Forest Loss Risk Index

Satelligence

Scaling the Forest Loss Risk Index (FLRI) approach across landscapes.

Summary

The Forest Loss Risk Index (FLRI) was developed by Olam in 2018 to get insights in forest loss risk within cocoa and coffee supply chains. The results of this index were used for farmer engagement and prevention of future deforestation in high risk areas.

Olam and Satelligence have together updated the methodology to scale to landscape level from the original farm / buying station level. The methodology was tested with improved forest baselines and deforestation data in three countries: Côte d'Ivoire, Ecuador and Indonesia.

The results show that the method is applicable at global scale, with insights scaling from a single farm to the entire landscape. The improved forest baseline and deforestation data show significant differences compared to the original forest baseline and data. In many places the original data deviated (underestimated as well as overestimated) from the actual Forest Loss Risk.

The improved risk assessment both at farm level and at landscape level allows companies to effectively address forest loss risk within their soft commodity supply chains.
The landscape-level FLRI can be applied to any part of the world and used for risk assessment within any soft commodity supply chain and help any company within these supply chains to reduce deforestation risk.

Introduction

Deforestation driven by mining, logging and soft commodity production remains high. Primary forest loss increased 12% from 2019 to 2020 [1]. Companies within soft commodity (e.g palm oil, cocoa, soy) supply chains are, however, increasingly committed to halting deforestation linked to their supply chains.

These companies need tools with which they can proactively engage in high deforestation risk areas. Near-Real-time monitoring is such a tool with which forest loss can be observed.It can help in quickly engaging in relevant areas. Monitoring alone might not be sufficient to adequately prevent future deforestation. Therefore, Olam developed the Forest Loss Risk index (FLRI) in 2018 [2].
Olam developed the FLRI to determine the forest loss risk of cocoa and coffee buying stations within their supply chain. The FLRI gives an indication of which areas are at risk for future deforestation by looking at (recent) historical deforestation and the remaining forest cover. The FLRI allows Olam to look at individual cocoa and coffee buying stations and farms to determine where the highest risks are, and how these have developed over time. The original FLRI, however, suffers from three issues:

- Under and over estimation of forest in the forest baseline
- Under and over estimation of deforestation
- Non-scalable approach by calculating the FLRI values for (farm) polygons only.

These issues were addressed by:

- Adapting the FLRI to be calculated for single pixels in a continuous raster instead of for polygons only, allowing the FLRI to be calculated at a landscape level.
- Improving the forest baseline and deforestation data with proprietary data from Satelligence.

Methods

Landscape-level Forest Loss Risk Index calculation

The improved FLRI can be applied on a pixel-by-pixel basis allowing to show the FLRI spatially and easily identify high-risk areas. This approach makes it possible to view deforestation risk at landscape level instead of deforestation risk limited to within farm boundaries.

Inputs:

- A forest baseline layer that indicates where forest was present 5 years before the date of interest;
- A protected areas layer;
- A deforestation layer that indicates which pixels have been deforested over the past 5 years.

Method:

1. For each day over the time period of interest (5 years), we check if there has been deforestation on that day within a predefined radius (1000m). Deforestation influence is inverse weighted by distance. At distance=1 the weight is 1, at distance=1000 the weight is 0;
2. Similarly, temporal distance is also weighted. 1 Day old deforestation has weight 1, 5 year old deforestation has weight 0;
3. The spatial and temporal weights are multiplied;
4. If there was no deforestation on the day-of-interest, the risk is 0;
5. This process is repeated for each day in the past 5 years. All values for all pixels are summed resulting in a risk value;
6. Finally, the pixel risk value is multiplied by a weight that relates to the location inside a protected area. If a pixel is inside a protected area the weight is 1, if it is outside the weight is 0.75.

The radius for related deforestation and the weight for protected areas are tunable parameters.
For a more detailed description see appendix.

Secondary risk factors

The new method also allows for additional risk factors, such as accessibility (e.g. distance to existing roads, terrain slope), population density and proximity to existing (cocoa) plantations. The way these factors influence the final outcome is still unknown. A sensitivity analysis is needed to be able to say something about the sensitivity of these factors, which is out of scope of this paper.

Scenarios

In the remainder of this paper, we refer to 3 different FLRI usage scenarios. The original FLRI is referred to as Olam FLRI. The updated, pixel-based method but with the original baseline and deforestation algorithm is referred to as the GFW FLRI. The updated, pixel-based method that also uses improved baseline data and deforestation algorithm is referred to as Satelligence FLRI. See the section below for a further explanation of the baselines and the deforestation algorithms.

Table 1. Scenarios for FLRI calculation

Name	Baseline	Deforestation algorithm	Pixel approach	Secondary factors
Olam FLRI	GFW	GFW	NO	NO
GFW FLRI	GFW	GFW	YES	NO
Satelligence FLRI	Satelligence	Satelligence	YES	NO

Forest Baseline and deforestation

GFW baseline and tree cover loss

Baseline

The baseline used for the original FLRI calculation was created using the Hansen et al. [3] tree cover and tree cover loss layers. Defining forest as having a tree cover of more than 30% in the 2000 tree cover layer and subtracting all tree cover loss since then until the year of interest.

Tree Cover Loss

The tree cover loss (not deforestation) that was used in the original FLRI calculation was Hansen et al. (2013) [3]. The authors explicitly note that the data refers to tree cover loss. But not all tree cover loss is deforestation. Plantations, for example, might be harvested or replanted. This is not considered to be deforestation.

Tree cover loss from GFW uses Landsat satellite imagery. There are 2 Landsat satellites orbiting earth, Landsat 7 and Landsat 8. Landsat is an optical satellite and has a revisit time of 16 days on the equator. Because there are 2 satellites that are exactly opposite to each other the revisit time is 8 days.

Optical imagery such as that from the Landsat satellites is hindered by clouds, which is especially apparent in tropical areas that often have persistent cloud cover.

Improved Baseline and deforestation

Baseline

Our improved baseline is created using several satellite data sources, with reference to government definitions and data. Importantly, using optical and radar satellite time-series imagery we distinguish forest from perennial crops such as oil palm plantations, cocoa farms and other tree crops. The GFW tree cover baseline widely used for deforestation detection does not make this distinction.

By processing the entire Landsat archive back to 1984, we determine previously deforested areas, and areas therefore no longer to be considered intact forest.

Tree cover changes

Tree cover changes were mapped using 'Iterative Bayesian Updating'; a method that was first applied to radar satellite images for deforestation detection by Wageningen University in collaboration with Satelligence [4].

This method calculates the probability that an area is deforested and temporally "stacks" these probabilities to have a higher degree of certainty about the deforestation event. The method first 'flags' pixels as possibly deforested, which can be confirmed or rejected by later measurements.

Imagery from Landsat and Sentinel-2 optical satellites and the Sentinel-1 radar satellites is used as input. Using multiple input sources, revisit time is reduced to 2-3 days. Additionally, radar imagery can detect tree cover changes through cloud cover.

Using this combination of satellite imagery inputs, the change detection accuracy reached is higher than 90% globally, and higher than 95% in the humid tropics [5].

By combining the improved baseline and improved tree cover change detection, we can more accurately pinpoint which changes are actually deforestation, and which ones are plantation clearing.

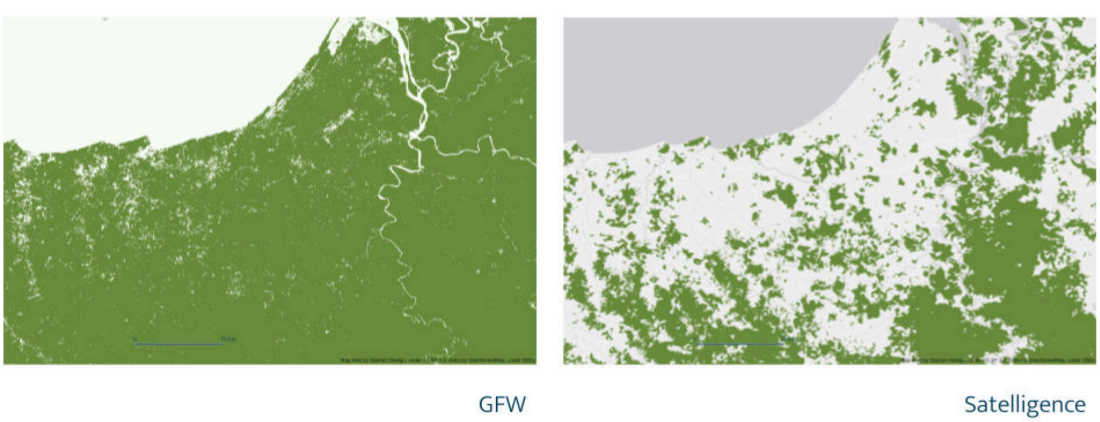

Figure 1. Forest Baseline Example for Ecuador of Global Forest Watch (left) and Satelligence (right)

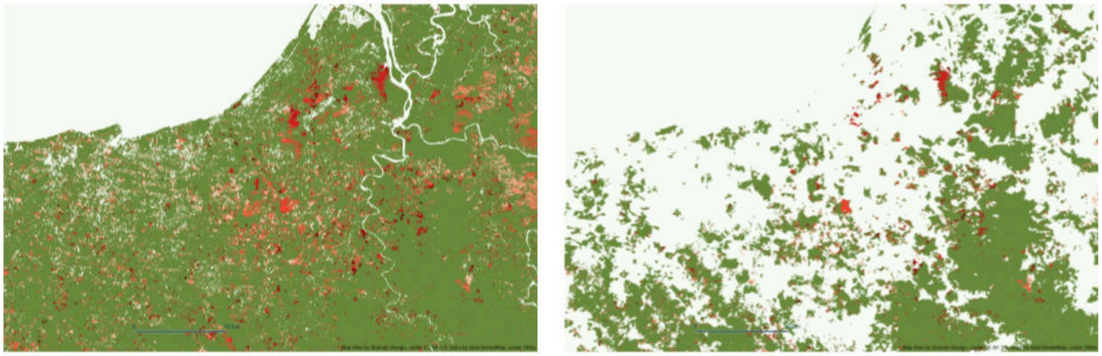

Figure 2. Tree Cover Change Example of Global Forest Watch (left) and Satelligence (right)

Study Areas

The FLRI was calculated for all scenarios in table 1 for cocoa farms and areas surrounding the cocoa farms in 3 countries: Ecuador, Cote d'Ivoire and Indonesia. There were 2735 farms in Ecuador, 3504 farms in Cote d'Ivoire and 3915 farms in Indonesia. The total number of farms assessed was 10154.

Figure 3. Overview of all study areas and farm locations in Ecuador, Cote d'Ivoire and Indonesia.

Results

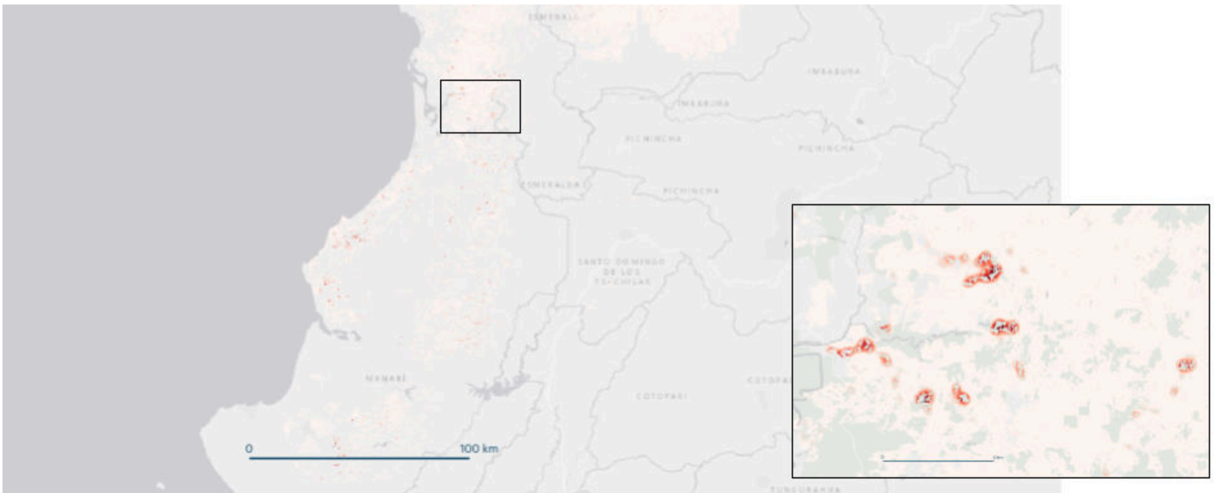

Figure 4. FLRI calculation result for Ecuador. High risk values can be found especially in the vicinity of recently deforested areas, such as those shown in the detailed inset.

Comparing FLRI and the pixel-based GFW FLRI show a high correlation (Figure 2). The pixel based FLRI method is useful in that it is a scalable method that can be applied anywhere within any supply chain. The FLRI method is not commodity specific and can also be applied to, for example coffee farms or oil palm concessions.

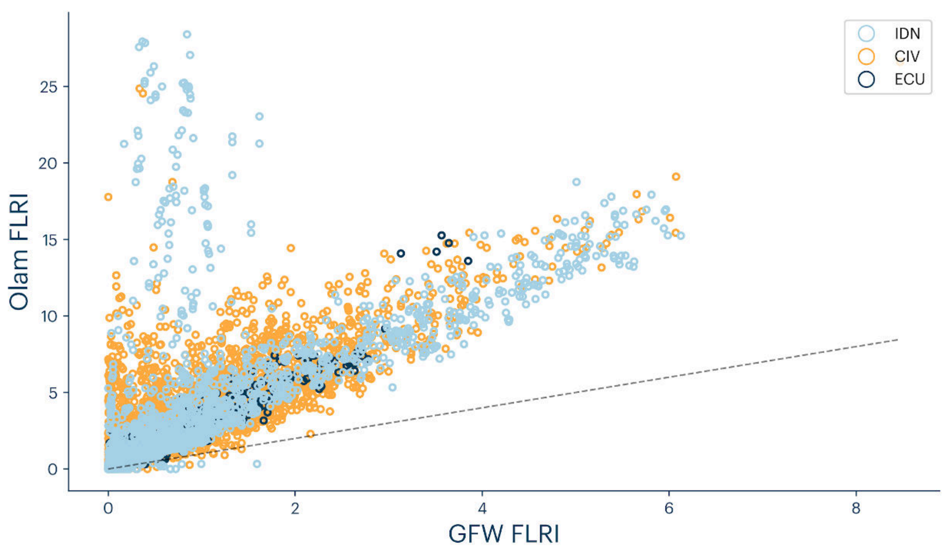

Figure 5. Correlation between Olam FLRI and GFW FRLI using the pixel-based approach, for 2019 for all OLAM Farms (+500 m buffer) in Indonesia (IDN), Côte d'Ivoire (CIV) and Ecuador (ECU). Dashed line is 1:1 line. Correlation of the entire dataset is 0.79. Olam FLRI threshold for high risk farms is 4. The GFW FLRI value that corresponds to that is ~1.

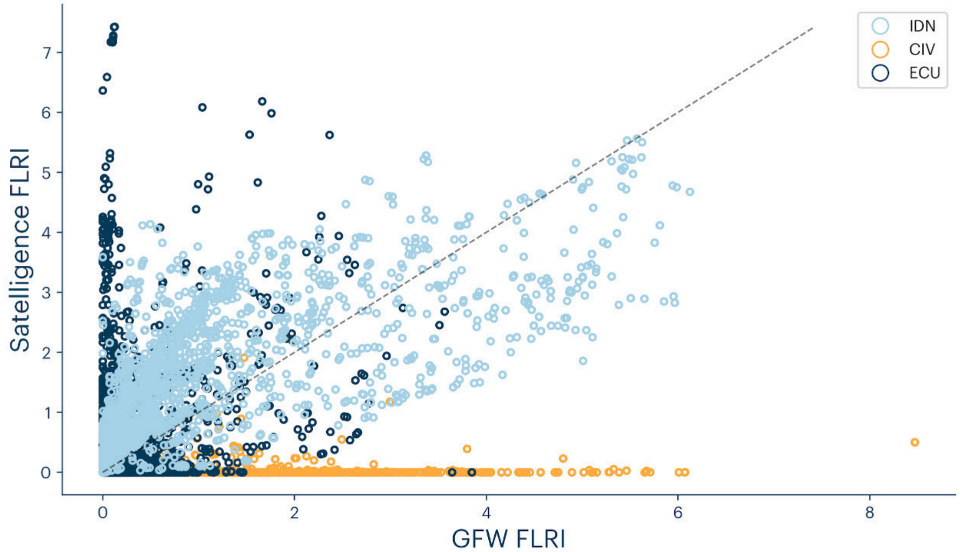

Figure 6. Correlation between FLRI values using full GFW approach (x-axis) and full Satelligence (S11) approach, y-axis in Indonesia (IDN), Côte d'Ivoire (CIV) and Ecuador (ECU). The farms that are far below the 1:1 line are those farms that have much higher FLRI values in the GFW approach, while those that are far above the 1:1 line are those that have higher FLRI values with the Satelligence data. Olam FLRI threshold for high risk farms is 4. The GFW FLRI and Satelligence FLRI value that correspond to that is ~1.

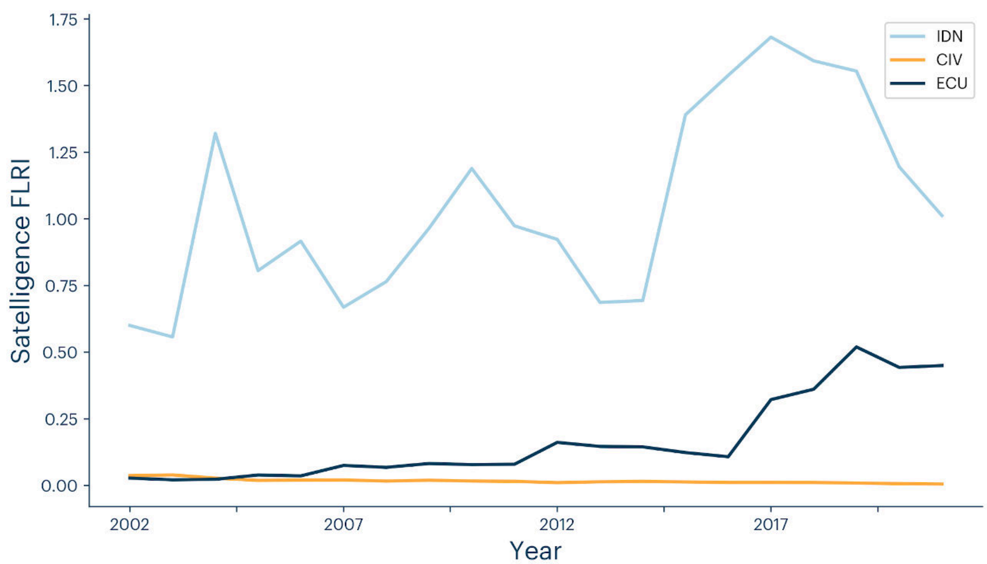

Figure 7. Evolution of Satelligence FLRI of farms + 500m buffer in all three countries. Mean FLRI values of all farms per country. Note: FLRI calculations of 2002-2005 contain fewer years of deforestation and do not look back the full 5 years.

The analysis of the results through time (Figure 3) show that each country has a different deforestation risk history:

- Cote d'Ivoire had high risk farms in the early 2000's; today there are only a few high risk farms.
- Ecuador had low risk up until 2016. After that deforestation activity increased, which in turn increased the deforestation risk of many farms.
- Indonesia had a relatively high risk for all farms; risk peaked in 2004, 2010, and 2017.

Country level risk is useful for knowing the overall status of farms within a country. High-risk areas in some regions may be missed however, which is why it is necessary to look at the risks of individual (groups of) farms to determine high risk areas within the supply chain.

This paper shows that when using only GFW data to calculate farm FLRI, there can be both risk overestimations and underestimations. Overestimations are abundant in Cote d'Ivoire, where the forest baseline overestimates forest cover.

Underestimations are seen in Ecuador (Figure 4) in areas where GFW misses important deforestation patches that do show up in Satelligence data. Risk indices are more accurate and consistent using an improved baseline.

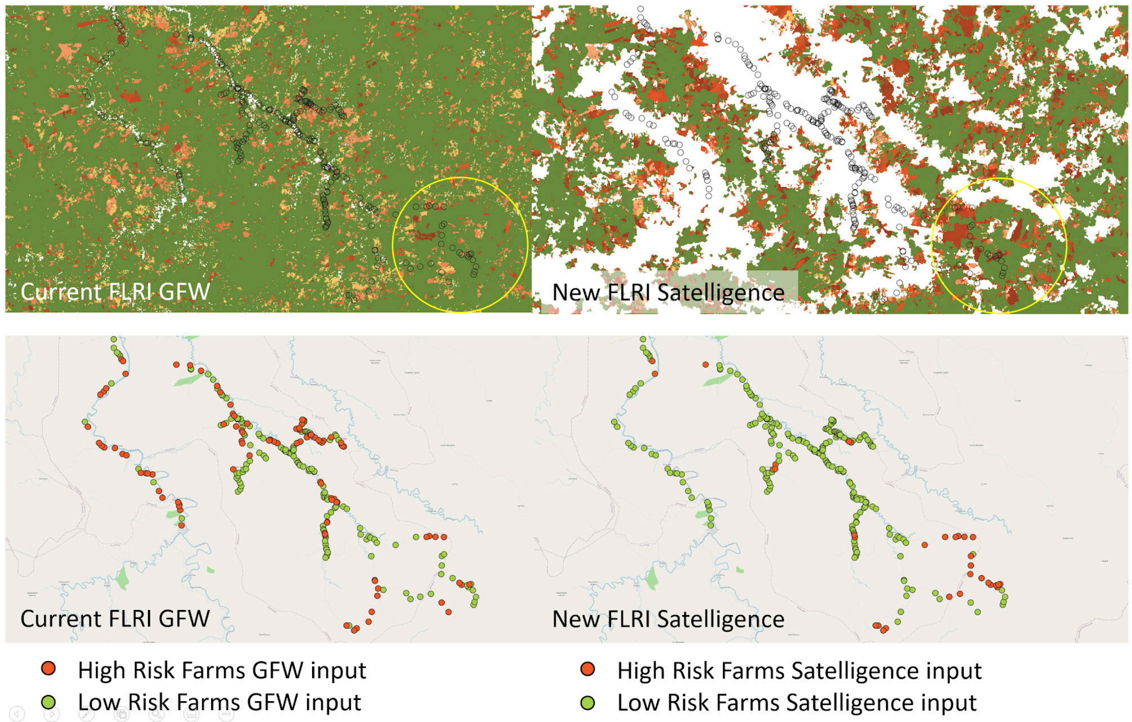

Figure 8. Example of difference in tree cover loss detection Global Forest Watch and Satelligence in Ecuador. In the top left we see the GFW forest baseline (green) and tree cover loss (shades of red). In the top right we see the Satelligence forest baseline (green) and tree cover loss (shades of red). The bottom figures show the difference the different input data have on the outcome of the risk of the farms.

Discussion

Landscape level approach

Defining a landscape based Forest Loss Risk Index as presented here instead of a farm or plot-based method makes for a more robust approach.

A landscape level approach, in combination with an open method, creates a level playing field for the entire industry; anyone can create a FLRI map that is in accordance with all other FLRI maps made with the same protocol. This increases transparency and companies don't have to make potentially sensitive supply chain data like farm locations publicly available.

Baselines

The baseline proposed in the original FLRI paper consists of the GFW tree cover layer with a threshold of 30% which includes perennial crops. In many places, this leads to an overestimation of forest cover. Especially in areas with a large number of cocoa plantations. This, in turn, leads to an overestimation of risk where there is none. One such example can be seen in figure 1. (Page 7)

Deforestation data

The major difference between the tree cover loss detection algorithm of Global Forest Watch and Satelligence, is that the Satelligence algorithm uses data from multiple satellites. This includes the Sentinel-1 radar satellite, which can penetrate cloud cover. Cloud cover is typically persistent in cocoa and coffee growing areas. The addition of Sentinel-1 and Sentinel-2 also means higher spatial (10m compared to 30m) and temporal detail (every 2-3 days compared to every 8 days).

The Satelligence algorithm picks up deforestation that is missed by the Global Forest Watch algorithm. That leads to an underestimation of risk for many farms when using the GFW method. We have seen this especially in Ecuador, where Global Forest Watch underestimates deforestation in many places (Figure 4).

Combining better deforestation detection with a better baseline means risks that are assigned to the farms are more accurate and consistent; Accurate and consistent information helps companies target high risk farms very precisely.

Conclusion

This report presents an updated methodology for scaling the Forest Loss Risk Index (FLRI), showing that it is applicable at the scale of global cocoa and coffee supply chains, with insights from the single farm up to the entire landscape. Improved forest baseline and deforestation data ensures that farmers clearing their perennial crops are no longer wrongfully associated with deforestation, at the same time providing better detection of clearing of intact forest that went previously unnoticed. In many places the original data deviated from the actual Forest Loss Risk, either underestimating or overestimating the situation.

The improved risk assessment both at farm level and at landscape level allows companies to effectively address forest loss risk within their soft commodity supply chains in a more automated and reliable fashion. Open sharing of the methodology ensures that it can be done in a completely transparent way.

The landscape-level FLRI is ready for scaling across soft commodity supply chains and geographies. We hope it inspires other companies in the cocoa and coffee sectors to join in addressing deforestation risk and promoting forest positive sourcing together.

References

[1]
https://www.globalforestwatch.org/blog/data-and-research/global-tree-cover-loss-data-2020/

[2] McLeish, M., Fasel, M., Vionnet S., Brown, C., Abeywardana, R. 2018. "Forest Loss Risk Index: A risk-based approach to prioritize action on supply chain deforestation".

[3] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

[4] Reiche J., Verhoeven R., Verbesselt J., Hamunyela E., Wielaard N., Herold M. "Characterizing Tropical Forest Cover Loss Using Dense Sentinel-1 Data and Active Fire Alerts". Remote Sensing. 2018; 10(5):777. https://doi.org/10.3390/rs10050777

[5]
https://satelligence.com/news/2020/3/24/why-you-dont-need-very-high-resolution-data-to-detect-deforestation

Appendix I. Forest Loss Risk Index Methodology

Landscape-level Forest Loss Risk Index calculation

The improved, landscape-level, FLRI can be applied on a pixel-by-pixel basis to show the FLRI spatially to easily identify high-risk areas. This approach makes it possible to view deforestation risk at landscape level instead of limited to within farm boundaries.

We made a distinction between primary and secondary risk. Primary risk contains the main parameters of the original forest loss risk index as described in [1]. Secondary risk contains additional parameters that could potentially influence the deforestation risk, such as accessibility and population density. The results described in this publication are limited to primary risk parameters, because it was outside of the scope of study to include other risk factors.

Primary Risk

Inputs

The primary forest loss risk index is calculated for an area based on the following inputs:

- A forest baseline layer that indicates where forest was present 5 years before the date of interest;
- A protected areas layer;
- A deforestation layer that indicates which pixels have been deforested over the past 5 years.

Method

For each pixel, historical deforestation in its surrounding is taken into account. The weighing factors for both distance and time are linear. This means that beyond a certain distance and time from the pixel, the weighting factors are zero.
The major change in comparison to the original FLRI is the addition of a spatial weighting factor.

This is necessary to do the calculation on a per-pixel basis. This way, the risk for that pixel can be determined using both spatial and temporal deforestation information.

Calculation

1. For each day over the time period of interest (5 years), we check if there has been deforestation on that day within a predefined radius (1000m). Deforestation influence is inverse weighted by distance. At distance=1 the weight is 1, at distance=1000 the weight is 0;
2. Similarly, temporal distance is also weighted. 1 Day old deforestation has weight 1, 5 year old deforestation has weight 0;
3. The spatial and temporal weights are multiplied;
4. If there was no deforestation on the day-of-interest, the risk is 0;
5. This process is repeated for each day in the past 5 years. All values for all pixels are summed resulting in a risk value;
6. Finally, the pixel risk value is multiplied by a weight that relates to the location inside a protected area. If a pixel is inside a protected area the weight is 1, if it is outside the weight is 0.75.
7. Risk values are only calculated for areas that are still classified as forest on the date of interest.

The radius for related deforestation and the weight for protected areas are tunable parameters.

Secondary Risk

Secondary risk factors can also be included in the calculation of the total forest loss risk. These secondary factors influence the probability of deforestation from e.g. an accessibility, or socio-economic point of view.

Inputs

The inputs described below are possible inputs that can be taken into account. This, however, is a non-exhaustive list of options. Any other spatial data that could influence deforestation can be taken into account to calculate the secondary risk.

Accessibility Risk

Accessibility relates to how well a certain area can be accessed. This depends on factors such as the distance to existing roads and the terrain slope. Flat areas next to existing roads are more likely to be deforested than steep slopes far away from existing roads.

Socio-economic risk

Socio-economic risk is deforestation risk related to e.g. population density, gender balance and the existence of perennial crops nearby. More densely populated areas could have higher deforestation risk, while areas where more women live might have lower deforestation rates. Similarly, when an area is nearby already existing plantations, the deforestation risk could potentially be higher than areas more distant to existing plantations.

Calculation

Secondary risk factors categories:

- Threshold
- Landcover
- Distance

Threshold

Threshold type input factors are maps that have hard upper and lower thresholds, and a linear weighting in between these two thresholds. A slope map is an example of a threshold factor. Flat areas up to a certain incline are treated with equal low risk (risk=0), while very steep areas are also treated with equal high risk (risk=1). Anything in between is linearly interpolated between 0 and 1.

Distance

Distance type input factors use the same procedure as the deforestation risk, but without the temporal component. Distance to the area of interest is weighed up to a certain maximum threshold (Figure A1).

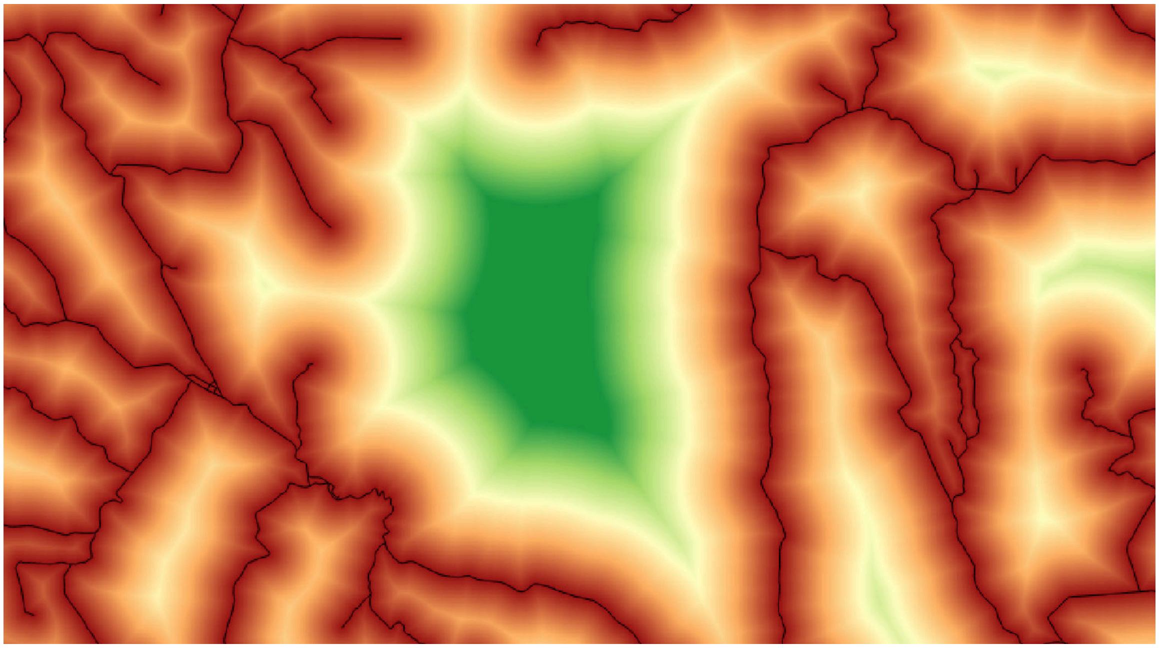

Figure A1: Deforestation risk due to road proximity. When a road (black) is very nearby, this results in a high risk score (red). This risk decreases as the distance to the nearest roads increases, until it reaches the threshold of 500m at which point the impact of roads on potential deforestation is considered negligible (green).

Landcover

Landcover type input factors are a type of distance factor, where the maximum influencing difference of the landcover types on the risk can vary. For example, a cocoa plantation could exhibit a different deforestation risk than for example an oil palm plantation.

Total Risk

The primary risk and secondary risk values are multiplied to reach a total risk per pixel as:

$$Total\ Risk\ =\ Primary\ Risk\ *\ (Secondary\ Risk\ *\ a)$$

Where a is a factor for weighting the total secondary risk factors.

When secondary risk factors are not used, they are assumed to be 1 everywhere.

Sourcing Areas

From the calculated landscape risk, we can calculate the risk for sourcing areas (e.g. cocoa farms or cocoa buying stations). These are calculated by overlaying the boundaries of these farms or buying stations with the risk map. By taking the total sum of deforestation risks within a specified radius of each farm and dividing that by the total number of pixels within a 500m radius a total farm risk is calculated with a value between 0 and 1. This aggregation does lead to situations where a small, high-risk forest patch will have less impact on the farm risk than a larger, low-risk forest, since the amount of nearby forest is taken into account in these calculations (Figure A2).

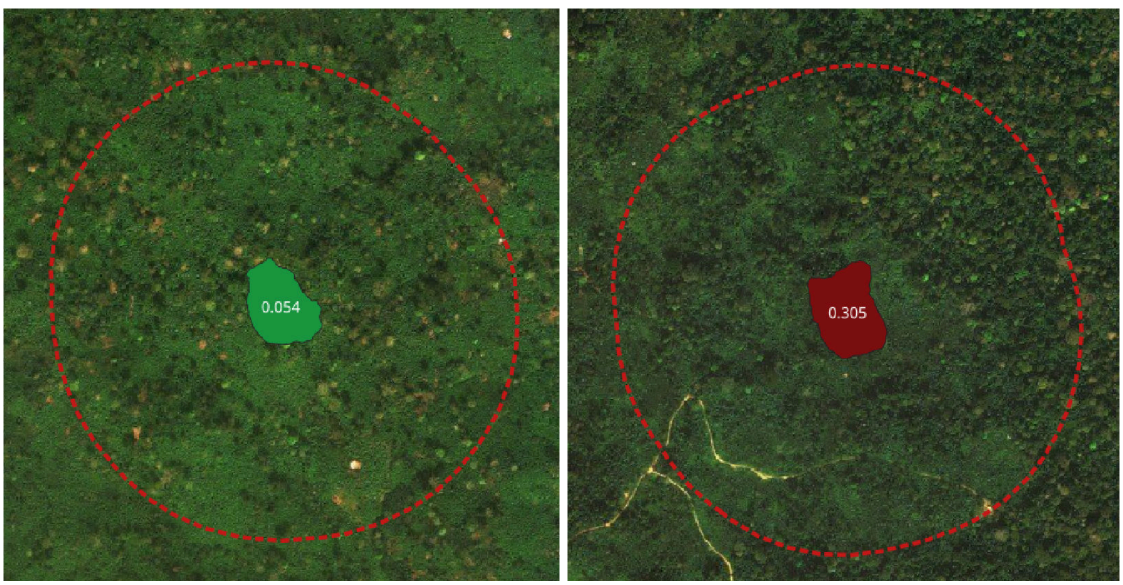

Figure A2: The cocoa farm on the left is almost entirely surrounded by other cocoa fields, with only relatively small patches of forest left within a 500m radius, leading to a low deforestation risk score. The cocoa farm on the right has a much higher deforestation risk score, due to the large areas of intact protected forest surrounding the farm.

Calculation example for single farm

A farm (+buffer) of 5 ha, consists of 4.5 ha cocoa and 0.5 ha of forest.
111 pixels of forest (~1ha) that have a mean risk of 0.3 within a farm + buffer area of 5ha, will result in a risk value of (111 * 0.3 + 888 * 0) / 1110 = 0.03, or 3 %.