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TECHNICAL NOTE

PLACES TO WATCH: IDENTIFYING HIGH-PRIORITY FOREST DISTURBANCE FROM NEAR–REAL TIME SATELLITE DATA

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EXECUTIVE SUMMARY

Forest change information is more widely available than ever before thanks to improvements in computing power, remote sensing science, and data dissemination platforms like Global Forest Watch (GFW). For example, the recently released GLAD alerts provide detailed information on when and where forests are being cleared on a weekly basis. However, for those interested in monitoring large areas (for example, an entire country, region, or even the world), such as international journalists, nongovernmental organizations (NGOs), and activists, the abundance of these alerts makes it difficult to visually interpret recent changes in priority landscapes. This technical note describes a workflow called Places to Watch, which filters the millions of GLAD alerts detected monthly to identify the most concerning instances of recent clearing for storytelling and activism. For this method, we divide the world into 10-kilometer grid cells, then multiply the number of weekly GLAD alerts in each cell by a "concern" score derived from the coverage of protected areas and intact forests within the grid cell. The cells with the highest resulting product are identified as Places to Watch and, after a curation process to provide further context, disseminated through the Global Forest Watch website and newsletter. This is an experimental methodology to filter alerts for the conservation community and will be revised in response to user feedback.

CONTENTS

Technical notes document the research or analytical methodology underpinning a publication, interactive application, or tool.

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INTRODUCTION

Recent advances in remote sensing science and technology have made it possible to produce globally consistent yet locally relevant maps of forest change (e.g., Hammer et al. 2014; Hansen et al. 2013; Hansen et al. 2016; Reymondin et al. 2012). The Global Forest Watch platform (GFW, www.globalforestwatch.org) hosts and visualizes these data sets with the aim of encouraging better forest management by providing improved access to information.

GFW offers a user-friendly, interactive map interface that enables users to view and analyze forest change data sets. Users can also sign up to receive e-mail notifications of new changes detected in their area of interest, such as within a protected area or a country. While these features provide useful information at multiple scales, they are most useful in areas small enough to permit easy visual tracking, such as a protected area or subnational jurisdiction. At these scales, patterns of loss over time and space are possible to interpret visually to help guide allocation of monitoring and enforcement resources. Over larger areas, analysis by visual inspection becomes more difficult due to the volume and complexity of the data; the University of Maryland tree cover loss data set alone consists of more than a billion 30-meter pixels (Hansen et al. 2013).

Actors with broad geographic interests in the status of forests, such as international journalists, NGOs, and activists, are the most affected by this challenge, though past experience suggests that these actors are interested in specific instances of recent deforestation. Just weeks after the release of the weekly GLAD[1] tree cover loss alerts (Hansen et al. 2016), a massive forest fire in the Republic of Congo was detected by the alerts. Researchers at the University of Maryland noticed the large cluster of alerts and publicized it, and the story was later picked up by the environmental news site Mongabay (Erickson-Davis 2016). However, now that the alerts have expanded from 3 countries to 16, with additional coverage planned, constant visual inspection becomes more difficult and time consuming. There is a risk that future large areas of alerts will go unnoticed by the public, even if these areas have implications for climate, biodiversity, and forest-dependent communities.

To address this challenge, we present a workflow, called Places to Watch, which identifies examples of recent alerts around the world that we believe will be most interesting to journalists and activists. We hope these actors will increase public attention to the areas identified by the methodology, and put pressure on those responsible. The Places to Watch process combines three criteria—protection status, forest intactness, and density of alerts—as proxies for areas where concerning deforestation may be taking place. This technical note describes the methodology, workflow, and distribution of the outputs.

METHODS

The Places to Watch methodology uses consistent criteria to filter the millions of forest loss alerts detected each month and identifies areas of recent clearing that may be of interest or concern to GFW users. The number of deforestation alerts in the past month is multiplied by a “concern” score based on the coverage of protected areas and intact forest landscapes to select the top Places to Watch.

Input Data

The weekly Landsat-based GLAD alerts produced by the University of Maryland, which identify 30-meter pixels that have recently been cleared, constitute a key input in the Places to Watch process. Though the data are updated on a weekly basis, the amount of time between detections on a local scale depends on cloud cover. Cloud-free images are required to detect forest changes, so the persistent cloud coverage found in many tropical countries limits the monitoring frequency, in some cases for months at a time. Alerts become confirmed when more than one Landsat image flags the pixel as an alert, though this process can take months in areas of persistent cloud cover. For the purposes of this exercise, which aims to prioritize recent clearing, we will consider both confirmed and unconfirmed alerts in order to avoid delays in detection as much as possible. GLAD alerts are currently available for the 16 tropical countries listed in Table 1, though there are plans to expand the system to the rest of the tropics.

Table 1 | **Current extent of GLAD alerts and Places to Watch**

SOUTH AMERICA	CENTRAL AFRICA	SOUTHEAST ASIA
Brazil	Burundi	Brunei
Peru	Cameroon	East Timor
	Central African Republic	Indonesia
	Democratic Republic of Congo	Malaysia
	Equatorial Guinea	Papua New Guinea
	Gabon	
	Republic of Congo	
	Rwanda	
	Uganda	

Filtering Criteria

Due to the high volume of alerts each month, efficient computation of Places to Watch is critical. We use a 10 × 10-kilometer grid as the basis for the analysis to ensure quick and efficient filtering of alerts. We estimate that the gridded method allows us to analyze the alerts on the scale of minutes rather than days, a crucial improvement as we scale up the analysis to the rest of the tropics. Ten-kilometer cells are large enough to capture large clusters of loss (such as from fires or clear cutting), decrease edge effects, and decrease processing time, while still being small enough to ensure variation across grid cells and capture detail. The grid is aligned with the World Eckert VI projection to allow easier processing, described in the next section.

Each grid cell is assigned a Concern Score to identify forests that, if cleared, would be of highest concern to our target audience. We assume that for journalists and activists, who rely heavily on storytelling and public support, the most concerning clearing takes place in remote, undisturbed areas with high ecological value. We choose to represent the Concern Score by the extent of protected areas and intact forest landscapes (IFLs) within the cell, both of which have global, up-to-date data available. These two factors are not perfect proxies for conservation value, but they do align with conservation priorities. Protected areas are created with diverse objectives including biodiversity and ecosystem service conservation (Watson et al. 2014), while intact forests are crucial for carbon and biodiversity (Potapov et al. 2017). Both data sets are also proxies for some of the last remaining forest frontiers—either because they are free of recent human activity (in the case of IFLs) or because they are protected from human activity (in the case of protected areas).

A global data set of protected areas is available from the World Database of Protected Areas (WDPA; IUCN and UNEP-WCMC 2016), which contains information on places that are legally protected and managed to achieve conservation objectives. We calculate the proportion of each grid cell covered by protected areas as an input to the Concern Score. We also weight the score based on International Union for Conservation of Nature (IUCN) categories (I–VI), indicating legal status and appropriate use. Strictly protected areas (IUCN Categories Ia, Ib, and II) do not allow any human resource use and thus are weighted higher in our analysis. Though protected areas are not perfectly aligned with and do not perfectly protect biodiversity, carbon, or other ecosystem values (e.g., Watson et al. 2014), they have been in theory set aside to maintain and conserve these values. Given the objectives and legal status of protected areas, clearing within these areas is often illegal or at least undesirable.

The second input to the Concern Score is the proportional coverage of 2013 IFLs (Potapov et al. 2017) within each cell. The data set identifies the world's last remaining unfragmented forest landscapes, large enough to retain all native biodiversity (here defined as 500 km^2) and showing no observed signs of significant human alteration in at least the last 30 years. IFLs provide a reliable indication of forested landscapes that are highly valuable for biodiversity and carbon sequestration. IFLs contain 40 percent of tropical carbon stocks despite comprising only 20 percent of tropical forest area (Potapov et al. 2017), and explicitly consider habitat intactness and connectivity. Although clearing in IFLs is not necessarily illegal, private industries are increasingly limiting clearing in IFLs to meet sustainability requirements (e.g., the Forest Stewardship Council). Clearing detected within these forests is concerning given their intactness, remoteness, and long history of remaining untouched; detected alerts usually represent new frontiers of human activity.

The final score for each 10-kilometer grid cell is calculated by considering the proportion of each cell covered by the target data sets, using Equation 1.

Grid cells covered by both IFLs and protected areas have a higher score than areas covered by one individually or neither. For example, a grid cell in which the entire area overlaps a Category Ia protected area as well as an IFL would receive the maximum score of 2. A grid cell containing neither target data set would receive a score of 0.

Identifying Places to Watch

We determine the number of GLAD alerts that have been detected within each grid cell monthly using an automated Python script that is initiated the first week of the month. The process begins by masking out any alerts detected more than 30 days ago. The remaining alerts are then converted to points, with coordinates corresponding to the center of each pixel. We reproject the alerts to World Eckert VI, the projection of the grid, and snap the coordinate values of each point to the lower left-hand corner of the grid cell (a simple procedure as the corners of the grid are aligned with integer values). We then tabulate the number of points falling in each cell. Early tests of this method suggest that it is several orders of magnitude faster than traditional geographic information system (GIS) methods (e.g., zonal statistics).

The number of GLAD alerts within the cell is then multiplied by its corresponding Concern Score, creating a new weighted index of values representing the importance of the cell as well as the magnitude of recent forest clearing. We isolate 10 top-scoring grid cells from each region (South America, Central Africa, Southeast Asia) each month as Places to Watch. This reduces the curation burden on the GFW team and ensures a geographic spread of identified Places. Once the automatic selection is complete, the GFW team undertakes a curation process to prepare the Places for dissemination and outreach, as described in the Discussion section below.

RESULTS

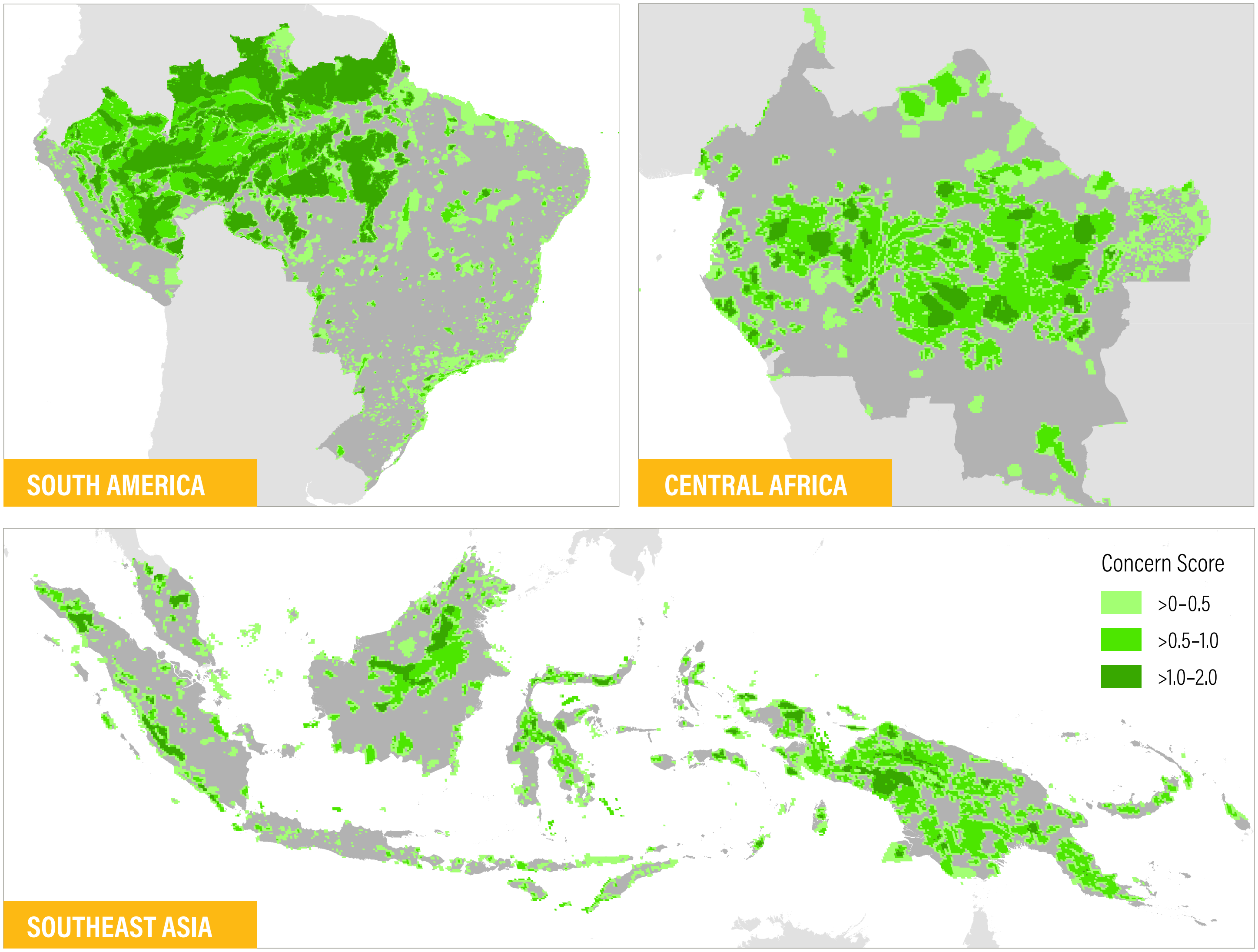
Figure 1 shows the result of the Concern Score calculation. Since IFLs and protected areas are not evenly distributed across the landscape, areas with higher Concern Scores are clustered around dense, intact forested regions like the Amazon basin.

Figure 2 shows the distribution of Concern Score and GLAD alert count, the two inputs to the final index value, for a test run in February 2017. The lines in Figure 2 represent the lowest index value needed to make the top 10 in

Equation 1: Concern Score Calculation for Each Grid Cell

$$\text{Concern Score} = \frac{(\text{prop. protected area}) + (\text{prop. protected area Category Ia, Ib, or II})}{2} + (\text{prop. IFL})$$

Figure 1 | **Map of Concern Scores**

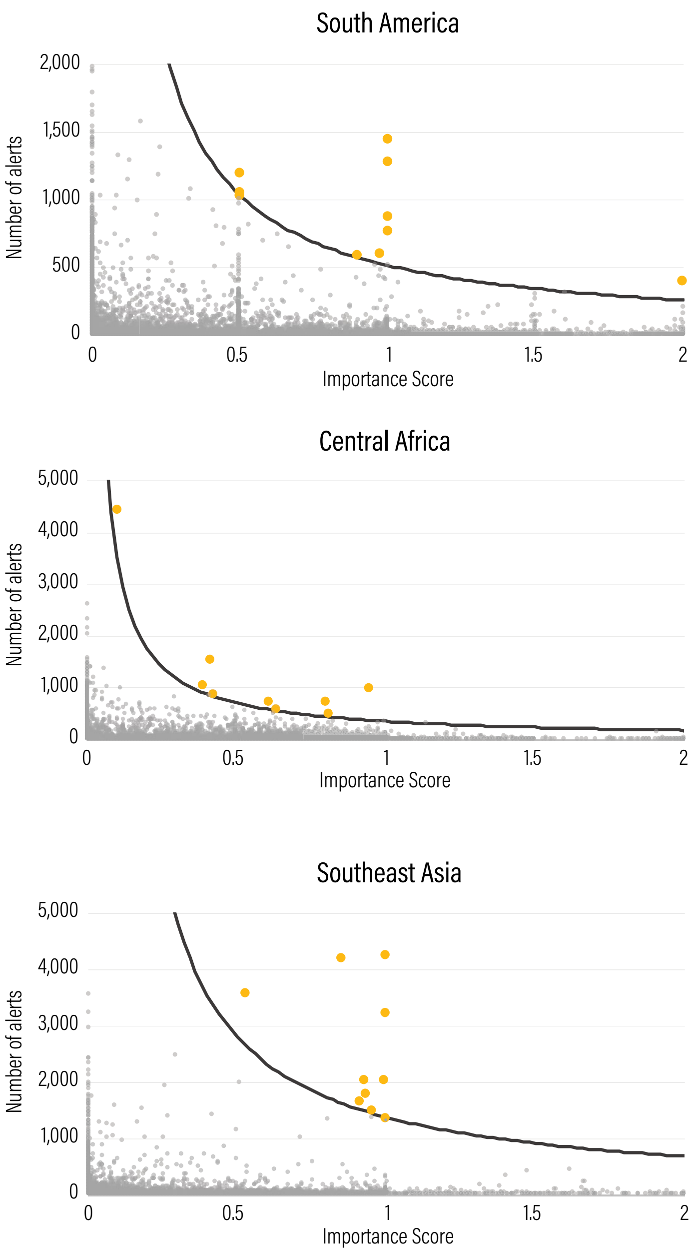


Note: A value above 1 indicates the cell is covered by both a Category Ia, Ib, or II protected area and an IFL. Dark gray areas indicate where GLAD alerts are available.

February 2017—for example, in Southeast Asia the lowest index value was 1,347 (Concern Score of 1.0, GLAD alert count of 1,347). Note that the lower-bound index values vary significantly from region to region, from 1,347 in Southeast Asia due to the higher density of GLAD alerts (mainly from clearing for oil palm) to 352 in Central Africa. We expect these numbers to fluctuate seasonally as well, as more deforestation occurs and is detected in the dry season.

The final map result of the Places to Watch methodology for February 2017 is shown in Figure 3, with 10 Places identified for each region of the tropics. The Places are clustered in some regions—for example, all 10 of the Places in insular Southeast Asia are on the island of Papua.

Figure 2 | **Distribution of February 2017 Concern Scores and Number of GLAD Alerts**



Note: The curves represent the minimum index value (Concern Score multiplied by number of alerts) required to make the top 10 list by continent. Points in gold represent the top 10 grid cells selected in February 2017.

For the test run in February 2017, we examined the resulting Places to Watch and gathered additional information about seven of them. One of the seven, shown in Figure 4, highlights the expansion of a logging road network within an IFL in Papua New Guinea. The others we chose to highlight as Places to Watch include expanding oil palm plantations in West Papua, new pasture areas in northern Brazil, smallholder farming in a protected area in Brazil, new logging roads in Papua New Guinea and Democratic Republic of the Congo, and expanding plantations in Cameroon. Places that did not make the cut in February include smallholder expansion around an existing frontier, loss from fires that happened several months previously, and cells adjacent to those selected.

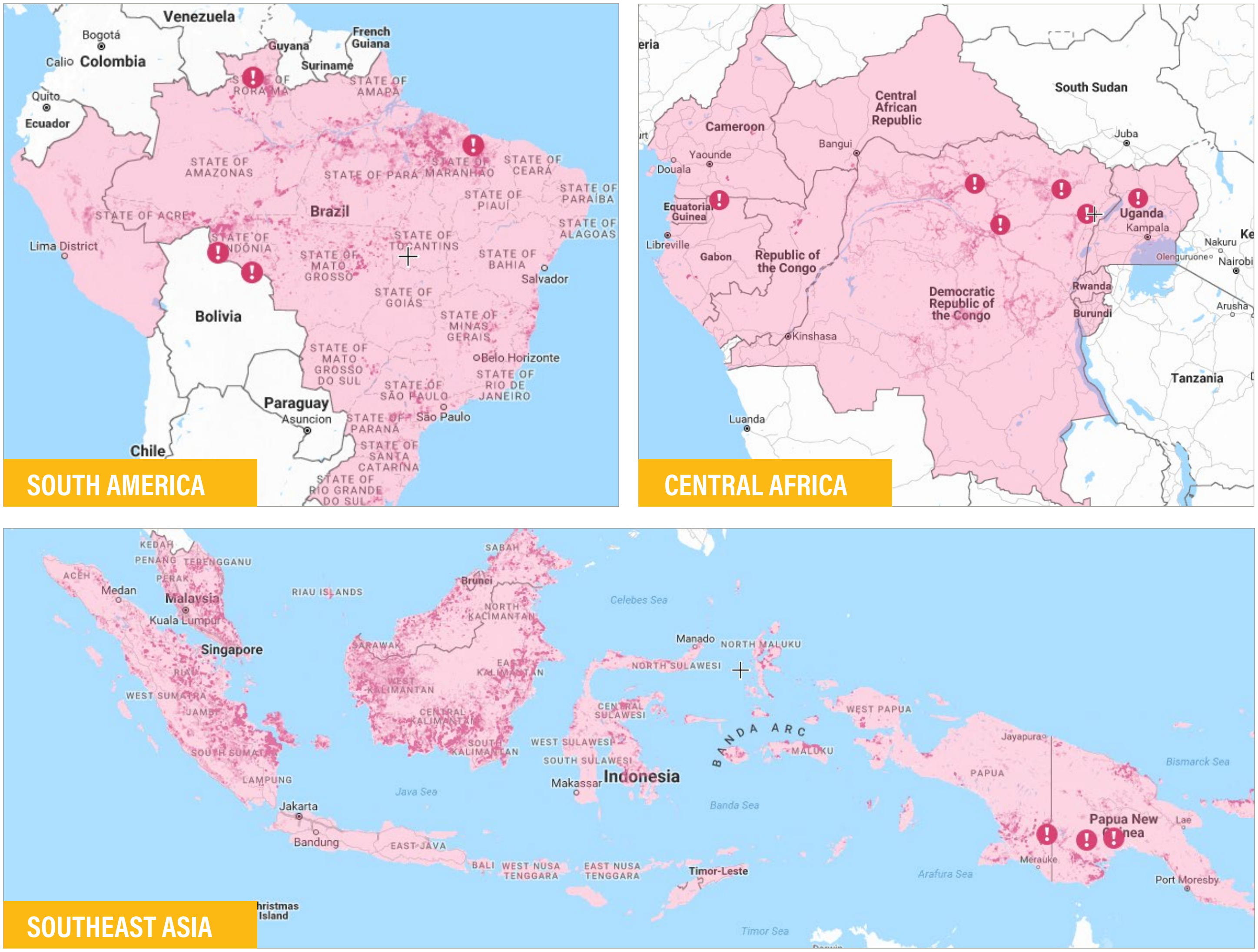
DISCUSSION

From Places to Watch into Impact

After testing the methodology, we determined that human curation is necessary before distribution of the most concerning Places to Watch. Not all Places identified by the methodology will be of interest to the target audiences—for example, loss with natural (nonhuman) cause, areas repeated from past months, or false positives may not make good stories depending on the circumstances. In addition, journalists and activists require additional information about the drivers and context of the deforestation before writing a story or beginning a campaign.

To ensure that our Places meet users' needs, we undertake a monthly curation process to select around 10 of the 30 automatically selected Places to Watch that we think will be most relevant. We then compile as much information as we can about these Places using our own knowledge, high-resolution imagery (when available), and existing media. With this starting point, we contact an "Action Network" of GFW partners that we think might know more about these areas, mostly made up of grassroots civil society organizations working at local scales. Information from partners is particularly valuable because it is often detailed and points to the actors involved. The Action Network also

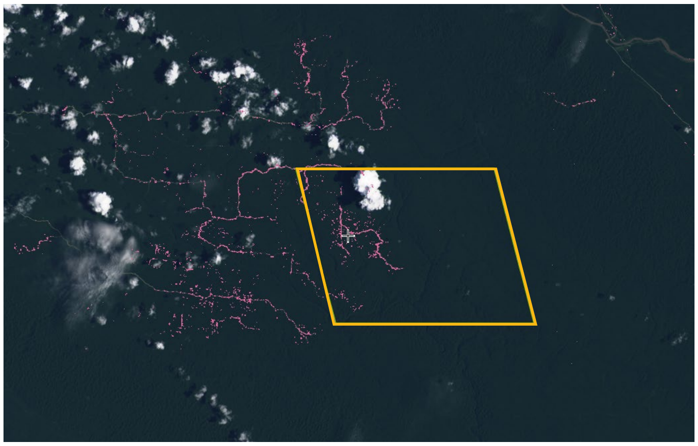
Figure 3 | **Location of Places to Watch, February 2017**



Note: The exclamation point icons represent the 30 Places to Watch (shown as 11 icons, as Places close together are clustered), dark pink shows cumulative GLAD alerts detected since the year 2015, and light pink shows the coverage of alerts. This figure shows the way Places to Watch will appear on the Global Forest Watch platform.

allows us to connect journalists or activists with contacts on the ground, with the added benefit of raising the profile of these local NGOs. From the Action Network and our own internal research, we compile summaries and images for each Place, which are then sent to a targeted list of contacts, focused on journalists and activists. The top Places are also added to the GFW map and posted to the GFW blog to reach a more general audience. The entire process is outlined in Figure 5.

Figure 4 | **A Logging Road Expands in Papua New Guinea in a February 2017 Place to Watch**



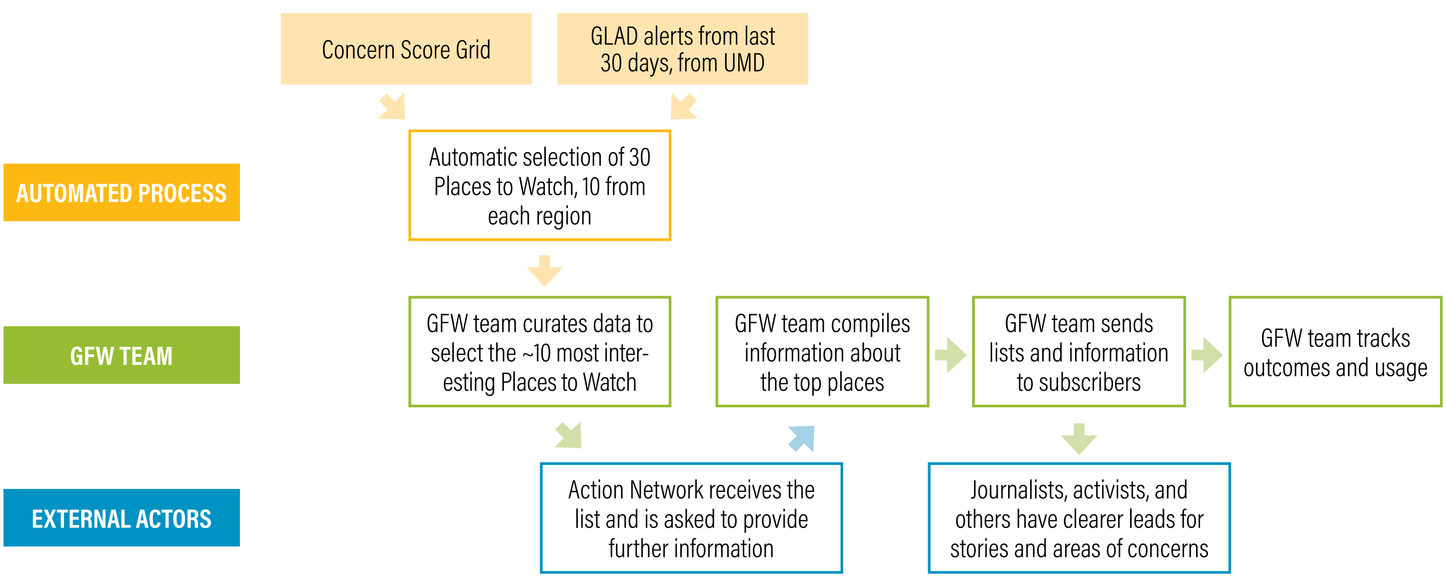
Note: The gold square shows the location of one Place to Watch identified for February 2017. The grid cell overlaps an intact forest landscape, and underlying satellite imagery (Sentinel-2 image from February 16, 2017; accessed via UrtheCast) indicates the expansion of a logging road network.

The following month, the previous month's Places are saved but removed from the map, and the process begins again. The methodology does not consider past Places to Watch any differently, but staff involved in the curation process may choose to highlight or avoid Places repeated from previous months depending on the storytelling potential.

Comparisons with Other Methods

Other methods have attempted to map forest value across landscapes, such as high conservation value (HCV) mapping and go/no-go approaches. Unlike these approaches, Places to Watch is a tool for filtering alerts only and is not intended to dictate appropriate land use activities. To reduce the chances of the Concern Score grid being used in this way, we will not release it to the public. Go/no-go approaches are ubiquitous in conservation, but the inputs considered are not standardized across methods. Both HCV mapping and go/no-go approaches use factors similar to those used by Places to Watch to map areas of

Figure 5 | **Work Stream Involved in Monthly Curation and Publication of Places to Watch**



concern. The World Conservation Congress, for example, called on businesses to respect all categories of protected areas as no-go zones (IUCN 2016). HCV mapping considers a total of six factors, including biodiversity, intactness, rare ecosystems, ecosystem services, local livelihoods, and cultural importance (HCV Resource Network 2017). As the Places to Watch methodology expands, we may consider more of these factors. However, HCV mapping is done on a site-by-site basis, and global data are not available for several of these factors.

Given the influx of global data on forest change, there have been other efforts to understand and prioritize areas of change. Many studies have used global tree cover loss data to assess impacts on IFLs and protected areas and identify areas of concern (e.g., Heino et al. 2015; Spracklen et al. 2015). Though these assessments are useful, they lack the near–real time, operational aspect of Places to Watch. Other efforts include mapping densities or hotspots of deforestation (e.g., Finer et al. 2016; Harris et al. 2017), to identify areas with the most or increasing loss. However, these approaches do not take into account the condition of the underlying forests.

One initiative closely related to Places to Watch is the Monitoring of the Andean Amazon Project (MAAP), led by the Amazon Conservation Association. This project also uses GLAD alerts to identify areas of concerning deforestation in Peru, through visual analysis of alerts and hotspot analysis results. Places to Watch was in many ways inspired by MAAP's success in capturing the attention of Peru's policy makers and public by highlighting concerning clearing. Compared to MAAP, the Places to Watch methodology is more automated and has a wider geographic coverage. Our workflow also leaves it to activists and journalists to investigate and tell the story of each area rather than developing detailed reports internally.

Limitations and Assumptions

Given that this is the first iteration of an experimental method, many limitations exist. First and foremost, our method assumes that IFLs and protected areas adequately represent areas that are most important to our target audience. Though protected areas and intact forests are correlated with high biodiversity and carbon value, they are not direct measures of conservation value and miss sites that are likely important to our users. These data sets are also imperfect—the WDPA data set, for instance, is often criticized for having incomplete or outdated data in some countries.

Carbon stock data are a strong contender for future inclusion in the Concern Score, but there are no agreed-upon thresholds to define high-carbon-stock forest, which would make it difficult to select an appropriate threshold for this analysis. The High Carbon Stock (HCS) approach, for example, relies on measurement of carbon stocks in situ to develop site-specific thresholds to define HCS forests (High Carbon Stock Approach 2017). Other thresholds for primary or very high carbon forest in moist tropical forest vary, but they fall near 250 mTons/ha (e.g., Dinerstein et al. 2014). However, these thresholds are not suitable for application in other biomes, which are also included in the Places to Watch analysis. We believe carbon is fairly well captured by our current method given that more than 40 percent of tropical carbon falls within IFLs and that IFLs have carbon stocks as much as three times higher than other areas (Potapov et al. 2017). Primary forest data may be an even better proxy for high carbon stock forests, since it would not have the minimum size requirement of IFLs and thus represent all old-growth forest. We will consider adding this layer to the analysis when pantropical data become available.

Biodiversity is another important factor for the conservation community, but we did not feel any available data sets for biodiversity added value to the analysis. Alliance for Zero Extinction sites had limited utility due to their narrow coverage, especially in humid tropical forests, while biodiversity hotspots were too broad and imprecise to add value (e.g., all of Malaysia and most of Indonesia fall inside a hotspot). We will continue to consider biodiversity data layers as they become available.

The method also ignores other potential values, such as endemicity, land rights, and habitats other than forests. In the end, we decided to favor model simplicity for the first iteration of this method, but we expect to expand the factors included in the Concern Score depending on feedback from target users.

Our method considers only the number of alerts in the past month, and ignores patterns and trends of alerts over time and space. For example, an area experiencing slow but steady loss over several months may never make the top 10 Places to Watch. Ignoring past tree cover loss may lead to the selection of Places to Watch in areas that have already experienced high levels of clearing, and thus may not have a high conservation value. Ignoring the spatial patterns of alerts may cause the method to miss features that have few alerts overall. For example, the GLAD alerts detect new logging roads remarkably well, but, unlike the example shown in Figure 4, many of these roads do not comprise of enough alerts to qualify as a Place to Watch. However, logging roads provide increased human access to remote forest areas and can cause major ecological impacts as a result (Barber et al. 2014).

As the name suggests, the goal of Places to Watch is to identify "places" of interest or concern for conservation rather than individual GLAD alert pixels. However, the use of 10-kilometer grid cells as the unit of analysis similarly results in arbitrary squares rather than areas defined by their significance to conservation. The use of grid cells introduces opportunities to miss important clearing, such as if a large patch of alerts spans more than one grid cell, or if a cell does not meet the Concern Score threshold because only part of it falls on land.

Additionally, the method looks only at the overall coverage of inputs and alerts; it does not consider whether alerts occur in a part of the cell that is protected or intact. Taking the overlap into account is possible, though integrating this into the current workflow would result in additional complexity of the method, which would make it less replicable and likely slower. We decided to consider all alerts, not just those that overlap with the inputs, since changes happening right at the borders of IFLs and protected areas may still be noteworthy for the target audiences. For instance, Laurance et al. (2012) suggest that environmental changes right outside of a protected area's boundaries may be nearly as ecologically damaging as changes within the protected area itself. The curation process also serves as an additional filter to leave out cases of change happening outside of IFLs or protected areas, if deemed uninteresting.

Finally, though the method is meant as an automated process to select the most important places for conservation, it still requires human curation before distribution to the target audience (described above). It is possible that overcoming the limitations listed above may reduce the need for curation, but the identification of context and pattern that curation provides may prove difficult to automate.

Areas for Future Work

As GLAD alerts expand to the pantropics by 2018, we will continue to extend the coverage of Places to Watch. With the addition of more countries, it may be necessary to select top Places in more than three regions, which will be evaluated when the data are available.

We intend the Places to Watch process to be iterative and hope to continue to improve it over time. One obvious avenue for improvement is the expansion of the Concern Score to include inputs such as aboveground live woody biomass (Harris 2016) and biodiversity value (work in progress by UNEP-WCMC and partners). Depending on user feedback, we may consider allowing users to dynamically adjust which inputs are important to them.

Other future avenues for work include identifying spatial patterns of loss to discern discrete features, such as roads or agricultural fields, that provide more context about deforestation drivers. For example, roads are often the first step to deforestation on the frontier and the pattern of resulting alerts are obvious to the human eye. If we could automate detection of these roads in IFLs, protected areas, and other areas of interest, this would be a valuable tool for alerting conservationists to new deforestation frontiers.

We also hope to better involve the temporal component by explicitly considering previous deforestation. One option is to keep track of previous Places to Watch and highlight those that are selected multiple times or have neighbors that have been selected (this is done unsystematically now through the curation process). Another option would be to prioritize new areas of change by reducing the value of cells with previous change.

Global Forest Watch is also exploring the use of this filtering mechanism to highlight other uses and target audiences, such as those particularly interested in biodiversity and palm oil companies that wish to work at a landscape scale. We hope to use the same back-end infrastructure, but with different factors for mapping concern, potentially greater user choice of those factors, and different outreach strategies.

After the full launch of Places to Watch, we intend to return to our target audiences to understand whether Places to Watch is meeting their needs, and how we can continue to improve the methodology and information flow.

ENDNOTES

1. Named for the Global Land Analysis and Discovery lab at the University of Maryland.

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World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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