PRIORITIZATION METHOD FOR TREE COVER CHANGE ALERT (GLAD ALERT) FOR VARIOUS CASES IN INDONESIA

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EXECUTIVE SUMMARY

Data from Global Forest Watch indicates a decrease in annual primary forest cover loss in Indonesia since 2016. However, the threat of illegal forest loss continues to loom over various regions, making it necessary to develop more effective forest monitoring methods. At initial stage, forest clearing is often difficult to detect, as it is generally carried out on a relatively small scale. Detection is easier for clearing at larger scale, but by that point, the extent of forest loss is already much larger, making it more challenging to address. This situation underscores the importance of having data and information available to detect early-stage forest clearing to prevent more extensive forest cover loss as early as possible.

Weekly tree cover change alert (GLAD Alert) data from the University of Maryland facilitates rapid and periodic detection of forest loss. GLAD Alert, generated every eight to fourteen days, allows users to monitor forest cover changes periodically. WRI Indonesia utilizes GLAD Alert data and combines it with contextual data, such as land status and land use, to enhance the forest monitoring and protection effectiveness in Indonesia.

This technical note is drawn up to explain the prioritization approach and methodology of GLAD Alert in three monitoring activities: (1) illegal logging monitoring, (2) landscape monitoring and (3) peatland clearing monitoring. This document is hoped to provide insights into forest monitoring methods used in various ecosystems that can be replicated by local governments, forest management units (KPH), civil society organizations, forest guards and other stakeholders in forest protection initiatives.

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WRI's Technical Note documents the methodology underlying research publications, interactive applications and other tools.

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1. INTRODUCTION

According to The State of Forest report issued by the Food and Agriculture Organization of the United Nations in 2020, Indonesia is among the top ten countries with the largest forest areas and the highest number of tree species. Since 2018, deforestation rates in Indonesia have been on a decline, averaging below 500,000 hectares per year (MoEF, 2020).[1] Global Forest Watch (GFW) data shows a similar trend.[2] Nonetheless, efforts to reduce deforestation rates must continue. The top four drivers of deforestation in Indonesia between 2001 and 2016 were (1) oil palm plantations; (2) small-scale agriculture and plantations; (3) forest conversion into cleared land, which is closely associated with the massive forest fire in 2015 and (4) timber plantations (Austin et al. 2019) (Gaveau et al. 2016). Deforestation typically starts with the opening of logging roads for access to forest areas and small-scale tree felling, which is difficult to detect. Both activities usually go undetected until the forest loss reaches a significant size (Austin et al. 2019).

The advancement of remote sensing technology has significantly contributed to improving the forest monitoring system (Taylor et al. 2020). Currently, monitoring forest changes at the global and national levels, as well as identifying driving factors, has become more feasible with the availability of medium-resolution satellite imagery (spatial resolution of 10-30 meters) that is freely accessible to the public (Margono et al. 2012). Forest change detection speed and accuracy are crucial in forest monitoring (Pratihast et al. 2016). GFW, as one of the global monitoring platforms that leverage cutting-edge technology, provides various alerts, including fire alerts and tree cover change alerts (GLAD Alert). These are all near-real-time data, which are useful for obtaining early information on potential forest fires and deforestation. Although GLAD Alert data has improved forest monitoring performance, especially at a small scale, its use for global-scale or jurisdiction-level analysis remains challenging. The large number of alerts within one observation period requires further data processing to filter and prioritize alerts that require greater attention.

In response to the challenge of large-scale forest monitoring, the World Resources Institute has developed the Places to Watch (PTW) initiative to highlight the most recent deforestation areas, which pose a threat to global forests, by prioritizing and interpreting GLAD Alert data (Weisse et al. 2017). This global initiative periodically reports the top three to five most urgent locations where the latest deforestation has occurred in protected or conservation areas and intact forest landscapes. In collaboration with various partners, this location information is then used for investigation and collecting contextual information as the basis for follow-up plans to reduce or prevent deforestation.

Brazil uses a similar prioritization method for early forest fires warning in Carajas National Park. This method has successfully helped forest fire task force personnel accelerate fire suppression actions, minimize burned areas and, in some cases, prevent the spread of forest fires (Roberto Barbosa et al. 2010). The use of prioritization methods can enhance the potential for forest monitoring on a larger scale and improve the distribution and management of human resources (forest/fire rangers).

Recognizing the benefits alert data prioritization and its potential use in Indonesia, this study adopts this method for testing in national and subnational (district) monitoring. The testing is conducted through three initiatives and with different monitoring objectives: (1) Places to Watch for Illegal Logging; (2) Landscape Monitoring and (3) Peatland Clearing Monitoring. Each initiative uses the same input data, which is the GLAD Alert data, and modifies the prioritization method to be more relevant to the conditions and data availability in Indonesia as well as aligned with monitoring goals.

Places to Watch for Illegal Forest Logging

The Places to Watch initiative set priorities on GLAD Alert data to detect forest logging in areas legally declared as illegal in Indonesia. Generally, logging methods within a forest, or deforestation, can be categorized into two types based on their approach and purpose. The first method is selective logging, which involves cutting down specific tree species within the forest, with the objective of harvesting valuable timber. The second method is land clearing in which all small trees and vegetation in the forest are cut down. The purpose of land clearing is to clear the forest land for replanting with other agricultural and plantation crops or to prepare the land for other activities such as mining.

Places to Watch for Illegal Logging, simply Places to Watch, distinguishes illegal deforestation from legal deforestation (as defined by Indonesian regulations), based on Law No. 18 of 2013 on the Prevention and Eradication of Forest Destruction. In this regulation, illegal forest logging encompasses tree felling in forest areas without valid permits.

Places to Watch data is verified using medium and high-resolution satellite images available within the three months of observation period.

Landscape Monitoring

The Landscape Monitoring initiative is a multi-stakeholder approach aimed at coordinating company partners in land-based sectors (including plantations and production crops), local governments and non-governmental organizations to collectively monitor a landscape and generate information that can be promptly and purposefully acted upon. Monitoring is done to track changes in forest cover at the landscape or jurisdictional level that are not in line with the environmental commitments of companies or the climate targets of local governments.

The monitoring system in the Landscape Monitoring initiative uses the prioritization of GLAD Alert data to detect changes in forest cover in critical areas of a landscape or jurisdiction, such as conservation forests, protected forests and peatlands. Additionally, field verification protocols are available for validating deforestation incidents and collecting field data or information as a basis for follow-up strategies.

Peatland Clearing Monitoring

This initiative is a part of the cooperation between WRI Indonesia and the Peatland Restoration Agency with a mission to monitor peat protection and conservation areas in peatland. This monitoring is part of the prevention of peat and forest fires and the protection of peatland areas in the effort to reduce national emissions. GLAD Alert is used to detect indications of peatland clearing, which is often done before the land burned as part of land preparation. Monitoring is also conducted only in forested peatland areas.

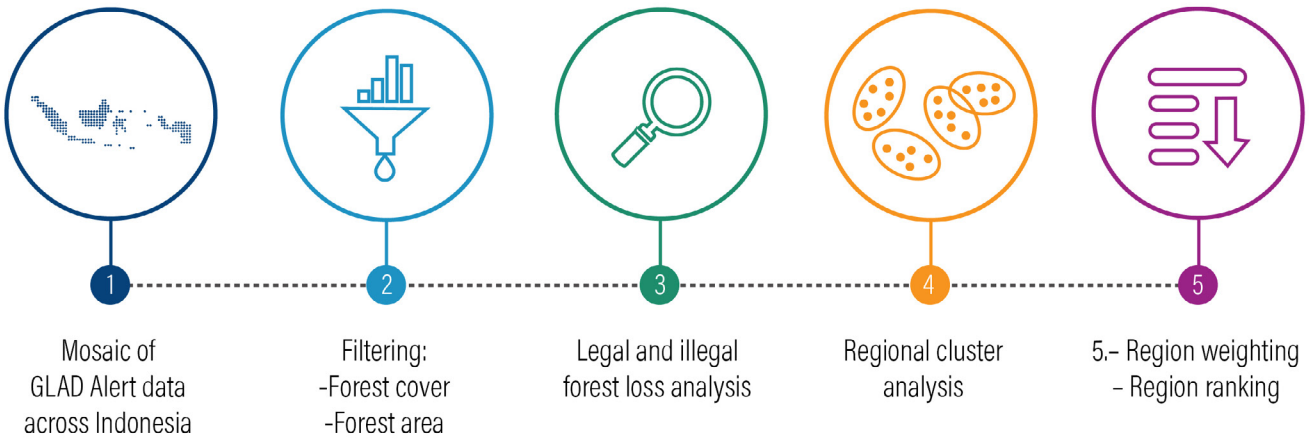
2.METHOD

Places to Watch for Illegal Forest Logging

Places to Watch for Illegal Forest Logging is the title of a blogpost published every three months on the WRI Indonesia website. The first edition of Places to Watch can be accessed here. Like Places to Watch, the Places to Watch blog lists five priority areas with the highest indications of illegal logging for monitoring. The Places to Watch analysis is limited to areas with actual forest cover, areas within forest areas and areas outside permits for forest utilization or within permits for forest utilization that prohibit tree felling. The analysis covers 5 km x 5 km grid cell covering the entire Indonesian territory.

In general, the method used by Places to Watch consists of two main stages: identifying areas with indications of illegal logging and determining the causes of illegal logging. Identifying areas with indications of illegal logging is done in five stages (Figure 1). Various satellite images (Planet, Landsat and Sentinel) are used to verify the data results of the analysis and determine the driver of deforestation. The spatial data used in Places to Watch is presented in Table 1.

Figure 1 | The five stages in identifying the top five regions indicating illegal logging under the Places to Watch method.



Tabel 1 | **Spatial data and satellite images used in the Places to Watch methodology**

Data	Source	Analysis
GLAD Alert	Global Forest Watch (https://www.globalforestwatch.org/map/global/)	Alerts for tree cover loss
Forest Area Map	Ministry of Environment and Forestry (KLHK) (https://geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	Production Forest (HP), Protected Forest (HL), and Conservation Forest (HK)
Land Cover Map		Actual forest cover (primary and secondary forests, excluding industrial forests)
Forest Utilization Permit Map		IUPHHK-HA, IUPHHK-HTI[3], IUPHHK-RE, Social Forestry, IPK[4], and IPPKH[5] regions
Satellite Images	Planet, Landsat and Sentinel images (on the Global Forest Watch website)	Validation of GLAD Alert data and identification of causes of forest loss

Indications of Illegal Logging

Indications of illegal logging are analyzed through five stages (Figure 1). First, GLAD Alert data over a three-month observation[6] period across Indonesia were collected in the form of data mosaics. Second, GLAD Alert data within Forest Areas (Conservation Forest, Protected Forest and Production Forest) with actual forest cover (primary and secondary forests, excluding industrial forests) are filtered for further analysis. This second stage uses the Forest Area Map and Land Cover map issued by the Ministry of Environment and Forestry (KLHK). Third, the filtered GLAD Alert data is then analyzed for legality based on the laws and regulations in Indonesia[7], so only illegal deforestation would be analyzed in the next stage. Table 2 summarizes the deforestation legality analysis. Fourth, the illegal deforestation data is grouped based on the highest spatial distribution in a 5 km x 5 km grid using Z-score analysis (Lwin and Murayama 2009). GLAD Alert data located in proximity to two different grids or more is then manually merged into one group or cluster. Fifth, the results of the cluster analysis are then ranked based on the size of the area, resulting in the top 10 regions to be verified using high and medium-resolution satellite images in the next stage. The satellite images used are Planet mosaic images (spatial resolution of 3-5 meters), Sentinel 2 (spatial resolution of 10 meters) and Landsat (spatial resolution of 30 meters).

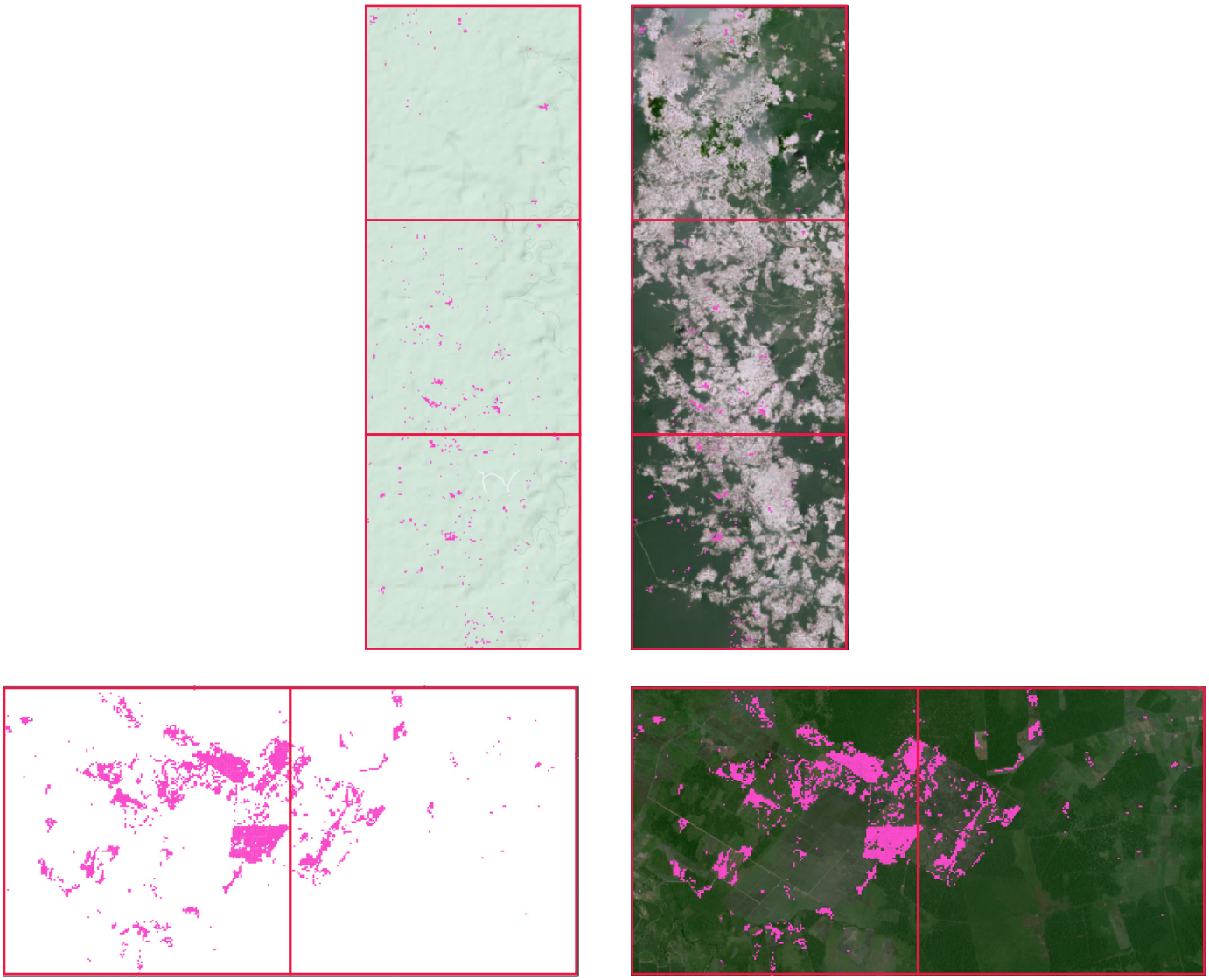
Tabel 2 | **Summary of deforestation legality analysis based on related laws and regulations**

FOREST AREA	ISSUED FOREST UTILIZATION PERMIT	GLAD ALERT	LEGAL/ILLEGAL STATUS
Conservation Forest	Social Forestry Permit is allowed, but tree felling and wood extraction are not allowed	Yes	Illegal
		No	NA
Protected Forest	Social Forestry Permit is allowed, but tree felling and wood extraction are not allowed.	Yes	Illegal
		No	NA
	Forest Utilization Permit for Forest Area Borrowing is allowed, and tree felling and wood extraction are allowed.	Yes	Legal
		No	NA
Production Forest: • Limited Production Forest, • Permanent Production Forest, • Convertible Production Forest.	Social Forestry Permit allowed for tree felling and wood extraction. Forest Area Borrowing Permit: tree felling and wood extraction allowed. Forest Timber Utilization Business License – Natural Forest (IUPHHK-HA): selective cutting allowed. Forest Timber Utilization Business License – Industrial Timber Plantation (IUPHHK-HTI): clear-cutting allowed. Forest Timber Utilization Business License – Ecosystem Restoration (IUPHHK-RE): small-scale tree felling allowed.	Yes	Illegal (if logging occurs outside of the concession area)
		No	NA

Unlike the other two prioritization methods, Places to Watch ranks priority areas solely based on the size of the area and does not consider concern score. This is based on the consideration that legal and illegal status is binary, with only two assessment outcomes, legal (0) or illegal (1), and nothing in between.

Another difference with the other two prioritization methods is the clustering grid analysis. Figure 2 illustrates why cluster analysis is required in identifying large-scale illegal logging activities. Some illegal activities, such as mining and plantation expansion, sometimes extend beyond that the 5 km x 5 km grid. Therefore, cluster analysis, in which several adjacent grids are analyzed to detect illegal activities on a large scale, is necessary. Figure 2 (top) shows mining activities that extend vertically from the north to the south detected in three adjacent grid squares. Meanwhile, Figure 2 (bottom) shows plantation expansion activities that extend horizontally from the east to the west detected in two adjacent grid squares. If the clustering process is omitted in the analysis phase, illegal logging activities in Figure 2 will not be detected as the same activity, potentially leading to misinterpretation of the analysis.

Figure 2 | **Examples of illegal logging activities for specific allocations, such as mining (top) and plantations (bottom)**



Verification using high-resolution satellite images

Verification of the 10 areas of interest (AOIs) generated from the analysis of illegal logging indications is carried out remotely using high and medium-resolution satellite images (Planet, Landsat, Sentinel). Verification is done to confirm the occurrence of forest clearing in areas that have received alerts within the AOI in the top 5. In cases of false positives, the area for which GLAD Alert data is generated, but no forest clearing has occurred, is removed from the analysis.

Figure 3 | Example of forest cover change verification using high-resolution satellite images (Planet)

Verification using Planet's monthly composite images[8] is performed to confirm the occurrence of forest clearing (true alert) and to determine the cause of forest clearing from observation of the images. Figure 3 shows an example of the results of forest cover change verification. Such change is usually visually observable through comparison of sequential images in terms of acquisition time. Figure 3 detects land change that occurs from the beginning of the observation period (April 2020) to the end of the observation period (June 2020). The pink areas indicate GLAD Alerts for tree cover loss during the three-month period (April 1-June 30, 2020).

Analysis of the Causes of Forest Loss

Areas where forest clearing has been verified are further analyzed to determine the cause of the forest clearing using satellite images. In this analysis, visual interpretation and assessment by analysts are used to observe changes in land color, patterns, shapes, estimated areas and texture. Forest clearing is typically done for purposes such as plantations, agriculture, mining, aquaculture or selective logging. Another purpose is land banking. In Indonesia, land banking refers to logging activities outside the authorized areas by clearing the forest, usually done to claim land tenure before it is used for other activities (Parker et al. 2018). For example, during the observation period in Figure 2, the cleared forest had not been utilized (planted or built upon) and remained as open land.

Therefore, the cause of forest clearing cannot be identified and is suspected to be land banking. If the forest clearing is indicated to be natural, such as from natural forest fires and landslides due to an earthquake in the vicinity of the cleared forest area, the area will not be included in the final analysis results. The final analysis results will consist of five priority areas that only include areas of forest clearing driven by human activities, instead of natural events.

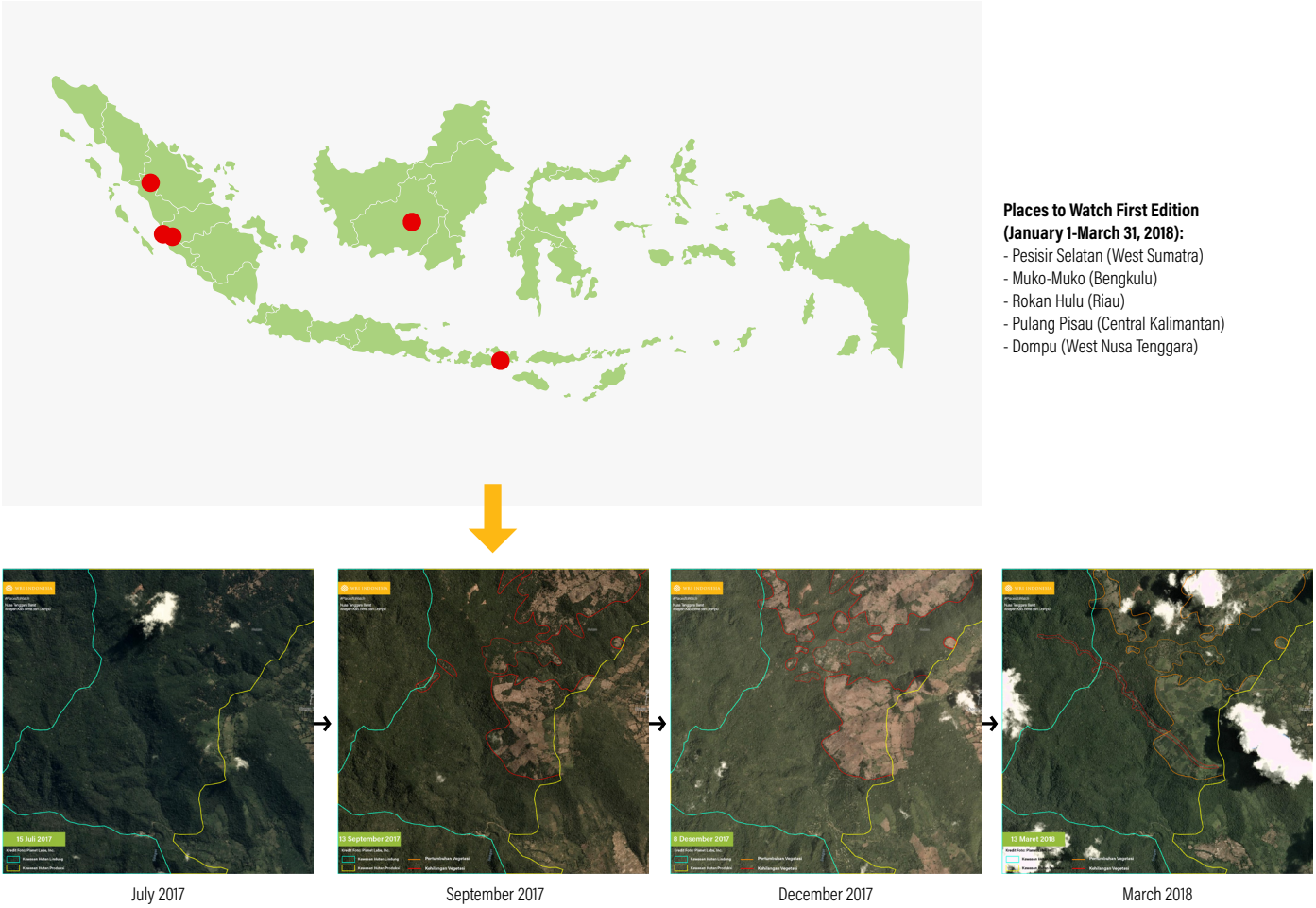
To strengthen the analysis results, the legal team also gathers secondary data from the media and reports of illegal logging activities in these five priority areas to be covered in the blogpost. Figure 4 shows the results of the prioritization analysis of the First Edition of Places to Watch (January 1-March 31, 2020). Figure 3 shows land cover changes in Dompu Regency, West Nusa Tenggara, occurring since September 2017. In March 2018, the cleared forest was observed to be utilized for dryland farming.

Field Verification

In general, the Places to Watch method is applied remotely without field verification. However, since 2020, field verification has been carried out in some locations under cooperation with various partners. In 2020, the Leuser Conservation Forum (Forum Konservasi Leuser or FKL) assisted in verifying the data generated from the Places to Watch analysis in the Leuser Ecosystem (Kawasan Ekosistem Leuser or KEL). The verified Places to Watch data had been modified to cover only KEL instead of the national coverage. The field verification in KEL indicated the occurrence of illegal forest clearing in 9 out of 10 priority areas identified by the Places to Watch analysis. The main driving factor for this forest clearing was dryland farming, such as banana and coffee plantations. One priority area couldn't be verified because access to that area was closed off by the local community due to the pandemic.

In 2021, field verification of the Places to Watch data was carried out in two provinces, Jambi and South Kalimantan, with assistance from the Independent Forestry Monitoring Network (Jaringan Pemantau Independen Kehutanan or JPIK). Similar to KEL, the Places to Watch analysis in these two provinces was also modified to focus on national parks in each province. A total of six points were verified in these two provinces, all of which indicated the occurrence of illegal forest clearing through both selective logging and clear-cutting. Factors driving forest clearing included the food estate program in South Kalimantan. In Jambi, the JPIK team faced difficulties in conducting further observations due to conflicts with the forest communities living around the deforested forest areas.

Figure 4 | **Prioritization results from the first edition of Places to Watch (January 1-March 31, 2020)**



Landscape Monitoring

In general, landscape monitoring uses the framework and process of Places to Watch (Weisse et al. 2017) with adjusted filtering and weighting criteria for identifying verification areas. The spatial data used in landscape monitoring analysis is presented in Table 3.

Table 3 | Spatial data and satellite images used in landscape monitoring analysis

Data	Source	Analysis
GLAD Alert	Global Forest Watch (https://www.globalforestwatch.org/map/global/)	Alerts for tree cover loss
Forest Area Map	Ministry of Environment and Forestry or KLHK (https:// geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	Conservation or protected areas
Forest Cover Map	Belinda Margono et al (2000) accessed through Global Forest Watch (https://www.globalforestwatch.org/map/global/)	Primary and secondary forest cover
Peatland Map/Peat Ecosystem Function Map	Ministry of Agriculture of the Republic of Indonesia (2012) accessed through Global Forest Watch (https://www.globalforestwatch.org/map/global/) Ministry of Environment and Forestry http://pkgppkl.menlhk.go.id/webgis/peta_dasar/	Peatland land cover
Oil Palm Plantation Permit Map	Global Forest Watch (https://www.globalforestwatch.org/map/global/)	Oil palm concessions
Forest Utilization Permit Map	Ministry of Environment and Forestry or KLHK (https:// geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	IUPHHK-HA and IUPHHK-HTI concession areas
Satellite Images	Planet, Landsat, and Sentinel images (in Global Forest Watch website)	Verification of GLAD Alert data and identification of causes of forest loss
Administrative Boundary Map	Geospatial Information Agency (2016)	Siak District boundaries

Landscape monitoring is generally divided into five stages, as explained in Figure 5.

Figure 5 | Landscape monitoring stages Determination of Concern Area

Landscape monitoring aims to prioritize land clearing that is not in line with no-deforestation commitments in commodity supply chains, especially palm oil. No Deforestation, Peat, and Exploitation (NDPE) is a commitment or policy commonly adopted by companies, particularly those in the plantation and forestry sectors, to ensure sustainable commodity supply chains that are not associated with deforestation, peatland clearance and exploitation of human resources. In the initial stage of determining concern areas, the following steps are taken:

1. GLAD Alert is compiled on a monthly basis and clipped based on the administrative boundaries of the target landscape.
2. GLAD Alert is further clipped based on data on oil palm plantation permits to eliminate alerts for oil palm replanting and data on forest utilization permits to eliminate alerts for timber harvesting
3. Identifying the biophysical conditions of the landscape and determining concern areas, such as primary and secondary forest covers, conservation and/or protected areas and peatlands.

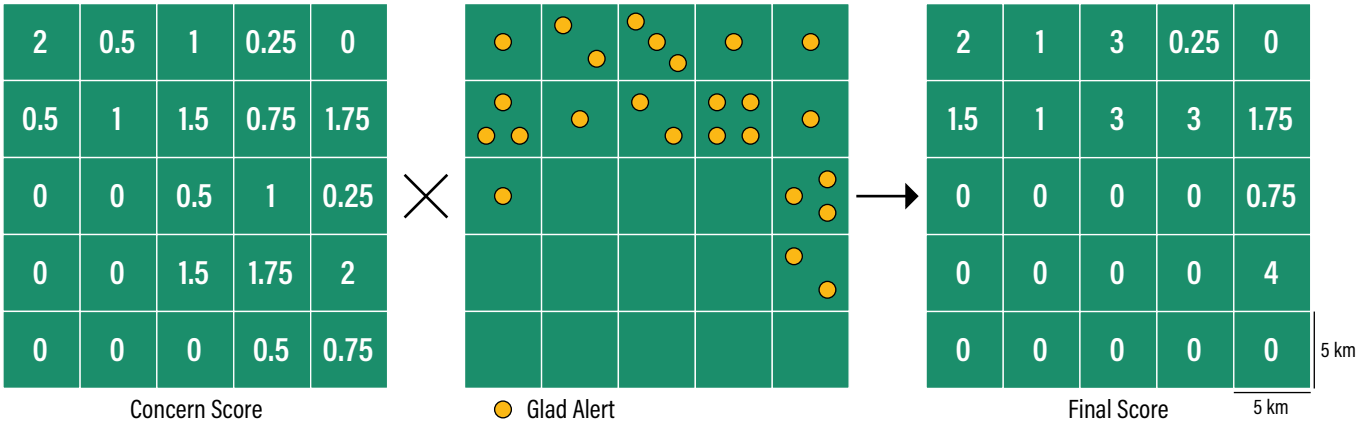
Weighting

1. Using a 5 km x 5 km grid size. Grid size adjustments are made to capture large loss clusters, such as from fires or clear-cutting, reduce edge effects and reduce processing time, while keeping the grid small enough to ensure variation across grid cells and capture details at the sub-national scale.
2. The formula used in the Concern Score calculation for each grid cell is based on the proportion of the concern area in each grid cell and through a process of trial and error. The Concern Score calculation is adapted from the Places to Watch method (Weisse et al. 2017), but adjusted to give a higher weight (times 2) to conservation areas to capture small tree cover loss clusters. This is because encroachment or land clearing in conservation/protected areas is often done by local communities on a small scale (Mat Zin and Ahmad 2015).

Verification Area Identification

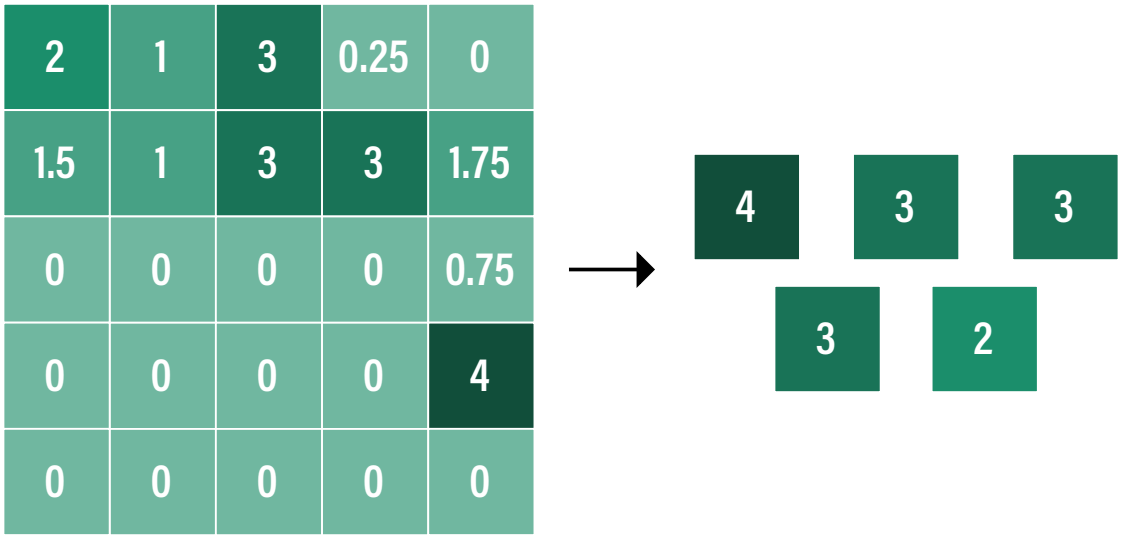
Identifying areas for verification includes a two-step prioritization process. The first stage in the prioritization process is converting the GLAD Alert raster input data into coordinate points, which serve as the center point of each pixel. Subsequently, the number of GLAD Alerts within each grid cell is multiplied by the Concern Score, resulting in a final score representing the importance of each grid cell and the urgency of forest clearing in that grid cell, as illustrated in Figure 6. The final score is calculated using the method used in Places to Watch (Weisse et al. 2017).

Figure 6 | First prioritization stage



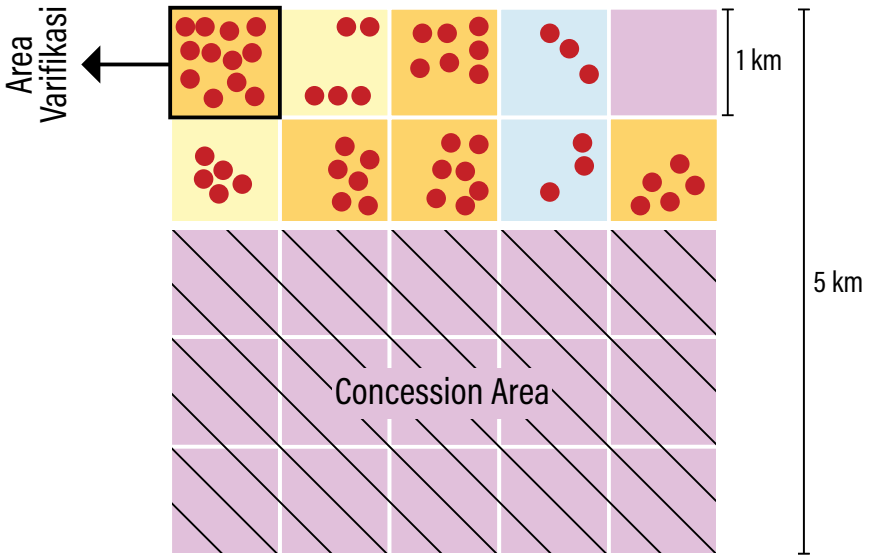
After a final score is assigned to each grid cell, the next step is the Jenks natural break classification, where class classification is based on the inherent grouping in the data. This means grouping the same values and maximizing differences between classes (Chen et al. 2013). The classification results divide and group grid cells into five classes: not urgent, less urgent, fairly urgent, urgent and very urgent. A total of 10-20 fairly urgent, urgent and very urgent grid cells are selected for initial verification using high-resolution satellite images (Figure 6). Initial verification is carried out to eliminate possible false positives. Verification using satellite images in landscape monitoring is carried out through the same process as Places to Watch as presented in Figure 3.

Figure 7 | Grid class classification



The second stage in the prioritization process is applying a 1 km x 1 km grid system to the 10-20 grid cells that pass the curation process. Subsequently, grid cells overlapping with concession boundaries are eliminated, and the GLAD Alerts density in each grid cell is calculated. Grid cells with the highest density value are selected as verification areas (Figure 7).

Figure 8 | Second prioritization stage using GLAD Alert density

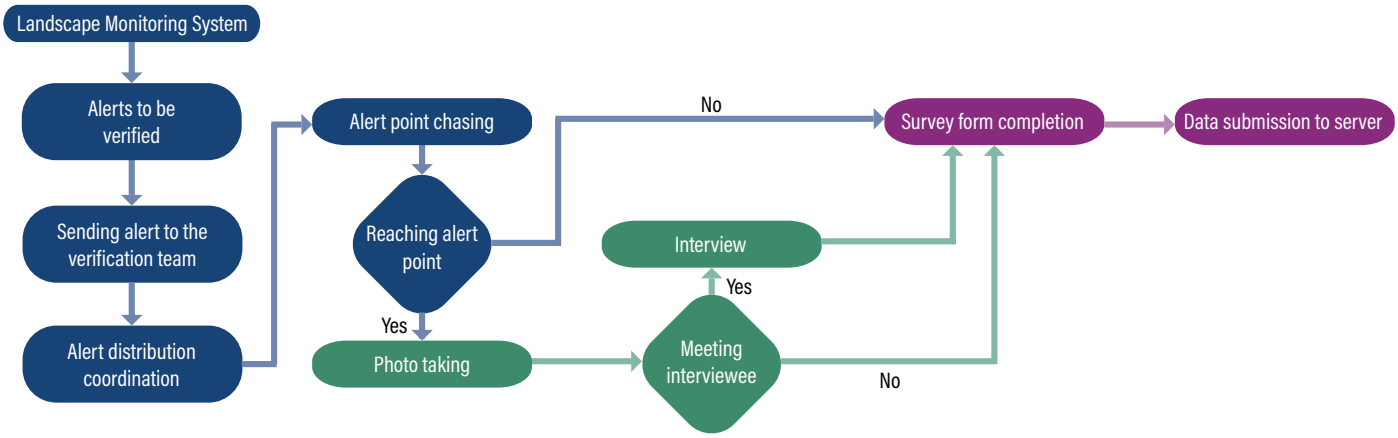


Field Verification Protocol

Field verification is carried out to test the accuracy of the Alerts and gather contextual data and information on the causes of deforestation. Field data will be the basis for further interventions as preventive measures against the spread of deforestation and for improvements of the GLAD Alert system performance.

The field verification protocol is designed to be used by various parties and adaptable to the needs and characteristics of specific landscapes. The field verification process flow can be seen in Figure 9 below.

Figure 9 | **Field verification process flow**

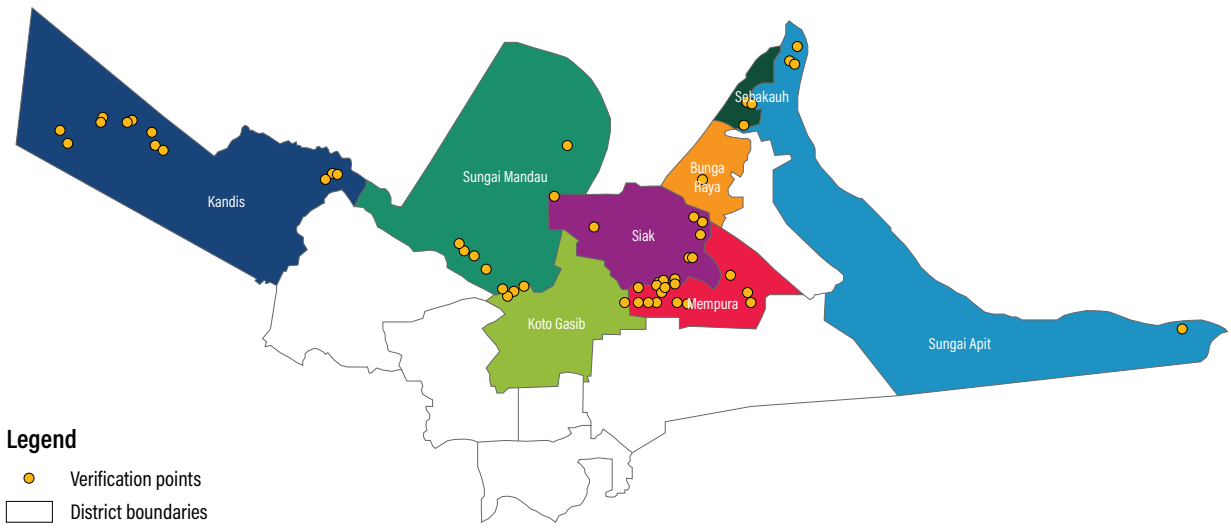


Field Verification Results of Landscape Monitoring

This Landscape Monitoring initiative was first piloted in Siak District, Riau Province in collaboration with the Siak District Agriculture Office. Monitoring was conducted in unauthorized Other Land Use (APL) areas containing forest covers and peatlands, covering an area of approximately 294,000 hectares. The Siak District Agriculture Office, in collaboration with WRI Indonesia, selected eight trained regional facilitators (fasda) to conduct alert verifications. Trained and equipped, every two months the regional facilitators received around 10-20 priority Alerts for verification.

In the field verification process, the regional facilitator team used a smartphone app to facilitate data collection in the field.

Figure 10 | **Priority alert verification points**



Throughout 2019, the technical team of WRI Indonesia selected 59 priority alert verification points for verification by the regional facilitator team. This was conducted in April, June, August and October 2019. The verification locations included 9 districts and 26 villages (Figure 9). In the verification process, it was found that 44 out of 59 points (75 percent) were confirmed to have experienced land clearing, while 9 out of 59 points (15 percent) were false positives, meaning that alerts were detected, but tree cover loss did not actually occur, and 6 out of 59 points (10 percent) could not be verified due to various obstacles such as lack of access roads and hazardous conditions.

Field observations found that, in 31 out of 44 points (70 percent) confirmed to have experienced land clearing, it was driven by activities such as oil palm and rubber plantations. Meanwhile, in 13 out of 44 points (30 percent), the land clearing was identified to be driven by other activities such as agriculture, horticulture, land clearing without direct utilization and burning.

Figure 11 below is an example of the photo and information collected from landscape monitoring verification in April 2019 in Teluk Merempan Village, Mempura Subdistrict, Siak District, Riau Province.

Figure 11 | **Verification point location photos**

In this location, 91 tree cover loss alerts were detected, equivalent to an area of approximately eight hectares. Upon visiting the location, a large, cleared land (more than 25 hectares) was observed. The alerts were suspected to indicate ongoing land clearing activities (Figure 10). Through field observations, the land clearing was estimated to occur approximately one month earlier. Dense forest cover was still visible around the cleared area. The land clearing was also located near the riverbanks. According to information from locals, the land was privately owned and was in the process of being developed into an oil palm plantation without a plantation permit. Community-owned oil palm plantations were also found in the vicinity.

Peatland Clearing Monitoring

Peatland and forest clearing monitoring serves to identify illegal land clearing in moratorium areas and the protective function of peatland ecosystem. Peatland monitoring is carried out in seven priority provinces of the Peatland Restoration Agency (BRG), namely South Sumatra, Riau, Jambi, West Kalimantan, South Kalimantan, Central Kalimantan and Papua. Peatland clearing monitoring is focused on peatland areas protected and prohibited for clearing based on Government Regulation Number 57/2016 on Peatland Ecosystem Protection and Management and the moratorium on peatland and forest clearing, which includes:

- Moratorium areas or areas where new land clearing permits in natural forests and peatlands are prohibited by the prevailing regulations.
- Peatland protective function is areas within peatlands designated for protective functions where new land clearing is prohibited.
- Protected forest and conservation areas.

Method for Peatland Clearing Monitoring

In general, peatland clearing monitoring is divided into five stages as explained in Figure 12 below.

Figure 12 | **Stages of Peatland Clearing Monitoring Method**

1. Concern Area Determination (area of interest)

   This stage is the initial determination of monitoring areas, which are focused on degraded peatland areas. The indicators used for concern area determination include:

   - Degraded peatland based on indicative peatland restoration maps
   - Priority Peatland Hydrological Units (KHG) designated by the Peatland Restoration Agency as priority intervention areas for peatland rewetting, revitalization and revegetation
   - Peatlands within peatland moratorium and forest areas

The data used in the analysis can be seen in Table 4.

Table 4 | **Data used in the prioritization analysis of peatland clearing monitoring areas**

Data	Source	Analysis
GLAD Alert	Global Forest Watch (https://www.globalforestwatch.org/map/global/)	Alerts for tree cover loss
Indicative Peatland Restoration Map	Peatland Restoration Agency (2017)	Distribution of degraded peatlands in consideration of various factors, such as burned peat, canalized peat, protective functions and peatland cultivation
Peatland Hydrological Units Map	Ministry of Environment and Forestry (KLHK) (https://geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	Boundaries of peatland ecosystems located between two rivers, between a river and the sea and/or in waterlogged or swamp areas
Peatland and Forest Moratorium Map	Ministry of Environment and Forestry (KLHK) (https://geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	Areas designated for not granting new land clearing permits in natural forests and peatlands by the applicable regulations
Forest Area Map	Ministry of Environment and Forestry (KLHK) (https://geoportal.menlhk.go.id/arcgis/rest/services/KLHK)	Areas designated as protected forest and conservation forest by the applicable regulations
Satellite Imagery	Planet, Landsat and Sentinel imagery (available on the Global Forest Watch website)	Verification of GLAD Alert data and identification of drivers of tree cover loss
Administrative Boundary Map	Geospatial Information Agency (2016)	Administrative boundaries of the seven priority provinces

2. Weighting

Weighting is conducted using the filtering method of Places to Watch with the following adjustments:

1. Filtering with a 5 km x 5 km grid

2. Calculation of concern area score
Calculate the Area Weight of Each Grid

$$Average\ Ratio\ Area = \frac{([Lk1] + [Lk2] + [Lk3])}{2500\ hectares}$$

Where:
Lk1: Conservation land area
Lk2: Protected land area
Lk3: Area of degraded peatland based on the Indicative Peatland Restoration Map.

3. Priority Area Determination

To determine priority areas, scores are calculated by overlapping grids that have been weighted through GLAD Alerts.

$$Score = Average\ Ratio\ Area\ x\ Number\ of\ GLAD\ Alerts$$

Upon obtaining the top 10 grids with the highest scores, initial verification is conducted by examining the latest high-resolution satellite imagery from Planet and Sentinel. Satellite image verification is carried out to identify early indications of the causes of deforestation and identify false-positive GLAD Alerts.

4. Verification using high-resolution satellite imagery

Verification is carried out using satellite imagery in peatland clearing monitoring through a process similar to what is used in Places to Watch. An example of the verification result can be seen in Figure 3.

5. Field Verification

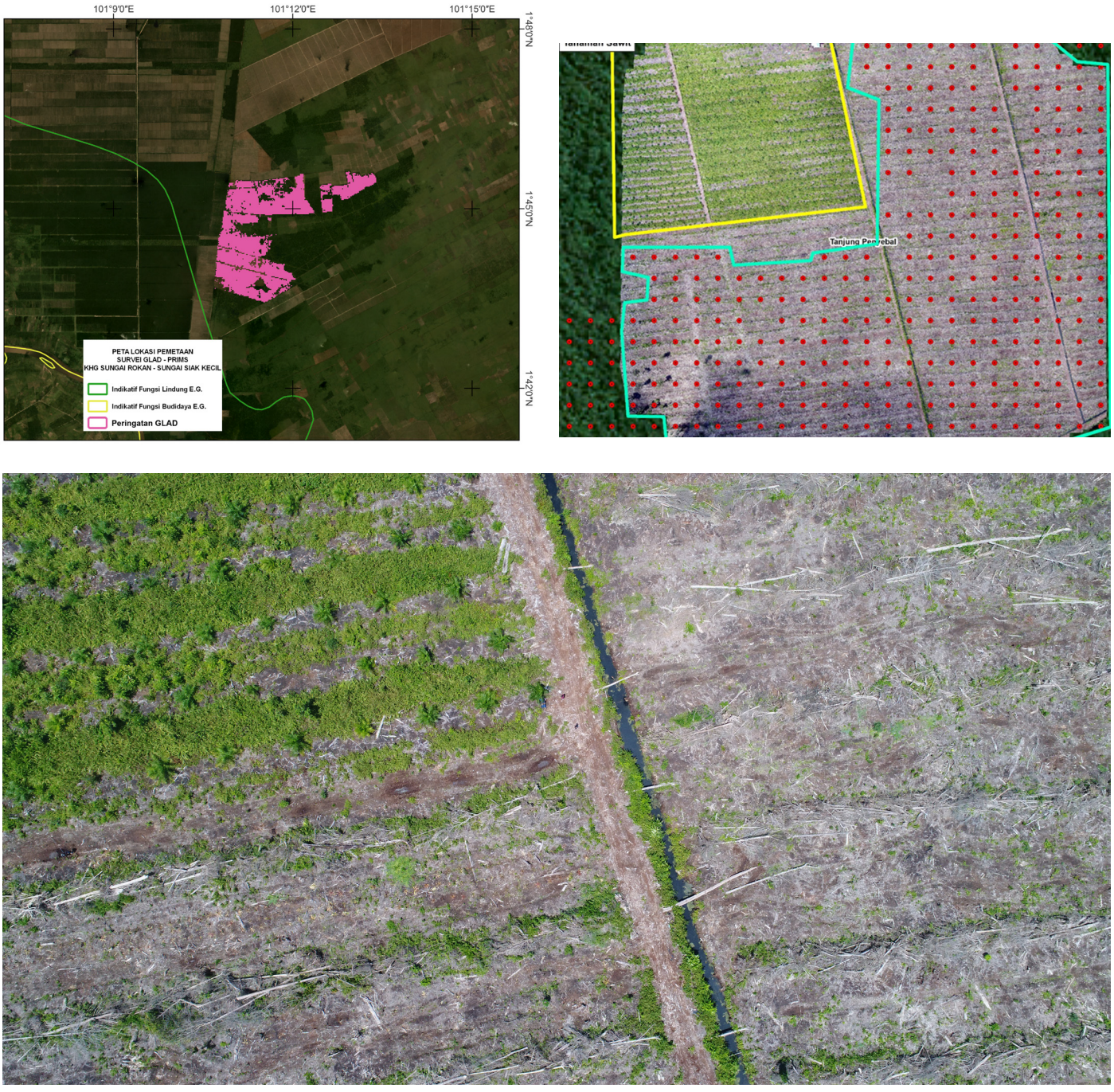
The data collected during field verification for identifying the drivers of peatland and forest clearing include:

- Peat thickness to verify whether the priority area falls under the protective peatland function based on peat thickness of more than three meters
- Indications of the drivers of peatland clearing and land status
- Mapping with drones

Example of field verification

Peatland clearing and field verification were conducted in Tanjung Penyebal Village, Sungai Sembilan District, Dumai Regency, Riau Province, which is located in the Sungai Rokan – Siak Kecil Peatland Hydrological Unit (KHG). It is located within a production forest area and a peatland moratorium area. Based on the priority area analysis, 8,276 GLAD Alert points were identified between June and December 2018, with an estimated peatland clearing of 745 hectares. However, field verification was only able to map 34 hectares of the peatland clearing location due to time and manpower limitations, so not all GLAD Alert points that needed verification could be visited.

Figure 13 | **Peatland clearing locations and drone field verification results in Tanjung Penyebal Village, Riau**



Note: The red dots represent detected GLAD alerts.

Based on the drilling results, the peat found in this location had a thickness of more than 5 meters, making it part of the protective peatland that should not be used for cultivation, especially oil palm cultivation. The surrounding land cover is cleared land where young oil palm trees have been planted and canals have been built.

Figure 14 | **Results of peat thickness measurement and land cover conditions**

Based on interviews with local community leaders, the land was a community land that was managed for oil palm cultivation and was located adjacent to industrial forest plantation concessions.

LIMITATIONS

The adoption and development of the prioritization method into three different monitoring initiatives in Indonesia are based on the best publicly available data. This method can be used by various parties to improve the effectiveness of existing monitoring systems. In the future, the information generated by this method is expected to be able to address the challenges of limited human resources, especially for the very limited monitoring personnel considering the vastness of the monitoring area, and limited funding. With this method, monitoring work is more efficient, and deforestation expansion can be prevented as early as possible.

Based on the case study of the GLAD Alert prioritization method for detecting changes in land cover, several limitations need to be addressed. First is the occurrence of data errors (false positives) during verification, both using high-resolution satellite imagery and field verification. Weaknesses of this data include: (1) GLAD Alert is the result of the processing of optical sensor satellite images, which are often affected by cloud cover and tidal areas; (2) A 16-day temporal resolution is a long waiting time for Alert confirmation in this system, where pixel value changes indicating forest clearing must be detected more than twice in the same area. If a clearing in a new area is detected only once, the status of the Alert remains unconfirmed, which means that the forest clearing cannot be confirmed by the system.

In the landscape monitoring trial in Siak Regency, some locations where GLAD Alert was detected were verified to be false positives and the locations turned out to be rain-fed rice fields. A similar situation was found in a Places to Watch analysis where high-resolution satellite images showed false positives in some areas with distinctive rainy season and dry season. This proves that GLAD Alert is sensitive to tidal areas.

In addition, it is difficult to determine the driver of the forest clearing through satellite image verification. In the case of Places to Watch, the driver of deforestation is difficult to determine because the observation period is only three months. Typically, deforestation (conversion to another land use) only occurs several years after land clearing (Gaveau et al. 2016). In the case study of landscape monitoring, the same problem occurred when trying to identify the driver of forest clearing through satellite imagery. However, the driver of the forest clearing is more easily identified during field verification by looking at planted commodity seeds, which is not visible through satellite imagery, and interviewing local communities.

Third, the limited availability of updated and publicly accessible data makes monitoring in some areas impossible or results in some monitoring prioritization error. The availability of high-resolution satellite images is needed in the Places to Watch method to verify true alerts in absence of field verification. In the case of landscape monitoring, updated maps of oil palm and timber plantations are needed to eliminate alerts resulting from oil palm rejuvenation and wood harvesting (acacia and others).

ENDNOTES

1. Ministry of Environment and Forestry of Indonesia 2020 press release in official website
2. Primary Rainforest Destruction Increased 12% from 2019 to 2020 | WRI Indonesia (wri-indonesia.org)
3. IUPHHK-HA stands for Izin Usaha Pemanfaatan Hasil Hutan Kayu dalam Hutan or Business Permit for Utilization of Forest Timber Products from Natural Forest)
4. IUPHHK-HTI stands for Izin Usaha Pemanfaatan Hasil Hutan Kayu Hutan Tanaman industry or Business Permit for Utilization of Timber Forest Products from Industrial Plantation Forests
   IUPHHK-RE stands for Izin Usaha Pemanfaatan Hasil Hutan Kayu Restorasi Ekosistem or Business Permit for Utilization of Timber Forest Products from Restoration Ecosystem.
   IPK stands for Izin Pemanfaatan Kayu or Timber Utilization Permit.
5. IPPKH stands for Izin Pinjam Pakai Kawasan Hutan or Forest Area Borrow-Use Permit.
6. January – March, April – June, July – September, October – December.
7. Law No. 41 of 1999 on Forestry
   Minister of Environment and Forestry Regulation No. 9 of 2015 concerning Procedures for Granting, Expanding Work Areas and Extending Business Permits for the Use of Wood Forest Products in Natural Forests, Business Permits for the Use of Ecosystem Restoration Wood Forest Products from Production Plantations in Production Forests
   Minister of Environment and Forestry Regulation Number 83 of 2016 concerning Social Forestry
   Minister of Environment and Forestry Regulation Number 50 of 2016 concerning Borrow to Use Permit of Forest Areas
8. Combining satellite images over a certain period is useful to get the best visual results (such as cloud-free imagery).

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ABOUT WRI INDONESIA

WRI Indonesia, established in Indonesia as Yayasan Institut Sumber Daya Dunia, is an independent research organization dedicated to contributing to the socioeconomic development in an inclusive and sustainable way. Our work is focused on six main areas: forests, climate, energy, cities and transportation, governance as well as ocean. We turn big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Approach
We measure our success through real-world change. Our approach consists of three crucial steps: Count It, Change It and Scale It.

COUNT IT
We start with data. We conduct independent research and use the latest technology to develop new understandings and recommendations. Our careful analysis aims to identify risks, open opportunities and inform targeted strategies. We focus our efforts on influential and emerging economies that will shape the future of sustainability.

CHANGE IT
We use our research to inspire real actions by governments, businesses and civil society. We test projects together with communities, companies and government institutions to build a strong evidence base. We then work with our partners to drive change that can reduce poverty and enhance human well-being. We set measurable and accountable goals to ensure the sustainability of our work.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts at regional and global levels. We engage decision-makers to implement ideas and enhance impact. We measure our success through the actions of governments and businesses that can increase opportunities for the well-being of communities and the preservation of a healthy environment.