diligence process. This is easier for simple supply chains like soybean from Brazil, where production is concentrated in a few companies operating in large areas. It is more challenging for complex supply chains like cocoa from Ghana, for example, which relies on a complex network of intermediaries and a large number of small growers.

Remote sensing technologies can be used to assist the mapping of supply chains. For example, optical satellite images can be used to detect roads and nodal points where goods are transported on their way to the European market. These maps make it possible to assess the deforestation risk associated with specific collection points identified along the supply chain. Geolocation data sourced from cell phone coordinates and transponder signals from trucks and ships can provide additional detail, subject to privacy and data protection constraints.

The capabilities and limitations of remote sensing technologies for detecting land use changes, identifying production plots and mapping supply chains vary from one commodity to another. Broadly, remote sensing technologies can, in principle, provide robust and up-to-date information for maize, palm oil, rubber, soy and wood sourced from managed forests. The complexity of remote sensing analytics increases for cattle, cocoa, coffee and wood sourced from natural forests, for various reasons.

Finally, the full traceability of agricultural products to their point of origin requires important efforts from supply chain stakeholders to register all direct and indirect suppliers, ensure the segregation of products coming from different areas or grown under different conditions and to share the products' origin with other stakeholders.

There are a range of existing data sources that can be used, and sometimes are already used, in combination with satellite analytics. This includes private and public certification schemes for agricultural commodities like palm oil, soy, maize, wood, rubber, coffee and cocoa. The Trase Platform is probably the most advanced initiative leveraging publicly available data, including satellite data, to monitor the supply chains of 13 forest-risk commodities. Finally, the use of stable isotope ratios has been considered as a way to verify the geographic origin of products like soya, cocoa and coffee, provided that a large library of samples can be established.

However, existing monitoring tools lack standardisation, both in the methodologies and in the metrics used. The absence of well-established methodologies and criteria to measure imported deforestation risks is also linked to a lack of transparency. More data must be shared by supply chain stakeholders to ensure full product traceability, and full accountability for deforestation associated with imported goods.

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Remote sensing technologies can be considered an important addition to the toolkit for monitoring at-risk supply chains. Limitations, related to weather-sensitive data sources and detection thresholds of mid-resolution satellites, only have a minimal impact on the ability of remote sensing to help operators map and transform their supply chains, and to help public authorities verify the reported data.

The operating costs of remote sensing technologies fall primarily on the exporters and importers of forest-risk commodities, not on the growers or domestic traders

The operating costs of remote sensing technologies depend mainly on the source of the satellite data (public or commercial) and on the complexity of the algorithms chosen to analyse the data. These costs fall primarily on the exporters and importers of forest-risk commodities, not on the growers or domestic traders. Whilst costs will vary between different types of commodities, they are going to be modest in relation to the turnover of the affected market participants. Kayrros estimates that even a complex monitoring system such as for cocoa from Ghana may cost less than 1% of turnover of a typical exporter. A comparatively simple monitoring system for soybean from Brazil is likely to represent less than 0.1% of a typical exporter's turnover. For competent authorities carrying out compliance checks, the costs are likely to be lower than for importers and exporters.

Remote sensing technologies can be used to ensure the successful implementation of the planned EU legislation, whilst keeping the associated costs and obligations manageable. As growers would only have to provide the geolocation data of their production areas, fears of impacting small producers are not justified.

1. INTRODUCTION

The European Commission has proposed to regulate the trade of forest-risk commodities in order to minimise the EU's role in global deforestation and forest degradation.[8] It aims to put in place a due diligence system for companies wanting to place such commodities on the EU market, or export them from the EU market. The proposed system covers six commodities (soy, beef, palm oil, wood, cocoa and coffee), as well as some of their derived products.

As part of their due diligence obligations, operators will have to collect geographic coordinates for all the plots of land where the relevant commodities and products were produced. Under the proposed regulation, commodities grown on parcels cleared or degraded after 31 December 2020 (the *"cut-off date"*) can no longer be placed on the EU market, nor exported from the EU. Since the publication of the draft legislation in November 2021, several parties have challenged the Commission to broaden its scope, particularly on the inclusion of additional commodities.

The proposed regulation envisages the use of satellite monitoring, a technology where the European Union is a world leader. According to the Commission's proposal, *"satellite images and positioning stemming from the use of EGNOS/Galileo and Copernicus can be part of the information used for compliance checks"*.

At the request of the Greens/EFA Group, Kayrros has assessed the ability of current satellite technology to support the implementation of the proposed EU legislation on deforestation-free products. The report covers all six commodities included in the proposed legislation as well as additional commodities that could be included (maize, rubber).

[8] COM(2021) 706 final

2. USE OF SATELLITE TECHNOLOGIES TO ENSURE PRODUCT TRACEABILITY

2.1 Evolution of satellite technologies

The capabilities of earth observation satellites and remote sensing algorithms are in constant evolution. The number of satellites available, their resolution and the diversity of captors have increased tremendously in recent years. In the decade to 2020, the number of NASA and ESA earth observation satellites relevant to forests increased four-fold, while their technical capabilities improved significantly in terms of spectral and spatial resolution (Figure 1). The launch of the EU's Copernicus constellation in 2015 was a tipping point in terms of the quantity and quality of satellite data available.

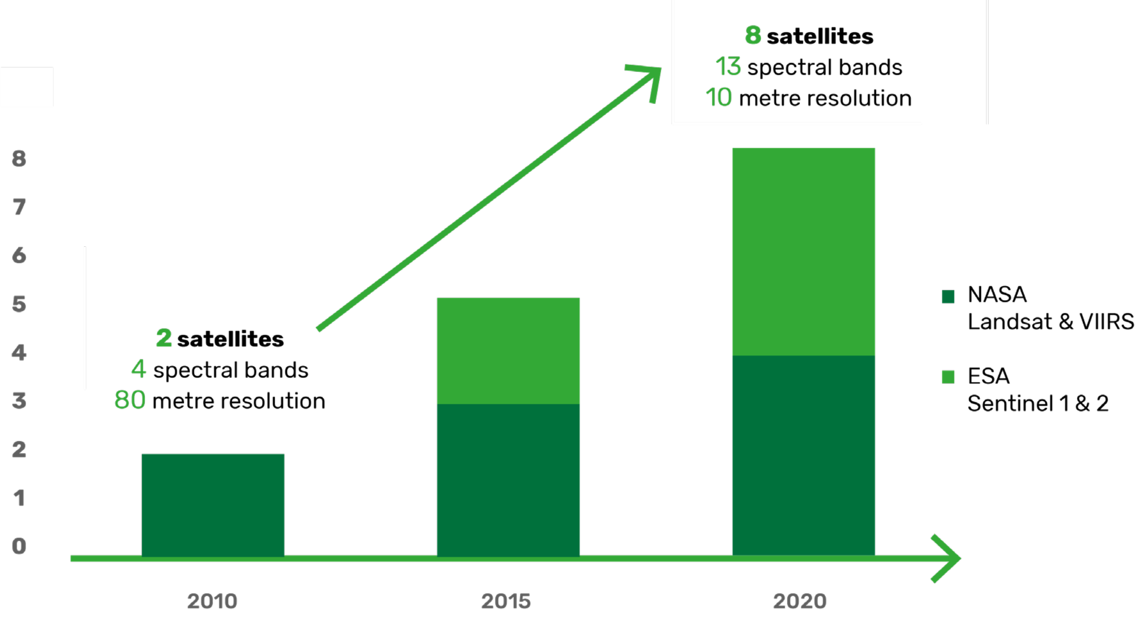

Figure 1: Number of active satellites and best available performance from NASA and ESA.
Source: Kayrros analysis of ESA and NASA data

The most recent launches include several hyperspectral satellites, which provide more resolution in specific wavelengths and NASA's GEDI, a LiDAR satellite which measures the height of forests. In parallel, commercial constellations (e.g Planet, Airbus, Maxar, etc.) offer very high resolution optical and radar images. Their application in forest monitoring started with the use of optical images, but more complex technologies based on radar or microwave imagery are increasingly being used to deliver more precise and scalable insights.

These applications come with an important advantage over traditional methodologies based on field data. As long as deforestation measurements had to be done on the ground, that meant high costs and a lack of reactivity, as maps could not be updated often. Alerting could only be set-up at a small scale by organising a network of stakeholders in the field. Forest degradation in remote areas could be completely ignored for a significant period of time. Satellite analytics, on the contrary, combines relatively low costs with precision and frequent (typically weekly) updates whilst operating at a global scale.

2.2 Monitoring of deforestation and forest degradation

By *"deforestation"* we understand the conversion of forest to another land use, including agricultural use. This also includes the conversion of forests that are not plantation forests into plantation forests. Deforestation is easily detectable because the contrast between forested areas and barren land stands out clearly in optical and radar satellite imagery.

By *"forest degradation"* we mean changes within a forest that negatively affect its species composition, structure, and/or function and reduce the forest's capacity to support biodiversity and/or deliver ecosystem services. These changes are harder to identify and measure, in particular at a small scale, for example if they consist of the selective logging of individual trees. To measure the degradation of a forest, remote sensing technologies can still be used but need to focus on the evolution of the density, height or biomass content of a forest.

The causes of deforestation and degradation can be natural (e.g. wildfires, pests, etc.) or anthropogenic (e.g. conversion to agriculture, urbanisation, etc.). In most cases, they cannot be directly derived from the observation of the impacted parcel of land but require an analysis of the broader context. For example, the conversion of a forested area to agricultural land can be confirmed a few months after the trees have been cut, once the newly sown crops become visible.

Several remote sensing data sources can be used to detect and analyse deforestation and forest degradation (Table 1). Optical images take a snapshot of the earth in different spectral band lengths. Bands in the visible spectrum provide a picture that looks exactly like what a human eye can see while infrared bands bring additional information for vegetation detection and analysis. Optical images are often the most reliable and useful source of information, but they are sensitive to weather conditions, including clouds. Additionally, some satellites use radar, microwave or LiDAR (laser) technologies; the resulting images may not be easily understood by the human eye but they can be analysed to detect changes in vegetation cover (Figure 2).

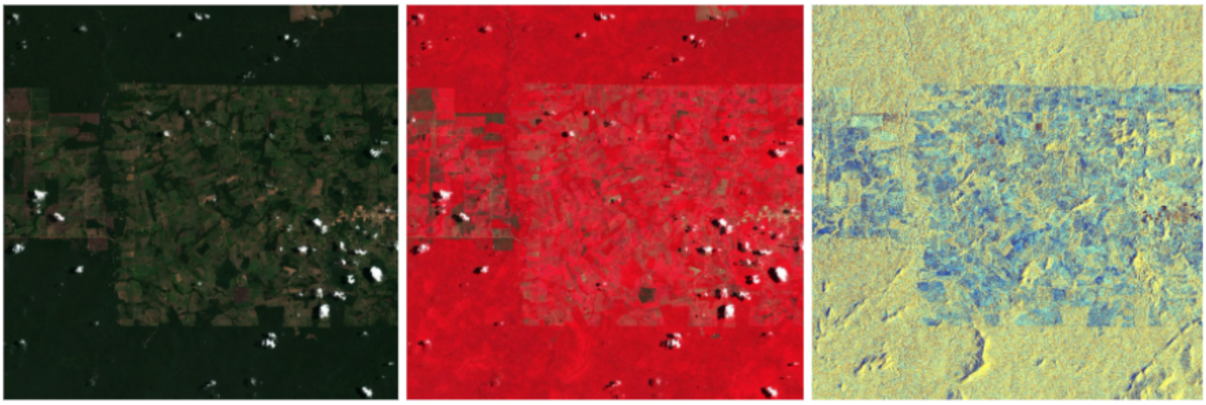

Figure 2: A partially deforested area as seen with optical (left), infrared (middle) and radar (right) satellites. Agricultural land in the middle of the image is surrounded by primary forest.
Source: Copernicus.

Table 1: Types of satellite data used for deforestation monitoring

Source	Uses	Limitations	Technical capabilities with ESA satellites
Optical	- Detect changes between forested and non forested areas. - Measure evolutions in forest density. - Detect fires. - Monitor vegetation health.	Weather sensitive (fewer exploitable images in cloudy areas).	Sentinel-2 Resolution: 10m Frequency: up to 3 days History: 2016 to date
Radar	- Detect changes in the land cover when optical images are not available due to cloud cover. - Measure tree height.	Cannot be used to measure surfaces but only to spot localised changes; sensitive to terrain elevation.	Sentinel-1 Resolution: 10m Frequency: up to 12 days History: 2015 to date
Microwave	- Detect changes in above-ground biomass content of vegetation.	Coarse resolution.	SMOS Resolution: 40km Frequency: quarterly History: 2011 to date
LiDAR	- Measure canopy height and cover. - Derive biomass content of vegetation.	Sparse points of measurement instead of a continuous area.	N/A

A broad range of outputs related to deforestation and forest degradation can be generated with algorithms developed and trained on these remote sensing data sources. This information can play a crucial role in the due diligence process and associated checks by competent authorities (Table 2). Additionally, information about precursor events to deforestation and forest degradation (e.g. the construction of new roads) can support collaborative efforts with producing countries and supply chain stakeholders for the protection of natural ecosystems.

Table 2: Uses of remote sensing technology for deforestation monitoring

Output	Description	Impact for EU Legislation
Forest cover mapping	Identification of the forests at a given point in time	Define the baseline. The global map for January 2021 can become the reference for due diligence verification.
Deforestation monitoring	Monitoring of the progression of deforestation fronts. Alerting system.	Measure supply chain deforestation risk for due diligence and verification.
Degradation detection	Identification of threatened areas.	Verify the impact of the wood supply chain, both for operators and authorities.
Deforestation anticipation tool	Detection of precursor events of deforestation (new roads, fires..)	Help competent authorities and operators engage with partner countries and supply chain stakeholders, based on scientific facts.

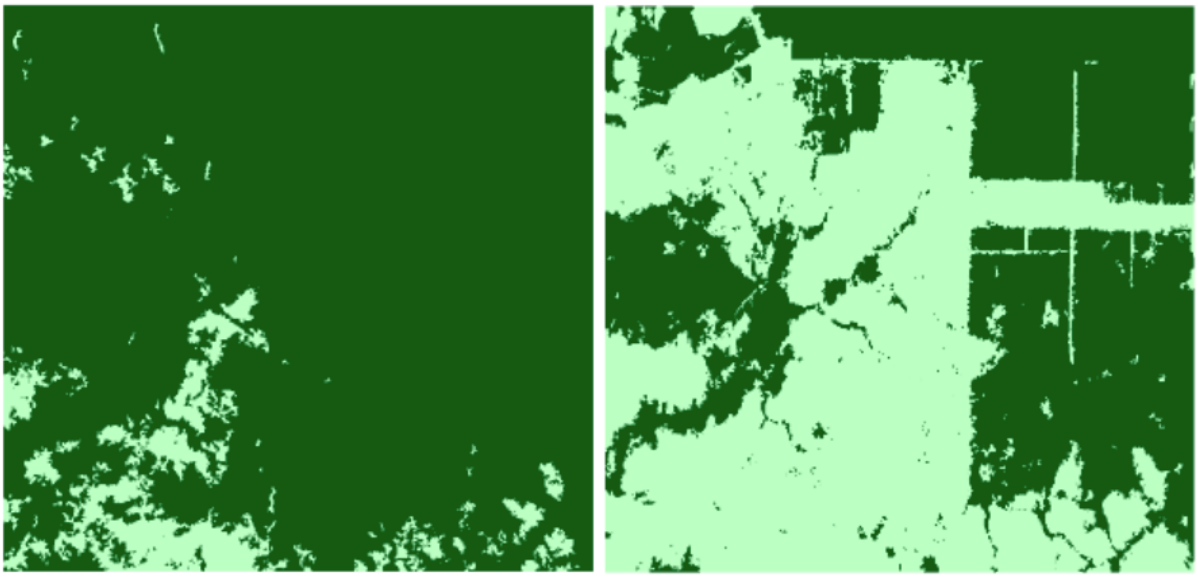

Figure 3: Deforestation in the Amazon Forest between April 2017 (left) and November 2020 (right) based on optical satellite analytics; the agricultural areas in light green are identified automatically.
Source: Kayrros analysis.

2.3 Land use segmentation

In addition to forest monitoring, the European legislation on deforestation-free products requires a reliable, transparent and continuous monitoring of agricultural production areas on a global scale. Only satellite-based systems can provide this information with high precision and at regular intervals. Optical and radar satellite images can be leveraged to identify different kinds of land use and in particular differentiate between agricultural land, forests and other zones like urban areas:

• **Optical:** detect different kinds of land use; detect changes over time; measure the surface of agricultural parcels.

• **Radar:** detect changes of land use when optical images are not available due to cloud cover; complement optical images for the identification of specific crops/species.

Because each type of land use has distinguishing features such as texture, colour and reflection capacity, models can be trained to recognize different classes (e.g. agricultural land, forests, urban areas) and to measure continuous surfaces of the same kind (Figure 4).

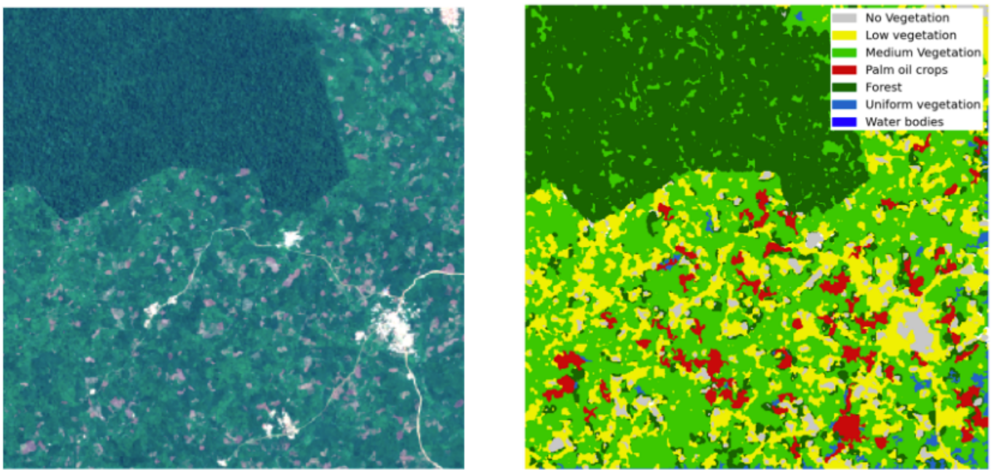

Figure 4: Automated segmentation of land use in Ivory Coast; palm oil plantations are colored in red.
Source: Kayrros analysis.

However, while it is relatively easy to distinguish between a few broad categories (i.e. urban areas, forest, agriculture) the complexity increases when trying to identify specific crop types. Permanent crops (e.g. palm oil), most of which are trees or bushes of the same species following a geometrical pattern, are relatively easy to identify. Pastures also are easy to recognize. The more challenging process concerns the different non-permanent crops (e.g. soybean) that often require contextual analysis or ground-truth, i.e. data collected in the field by visual observation and/or ground sensors, to confirm the type of commodity grown on the parcel.

Several outputs can be derived from optical and radar satellite images thanks to appropriate algorithms (Table 3). The identification of agricultural zones and of specific crops enables a precise understanding of the commodities covered by the European legislation. When combined with the previously presented information about deforestation and forest degradation, satellite-based analytics can help operators and authorities check the compliance of agricultural products with the proposed legislation.

Table 3: Relevance of remote sensing to land use segmentation

Output	Description	Impact for EU Legislation
Map of agricultural areas	Identification of land devoted to agricultural production.	Get metrics about the conversion rate from forest to agriculture.
Map of crops	Identification and measurement of areas by crop type	Track each parcel where commodities covered by the legislation are produced and verify reported information.
Monitor land use	Continuous monitoring and detection of land use changes	Measure the footprint of farms and their impact on surrounding forests.

2.4 Traceability and supply chain mapping

Detecting deforestation and mapping global production areas is only one step in the process of identifying deforestation-free commodities. Indeed, this information must be associated with specific supply chains and companies in order to support the due diligence process and compliance checks. The availability of supply chain data is extremely variable, with some companies having developed comprehensive traceability systems, while others lack basic information even about their direct suppliers. On top of that, data collected by economic operators are often kept private for commercial reasons.

Generally speaking, supply chain mapping is further developed for *"simple"* supply chains that involve fewer stakeholders. For example, soybean production in Brazil is highly concentrated in a few companies operating in large areas, therefore it is relatively easy for international traders like Cargill to gather standardised and verifiable information on the product's origin. Conversely, less information is available on fragmented supply chains like cocoa or coffee that rely on a complex network of intermediaries and a large number of small growers who may not always be registered, making data collection more difficult. For example, at least 60% of all cocoa from Ivory Coast is indirectly sourced, meaning that traders buy from intermediaries rather than producers.[9] That said, certification schemes like Fairtrade International or Rainforest Alliance have achieved traceability on some of these complex supply chains. (Several initiatives aimed at improving traceability in these sectors are outlined in Section 4.)

Remote sensing technologies can be used to assist supply chain mapping, in order to link the imported goods to their production site. Optical satellite images can be used to map networks by automatically spotting roads and nodal points where goods are transported on their way to the European market. These maps make it possible to measure the deforestation risk associated with specific collection points identified along the supply chain. Geolocation data sourced from cell phone coordinates and transponder signals from trucks and ships can provide additional detail, subject to privacy and data protection constraints. While its geographical coverage varies from one country to another, this type of data can identify the strongest connections between nodal points in the transportation network. Moreover, complementary data sources can be leveraged to improve the mapping of the supply chain, including Google API's database of infrastructure ownership (Table 4).

Table 4: Types of geospatial data relevant to supply chain mapping

Source	Use	Limitations
Geolocation	Identify main supply chain connections. Follow specific cargoes during their journey from the production region to Europe.	Data availability and quality vary greatly depending on the country.
Optical	Map roads and supply chain nodal points. Draw supply zones around first collection points.	Weather sensitive (fewer exploitable images in cloudy areas).
Publicly available sources	Map supply chain nodal points. Identify companies. Get commercial information.	Lack of standardisation across different sources. Infrequent updates. Access to data can be restricted.

[9] zu Ermgassen et al, 2022, Addressing indirect sourcing in zero deforestation commodity supply chains. https://doi.org/10.1126/sciadv.abn3132

For example, Figure 5 illustrates a sample of deforested areas between 2017 and 2020 and their new land use. Most areas have been converted to pastures (areas in light green) or agriculture (areas in red). Knowing that soybean cultivation is driving most land use conversions in this region, it is possible to identify the producer and the closest silo for every plot. With this information, EU authorities can perform checks on imported products and hold operators accountable for any deforestation detected after the cut-off date.

Figure 5: Identification of the new land use of deforested parcels in Mato Grosso (Brazil) and of the closest silos. In this region, new agricultural areas are mostly devoted to soy production.
Source: Kayrros analysis. Mapbox basemap.

It should be noted that full product traceability requires important efforts from supply chain stakeholders to register all direct and indirect suppliers, ensure the segregation of products coming from different areas or grown under different conditions and to share the products' origin with other stakeholders. Today, these important steps are often missing because of:

• **Large number of suppliers:** for example, cocoa production in Ivory Coast depends on tens of thousands of growers who produce small quantities to cooperatives and other intermediaries.

• **Proprietary information:** companies are often reluctant to share commercially sensitive information with their counterparts. Traceability is broken whenever a supplier decides to withhold the origin of commodities to the buyer.

• **High setup costs:** new infrastructure may be required to effectively register and segregate different products. New digital tools may be needed to collect and share sensitive information, and/or continuous training to ensure the application of company's policies.

TRACEABILITY INITIATIVE IN IVORY COAST

Cocoa is a key commodity for Ivory Coast. The country accounts for more than 40% of global production but has been struggling to identify production areas and reduce associated deforestation. The Coffee-Cocoa Board of Ivory Coast (CCC) announced[10] in March 2022 that it would launch a pilot programme to trace cocoa beans from farm to market. The pilot will focus on:

- identification of cocoa growers with the attribution of individual registered numbers;
- diffusion of specific packaging;
- set-up of an innovative payment system.

The CCC has already registered almost 1 million growers responsible for 3.2 million hectares of production[11], and similar initiatives to achieve full traceability from plot to port are under way in Ghana and Cameroon.[12] These efforts are crucial for product traceability, and are necessary to complement the capabilities of remote sensing technologies.

2.5 Technological capabilities and limitations by commodity type

The capabilities and limitations of remote sensing technologies for detecting land use changes, identifying production plots and mapping supply chains vary from one commodity to another. While the detection of deforestation is only subject to the technical limitations of satellites (i.e. data availability, detection threshold, etc.), crop identification and product traceability can be complicated by other factors. In this section, we provide an overview of what can be done with current solutions for all the commodities covered by the proposed European legislation, plus maize and rubber.

For **maize, palm oil, rubber, soy** and **wood sourced from managed forests**, remote sensing technologies can, in principle, provide robust and up-to-date information (Table 5). They can be used to identify the crops, measure the relevant areas and detect land use changes. These commodities are often produced on rather large parcels, making it easier for algorithms to identify the areas. Soy and maize are generally grown on rather flat lands, which improves the quality of radar-based change detection monitoring. Oil palms and rubber trees have specific textures, and plantations follow a geometric pattern; these factors provide a clear differentiation from the surrounding forest (Figures 6 and 7). In managed forests, clear-cuts follow a geometric pattern and overall vegetation is less dense than in primary forests.

[10] Reuters, 22 March 2022, Ivory Coast tests new cocoa traceability system to fight deforestation

[11] Conseil Café Cacao, 6 April 2022, Le Conseil du Café-Cacao procède à la distribution de la carte du producteur

[12] IDH, GISCO, C-lever.org, 2021, Technical Brief on Cocoa Traceability in West and Central Africa

Table 5: Capabilities and limitations of remote sensing technologies by crop type

Commodity	Capabilities	Limitations
Maize	Crop identification, surface measurement, change detection, supply chain mapping, historical analysis	Can be hard to distinguish from similar crops (i.e. soy)
Palm oil		Young trees are harder to identify
Rubber		Young trees are harder to identify
Soy		Can be hard to distinguish from similar crops (i.e. maize)
Wood from managed forests		N/A

Figure 6: Palm oil plantations in Indonesia on high resolution imagery. Source: Worldview

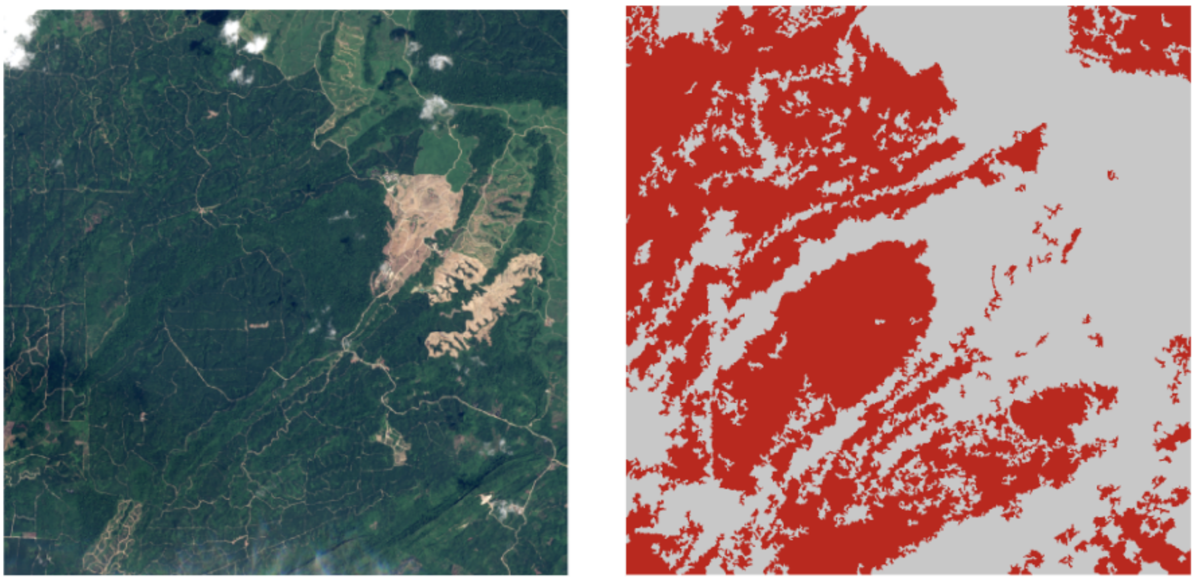

Figure 7: Palm oil detection tool. Left : Sentinel 2 image of the area. Right: palm oil plantations detected (in red). Source: Kayrros analysis based on Copernicus data.

The complexity of remote sensing analytics increases for **cattle, cocoa, coffee** and **wood sourced from natural forests** (Table 6). Coffee and cocoa are often cultivated in small, difficult to detect areas. Additionally, they are sometimes grown under the canopy of bigger trees that hide them from optical images. While it is possible to map a large part of the global production of these commodities, it should be noted that crop identification can be more complex and may require ground-truth data from public sources and/or from companies along the supply chain.

In the case of cattle, the challenge lies not in identifying pasture land but in mapping the many intermediate steps in the supply chain itself. While most commodities are stored in silos and warehouses near the area of production, cattle can be shipped over long distances at different stages of their lifecycle. When not properly documented, these journeys are difficult to reconstruct based only on satellite imagery. Complementary methods, such as the use of electronic ear tags to track an animal's place of birth and the different farms where it was raised, can provide the missing information. But animals would have to be tagged at birth in order for such a system to be effective, and their use is far from widespread because the associated costs are significant.

Table 6: Capabilities and limitations of remote sensing technologies for different commodities.

Commodity	Capabilities	Limitations
Cattle	Crop identification Surface measurement Detection of land use changes	Supply chain mapping requires additional data
Cocoa **Coffee**	Crop identification Surface measurement Detection of land use changes Supply chain mapping	Crop identification can be complex. Ground-truth data can be required to calibrate algorithms
Wood from illegal logging	Measure logging Detection of land use changes	Supply chain mapping requires additional data

Finally, the detection of (illegal) logging in primary forests has its own challenges as it can consist of selective cuttings of high-value trees that are dispersed across a wide area and that can therefore go unnoticed (Figure 8). For these reasons, illegal logging can only be detected by satellite if cuts are performed on a continuous surface measuring approximately 500m2 or more. Moreover, it can be hard to link instances of logging to a specific supply chain, as illegal networks may be light in infrastructure and able to change frequently.

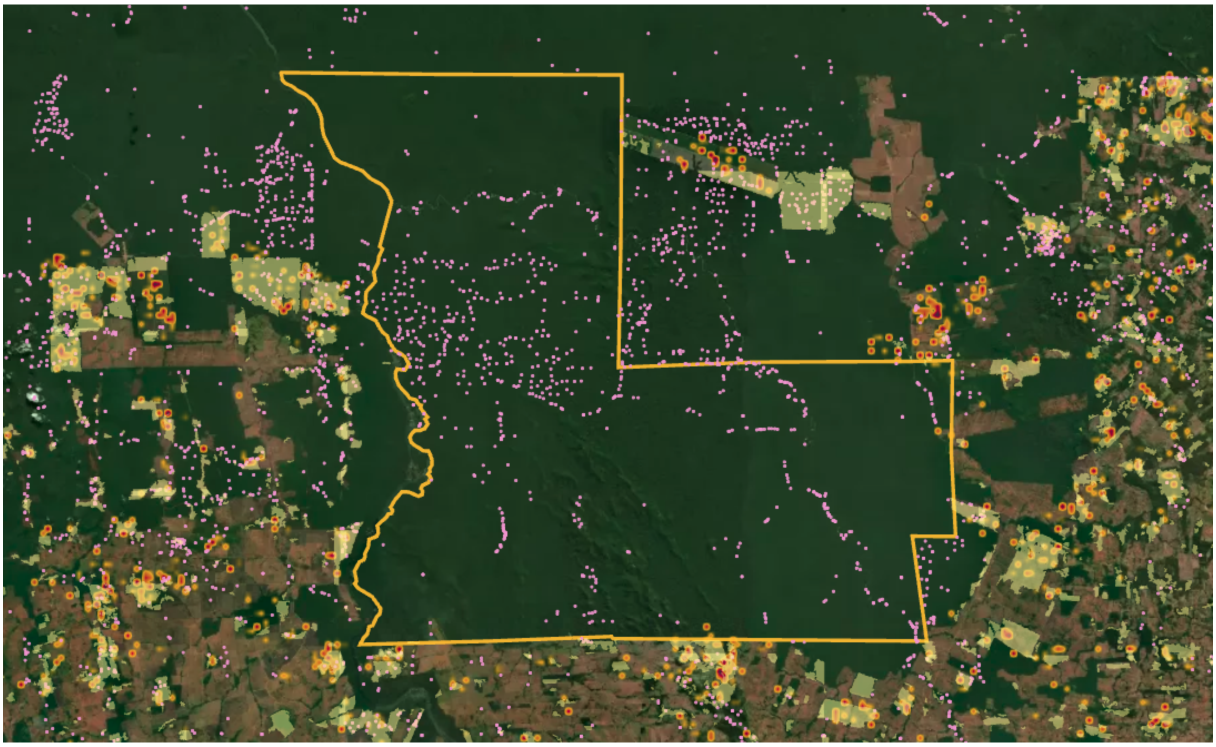

Figure 8: Selective logging (purple dots), fires (orange) and deforested plots (light green) detected in a sustainable forestry project (yellow perimeter) and neighbouring areas in the Amazon forest since 2017. Source: Kayrros analysis on Mapbox basemap.

In conclusion, whilst the complexity of the analytics varies by type of commodity, remote sensing technologies can be used for all commodities listed by the proposed legislation, as well as maize and rubber. For many of them, however, satellite-based mapping systems do not currently exist for many regions.

3. COST IMPLICATIONS OF USING REMOTE SENSING TECHNOLOGIES

3.1 Operating costs of remote sensing technologies

The operating costs of remote sensing technologies depend mainly on the data source and on the complexity of the algorithms chosen to analyse the data (Figure 9).

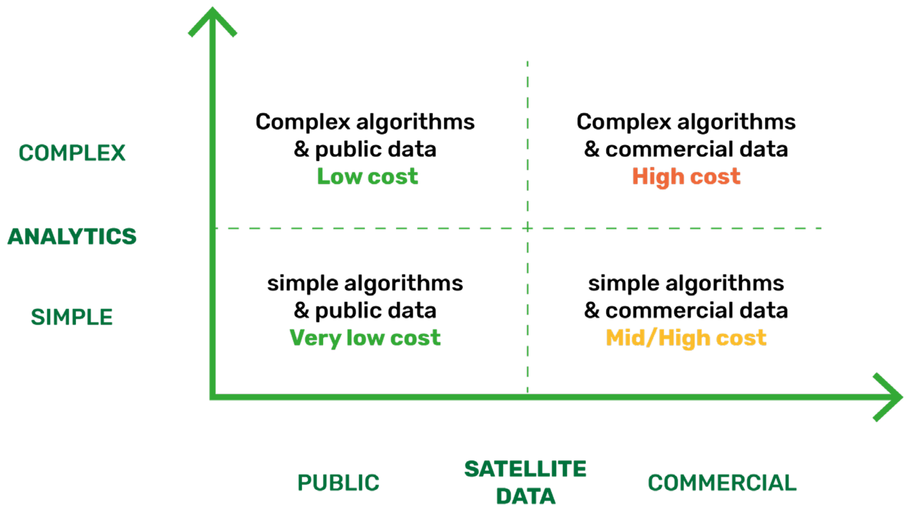

Figure 9: Cost of satellite analytics according to complexity and data source

The cost of sourcing satellite data from one, or possibly several, satellite constellations depends on the mix of public and commercial satellites, as well as the volume of data required. Data from EU satellite constellations is free of charge, whereas commercial constellations charge a significant fee for their services.

Satellite imagery needs to be complemented by additional data sources such as geolocation and land registry data. This 3rd party data is not likely to be expensive, and may even be free of charge. The additional data sources are integrated by the solution provider with the use of advanced algorithms (Figure 10).

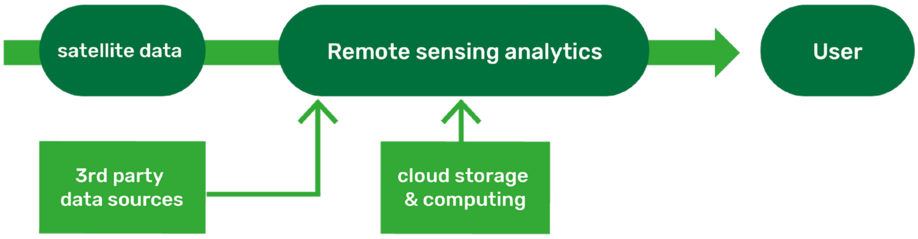

Figure 10: Value chain for remote sensing technology

The main cost drivers of remote sensing analytics are labour and intellectual property. Mapping the agricultural supply chain and integrating country-specific sources of 3rd party data can add up to several thousand person-hours during the setup phase, and dedicated resources are needed to maintain the system and provide technical support to the user. The IP costs relate to the use of algorithms, which can range from open-source code to proprietary.

Finally, the IT infrastructure costs associated with storing remote sensing data and providing computing capacity for the analytics are relatively modest, particularly when cloud computing services are used.

3.2 Cost implications for market participants

The cost of implementing remote sensing technologies falls primarily on the exporters and importers of forest-risk commodities. They will aggregate the information provided by growers and wholesalers to ensure the traceability of their products. The burden of proof lies with them as the parties bringing these commodities into the EU market.

The cost incurred by an exporter/importer will vary by commodity. For example, the supply chain for cocoa is highly fragmented and the number of small growers can potentially reach into the tens of thousands. Moreover, cocoa trees can grow in partially forested areas and their detection using remote sensing technologies will require more advanced algorithms and more expensive satellite imagery. Kayrros estimates that the additional effort required to monitor a large number of agricultural plots at a higher resolution can drive a fivefold increase in costs compared to monitoring large-scale monocultures like soy and oil palm plantations.

That said, the monitoring costs are going to be modest in relation to the turnover of the affected market participants. Given the high level of concentration in the industry and the large size of the EU market (Figure 11), Kayrros estimates that even a complex monitoring system may cost less than 1% of the turnover of a typical cocoa exporter in Ghana. A typical soybean exporter in Brazil is likely to spend less than 0.1% of its turnover given the higher trade volume and the lower complexity of the required solution (Table 7). Large international traders may also benefit from economies of scale if the cost of the monitoring platform can be spread across two or more commodities and/or supply chains. On top of that, as several of the largest soy traders have have already developed satellite-based monitoring systems and have committed to achieve full traceability in the coming years, the future legislation might be handled with already planned investments.

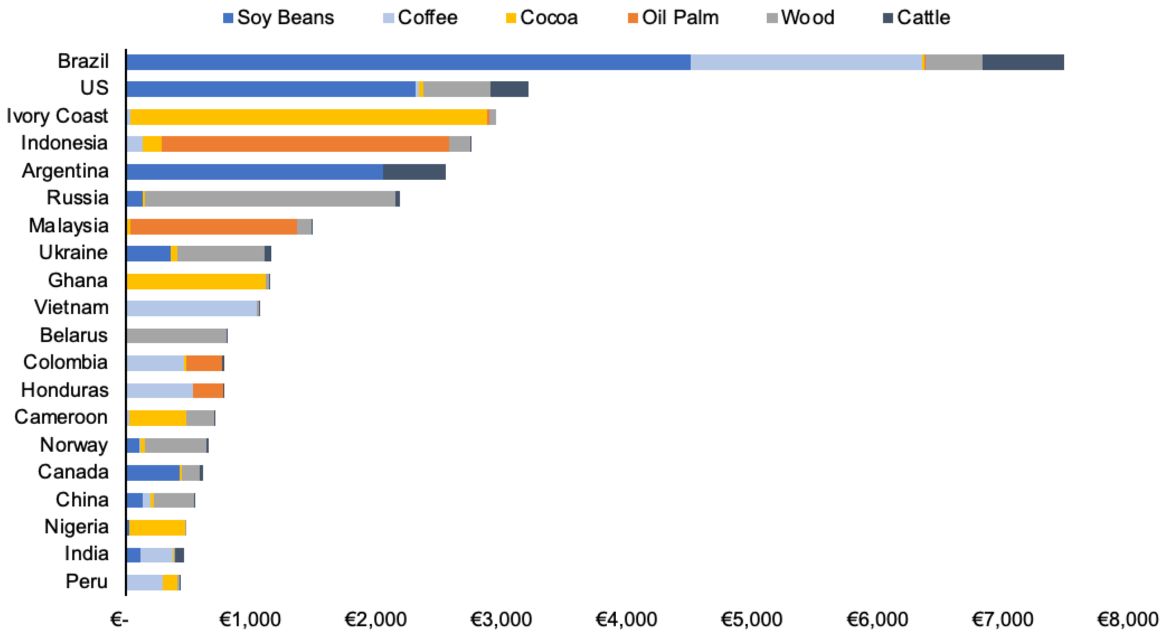

Figure 11: Top 20 countries supplying to the EU market based on the import value of the six forest-risk commodities covered under the proposed legislation (2018-20 average, € million). Source: Kayrros analysis of Eurostat data.

Table 7: Indicative costs of remote sensing technologies relative to the turnover of a typical exporter of Brazilian soybeans and Ghanian cocoa.

Country	Brazil	Ghana
Crop	soybean	cocoa
Remote sensing requirements	Map a small number of large production areas Use low-cost satellite imagery and analytics Detect deforestation	Map a large number of small production areas Use high-res imagery and advanced analytics Detect deforestation and forest degradation
Annual turnover of typical exporter (est.)	€550 million p.a.	€150 million p.a.
Indicative cost of monitoring	**0.05 to 0.1% of turnover**	**0.5 to 1.0% of turnover**

Growers and domestic traders do not need to use remote sensing technologies. Growers will support the mapping of agricultural areas based on geo-localised data. They are not affected by the cost of remote-sensing technologies.

Indeed, both Indonesian oil palm smallholders[13] and Ivorian cocoa farmers[14] support the legislation's traceability requirement. The required tools, which include GPS devices such as mobile phones to delineate production areas, are low-cost and widely available. Wholesalers and domestic traders can aggregate the information provided by growers in a registry to facilitate the verification of the data by the international trading companies (Figure 8).

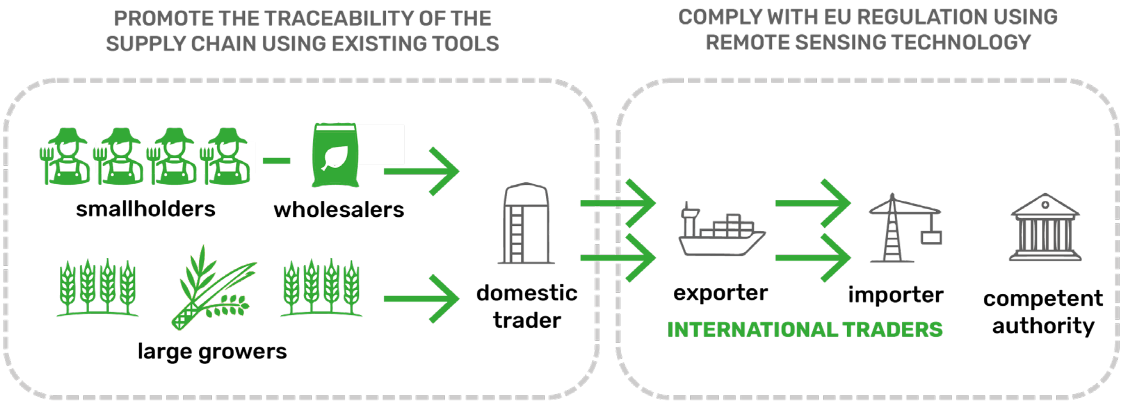

Figure 12: Use of remote sensing technology across different actors. Source: Kayrros.

For competent authorities carrying out compliance checks, the costs are likely to be lower than for importers and exporters. Firstly, their use of remote sensing data will be limited to compliance checks rather than delivering a full account of the entire supply chain. Secondly, they may be able to spread the cost across different commodities and supply chains to a greater extent than individual companies.

[13] SPKS, 24 March 2022, Submission to the European Commission on the proposal for the regulation regarding commodities associated with deforestation and forest degradation

[14] ADDF et al, 28 February 2022, Support for the geolocation requirement in the draft EU regulation on deforestation free supply chains

4. SATELLITE MONITORING FOR CORPORATE DUE DILIGENCE

4.1 Existing data sources to monitor deforestation

In recent years, the ability to monitor deforestation in global supply chains has improved due to new initiatives and methodologies. Private certification schemes like the Forest Stewardship Council (FSC) have been introduced to address consumer demands for more transparency and sustainability; the Trase Platform provides a better understanding of global supply chains and their impact on global ecosystems; and finally, isotope analysis is being explored as a tool for traceability analysis. These are valuable data sources that can also be used in combination with satellite analytics.

Private certification schemes often include criteria for forest protection (Table 8). They are usually limited to one or two commodities. The share of certified commodities varies from close to zero for cattle products to 23 to 38% for cocoa.[15]

[15] zu Ermgassen et al, 2022, Addressing indirect sourcing in zero deforestation commodity supply chains. https://doi.org/10.1126/sciadv.abn3132

Table 8: Main certification schemes relevant for forest protection

Certification	Commodity	Forest protection criteria
Round-Table on Sustainable Palm Oil (RSPO)	Palm oil	Ban on new land clearing of primary forest after 2005; carbon content assessment must be made before land clearing other types of forests.
International Sustainability and Carbon Certification (ISCC)	Palm oil	Protection of lands with high biodiversity value or high carbon stock.
Round-Table on Sustainable Soy (RTRS)	Soy, Maize	Ban on deforestation of native forests and protected areas.
Forest Stewardship Council (FSC)	Wood, Rubber	Ban on any conversion of natural forests into plantations after 1994.
Rainforest Alliance	Coffee, Cocoa	Ban on deforestation of primary forests after 2008 and of destruction of natural ecosystems after 2014.

Deforestation bans are generally restricted to primary forests or to high carbon or biodiversity-rich land and the criteria to assess the value of forests are not standardised. The certification requirements (monitoring, audit, reporting) tend to be expensive, in particular for small producers. Even though several of these schemes have started using geospatial tools, remote sensing is not usually a central part of the verification process.

IDENTITY PRESERVATION AND PRODUCT SEGREGATION

Identity preservation is the process of separating a product that is grown or transformed according to specific standards from non-compliant production all along the supply chain. It is largely used for organic products or genetically modified organisms (GMO).

Several certification systems use identity preservation, along with product segregation (which allows the mixing of products that comply with the standard's specifications, but were produced in different farms) to enhance the credibility of their label. However, most systems tend to rely on mass balance, a more affordable methodology for supply chain stakeholders, even though they encourage product segregation.

The feasibility of identity preservation and product segregation depends on the structure of the supply chains. It is harder to achieve for commodities that rely on numerous small growers, like cocoa beans.

The International Trade Centre estimates the shares of the global production area certified by voluntary sustainability standards to be 27 to 40% for cocoa, 20 to 40% for coffee, 15% for palm oil and 2% for soy.[16]

Currently, physically segregated supply chains are most widely available for palm oil under the Roundtable on Sustainable Palm Oil (RSPO) standard. According to Trase, in 2020, roughly half of RSPO certified palm oil was physically segregated. This represents less than 10% of global palm oil production. Product segregation also exists for non-GM soy and for coffee and cocoa, but at a smaller scale.[17]

[16] ITC et al, 2022, The State of Sustainable Markets 2021

[17] Trase, 2022, EU due diligence proposals on deforestation-free products

In addition to private certification schemes, some schemes have also been developed by governments. The most advanced initiative is probably the Belgian Beyond Chocolate, which covers 90% of the Belgian chocolate production market. Its goal is to increase cocoa bean traceability and generalise certifications and corporate sustainability schemes. Similar initiatives have been developed in Switzerland (SWISSCO), Germany (GISCO) and the Netherlands (DISCO).

The open-access platform **Trase Supply Chains** monitors trade flows along the supply chains of 13 commodities whose production is known to be linked with deforestation[18]. These include most of the commodities covered by the proposed EU legislation (Figure 13). For each commodity, Trase offers a range of information:

• **Market-related information:** traded volume, financial flows, production area size.

• **Environmental impact:** deforestation risk, CO2 emissions risk associated with production, biome of sourcing region.

• **Compagny commitment:** Global Canopy Forest 500 Score, zero deforestation commitment.

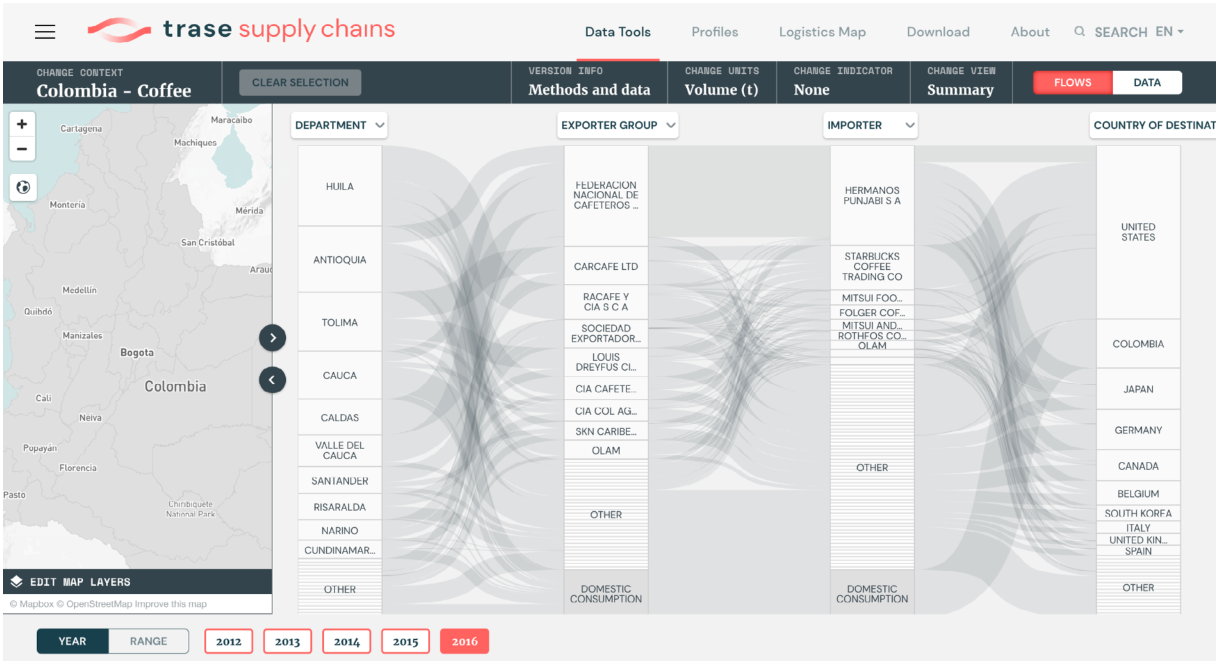

Figure 13: Supply chain analysis for Colombia-grown coffee.
Source: Trase.

Trase gathers information found on government websites and industry inventories, such as customs records and maritime shipping contracts, tax registration data, logistic ownership and capacity, and sanitary controls. The platform also takes advantage of satellite imagery to assess deforestation risks, confirm the mapping of physical assets and analyse transport networks.

Several initiatives have emerged in recent years to identify the origin of products based on scientific tests. **Stable isotope ratios** in particular have been considered as a reliable way to distinguish products such as timber or strawberries from different geographic locations. The method has been used to identify illegally harvested timber as well as illegally mined gold, for example. In the case of agricultural products, this measure can be combined with other characteristics such as DNA. However, it requires the constitution of a large library

[18] Namely: soy, palm oil, beef, shrimp, cocoa, coffee, corn, wood pulp, palm kernel, chicken, cotton, sugarcane and pork.

of samples to be tested against, and the design of a testing process when the product enters the European market. A new initiative, World Forest ID, is currently collecting reference samples of soya, cocoa and coffee from around the world, to be followed by palm oil and cattle. The Commission proposal on deforestation-free products mentions *"isotope testing"* as a way to strengthen national authorities' checks on operators.

4.2 Existing satellite-based monitoring systems

Several providers of satellite-based monitoring systems are currently available. The technical capabilities and associated costs depend to a large extent on the type of provider, which can be categorised as non-profit, public sector and private.

• **Non-profit:** some providers like Global Forest Watch or MapBiomas have developed monitoring capabilities that are available for commercial use. Their main advantages are the low cost to the user, which can drive wider adoption. However, this may limit the choice of satellite imagery and algorithms, and ultimately impact the performance of the system.

• **Public sector:** some governments (e.g. Indonesia) have also developed their own monitoring capabilities. Their expertise in the monitoring of commodities produced in the country is likely to be a strong point, but solutions developed for a specific country may be less relevant to other crops and/or regions.

• **Private:** geospatial analytics companies like Kayrros or Starling develop their own proprietary algorithms. Vertically integrated providers will rely on their own fleet of satellites, while source-agnostic providers will use a combination of public and commercial satellites.

Table 9 provides a non-comprehensive overview of some of these providers.

Table 9: Non-comprehensive survey of existing satellite-based monitoring systems

<table>
<tr><th></th><th></th><th></th><th colspan="3">Satellites used</th><th colspan="2">Services provided</th></tr>
<tr><th>Type</th><th>Provider</th><th>Scope</th><th>ESA</th><th>NASA</th><th>private</th><th>deforestation</th><th>supply chain</th></tr>
<tr><td rowspan="3">Non Profit</td><td>Global Forest Watch Pro</td><td>Global</td><td>✓</td><td>✓</td><td></td><td>yes</td><td>no</td></tr>
<tr><td>Monitoring of the Andean Amazon Project</td><td>5 Andean countries</td><td></td><td>✓</td><td>✓</td><td>yes</td><td rowspan="4">limited
no global coverage
unable to track flows</td></tr>
<tr><td>MapBiomas</td><td>Brazil 6 biomes</td><td></td><td>✓</td><td></td><td>yes</td></tr>
<tr><td rowspan="2">Public Sector</td><td>PRODES</td><td>Brazil 1 biome</td><td></td><td>✓</td><td></td><td>yes</td></tr>
<tr><td>Terpercaya</td><td>Indonesia</td><td></td><td>✓</td><td>✓</td><td>yes</td></tr>
<tr><td rowspan="2">Private</td><td>Kayrros</td><td>Global</td><td>✓</td><td>✓</td><td>✓</td><td>yes</td><td>yes</td></tr>
<tr><td>Starling</td><td>Global</td><td>✓</td><td></td><td>✓</td><td>yes</td><td>limited
unable to track flows</td></tr>
</table>

1. **Global Forest Watch Pro:** this tool provides an alerting system for deforestation and forest fires; it is the commercial version of Global Forest Watch, a free-to-use platform.

2. **Monitoring of the Andean Amazon Project:** building on GFWP, this service uses higher-resolution imagery to identify the drivers of deforestation, including agriculture (oil palm, cocoa, cattle, etc.), logging, mining and infrastructure. However, like most other platforms, it does not provide additional information on agricultural supply chains.

3. **MapBiomas:** this platform monitors deforestation and land use changes with a focus on 5 agricultural commodities: soy beans, sugarcane, rice, citrus and coffee.

4. **PRODES:** this platform, an initiative by the Brazilian government, monitors deforestation and vegetation losses in the Cerrado. It combines Landsat data with imagery from the Sino-Brazilian satellite CBERS-4, but the platform may shut down in early 2022 because of budget cuts.

5. **Terpercaya:** this initiative by the Indonesian government is focused on the oil palm industry with the participation of producers, local governments, and civil society. It issues sustainability certificates that are based on 22 indicators, including deforestation.

6. **Kayrros:** in addition to deforestation, the Kayrros platform can measure forest degradation and changes in biomass using advanced algorithms. It can also monitor the flow of commodities along the supply chain based on geolocation data.

7. **Starling:** an Airbus venture that combines proprietary data from SPOT satellites with ESA imagery to detect deforestation and land use changes.

Additionally, some economic operators have already put in place private monitoring systems and applied remote sensing technologies to their own supply chain to reduce deforestation risks. As an example, Cargill has recently developed several tools to measure the deforestation risk in its supply chains. In Latin America, the company has set up a platform named Connected4Change to engage with its palm oil suppliers, enabling them to share data all along the product's journey. As a complement, data from Global Forest Watch are used for farm monitoring. Similarly, Unilever uses Google Earth Engine and Orbital Insights and partners with Global Forest Watch to improve palm oil and soy traceability in its own supply chains. While it is sometimes difficult to assess the quality of such tools and their impact on supply chains based solely on voluntary disclosures from companies, it is clear that these systems have become increasingly important to large traders and importers, especially in Europe.

4.3 Additional considerations

The risk of satellite failure is inherent to remote sensing technologies. Every satellite has a design life measured in years, but its operating life can be cut short by equipment failure or by the depletion of its fuel reserves (without fuel the satellite will eventually crash down to earth). For example, on December 23, 2021 the European Space Agency detected an anomaly in the satellite Sentinel-1b. Further investigations showed that a serious failure in the power system has disabled the satellite, and its operating life (6 years) will fall short of its design life (12 years).

Users are advised to assess this risk for every remote sensing product under consideration. The risk of satellite failure is greatest when there are no similar satellites to fall back on. In the previous example, a twin satellite (Sentinel-1a) remains active and the main impact of the loss of Sentinel-1b is limited to a 50% drop in the frequency of measurements. In other cases, the premature loss of a satellite may be fatal for remote sensing products (Table 10).

Table 10: Additional considerations in the use of remote sensing technology

Service	Technology risk	Proprietary data
Deforestation	**Low** many providers of optical imagery	**Not required** except for small-scale, high-value crops like coffee that may require high-resolution imagery
Forest Degradation	**High** new sources of radar/ microwave satellite imagery	
Land use and crop identification	**Low** many providers of multi-spectral imagery	

Users also have to consider the legal and commercial aspects of satellite analytics. In the case of public satellites, the raw data is a public good provided by the government. Users are therefore free to negotiate the terms under which they can share the analysis and underlying visuals with other market participants. These terms may be more restrictive in the case of commercial satellite data.

5. CONCLUSION

Remote sensing technologies can play a central role in the application of the proposed EU regulation on deforestation-free products. They can support the implementation of the due diligence requirements imposed on operators, and checks carried out by competent authorities. Operators can use the satellite-based information to estimate the deforestation risk associated with traded goods. Competent authorities can use it to verify the reported information.

Satellite performances are increasing each year, both in quantity and quality, with finer resolution and more available metrics. However, current data sources and derived analytics based on artificial intelligence and advanced algorithms already provide the data needed to put in place a strong supply chain monitoring system.

Today, satellite analytics make it possible to detect deforestation and land use changes on a global scale in near-real time. Limitations, related to weather-sensitive data sources and detection thresholds of mid-resolution satellites, have a minimal impact on the ability of remote sensing to contribute to a better understanding of imported deforestation and to help operators map and transform their supply chains. Achieving complete traceability however requires the use of complementary sources of information and the contribution of all supply chain stakeholders.

Existing monitoring initiatives and tools lack standardisation, both in the methodologies and in the metrics used. As of today, there is no agreed standard but numerous different standards are used in initiatives established by a variety of stakeholders ranging from NGOs to private companies and public entities. The absence of well-established methodologies and criteria to measure imported deforestation risks is also linked to a lack of transparency. More data must be shared by supply chain stakeholders to ensure full product traceability, and full accountability for deforestation associated with imported goods. Today, operators struggle with confidentiality issues that hinder the adoption of shared monitoring tools.

Finally, the costs of remote sensing technologies and their distribution along the supply chain are an important aspect of the future regulation. Satellite analytics, when based on middle-resolution imagery and algorithmic analysis, can be very cost-effective, representing a rather modest cost for large exporting companies, traders, importers and regulators. Growers would merely provide the geolocation data of their production areas. The use of remote sensing technologies in the implementation of the new EU legislation can therefore be considered without fear of impacting small producers.

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