WORLD RESOURCES INSTITUTE

TECHNICAL NOTE

PLACES TO WATCH PALM AND SOY: IDENTIFYING HIGH-PRIORITY FOREST DISTURBANCES RELATED TO PALM IN SOUTHEAST ASIA AND SOY IN SOUTH AMERICA USING GLAD ALERTS

IFEOMA COLLINS, THAILYNN MUNROE, ANNE ROSENBARGER, RYAN SARSFIELD, AND CAROLINE WINCHESTER

EXECUTIVE SUMMARY

Places to Watch Palm and Soy (PTWPS) provides a method to filter thousands of deforestation alerts from the Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland, prioritizing clusters of deforestation alerts that are especially alarming (Hansen et al. 2016). PTWPS is a descendant of the quarterly, global Places to Watch (PTW) analysis, which provides inputs for curated stories about emerging deforestation. For PTWPS, these alerts are related to current palm and soy plantation areas that are likely to be in noncompliance with zero-deforestation commitments made by large companies if planted with oil palm in Southeast Asia, specifically Indonesia and Malaysia, and if planted with soy in various countries in South America. In particular, the PTWPS method picks up large clearance events most likely caused by industrial palm concessions or large soy farms. The analysis is an automated process that is executed once a month with the curated results displayed as a layer on the Global Forest Watch flagship platform. The main differences between PTWPS and PTW is that PTWPS focuses only on potential oil palm expansion in Southeast Asia and potential soy expansion in South America rather than on any deforestation in the entire tropics. The sheer number of deforestation alerts produced weekly makes it difficult for most journalists and the media to find new clearing events of enough consequence to report to the public, and this method aims to elucidate those areas. This methodology is focused on clearing events geographically associated with agricultural commodity production but does not attempt to resolve direct attribution through geospatial analysis or other means.

CONTENTS

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

Suggested Citation: Collins, I., T. Munroe, A. Rosenbarger, R. Sarsfield, and C. Winchester. 2020. "Places to Watch Palm and Soy: Identifying High-Priority Forest Disturbances Related to Palm in Southeast Asia and Soy in South America Using GLAD Alerts." Technical Note. Washington, DC: World Resources Institute. Available online at: www.wri.org/publication/places-to-watch-forest-disturbance.

LIST OF ABBREVIATIONS

GFW	Global Forest Watch
GLAD	Global Land Analysis and Discovery
PTWPS	Places to Watch Palm and Soy
PTW	Places to Watch

INTRODUCTION

Identifying Places to Watch Palm and Soy

Conversion of tropical forests into agriculture or monoculture tree plantations is the leading cause of tropical deforestation, leading to destruction of habitat and ecosystem services, increased carbon dioxide emissions, and increased risk of land conflict (Carlson et al. 2013; Pye et al. 2017). In Southeast Asia, one of the main plantation crops is oil palm (*Elaeis guineensis*). Oil palm is the most productive oil-producing plant, yielding up to eight times more oil per hectare than soybeans (Wahid et al. 2005). Since 1990, oil palm has been expanding at an increasing rate, with over 2 million hectares (ha) of oil palm developed on peat lands in 2010 (Miettinen et al. 2012). Oil palm has brought economic opportunities to the region, but large-scale industrial agriculture associated with it has also brought major destruction to large expanses of tropical and primary forest, which are critical for biodiversity, community health, and other ecosystem services (Marti 2008).

Soybeans (*Glycine max*) from South America make up the largest portion of global soy exports and production. Five out of the top 10 soy-producing countries in 2018 were located in South America, specifically Brazil, Argentina, Paraguay, Bolivia, and Uruguay. Large-scale soy production in Argentina began in the 1970s and by 2008 about 50 percent of Argentina's agricultural land (16.6 million ha) was planted with soy. In Bolivia, soy expansion (mostly in the eastern lowlands) started in the 1990s and by 2009 it grew quickly to approximately 980,000 ha. After the "soy boom" in the 1990s, Paraguay's soy area expanded to around 2.4 million ha by 2008. By 2012, the area of soy cultivated in Argentina, Bolivia, Brazil, and Paraguay was around 47 million ha (OSAS 2014). Most recently, Brazil's soy planted area alone is expected to be around 36 million ha in crop year 2018–19 (Gomes 2018; CONAB 2019). With the demand for soy increasing, the challenges of maintaining the forest cover in various South American countries are also increasing (Rudorff et al. 2011, 2015; Freitas and Mendonca 2016).

Deforestation monitoring methods using near real-time alerts to identify deforestation near oil palm in Southeast Asia and soy production in South America are limited. However, in recent years, major advancements in satellite data availability, remote sensing techniques, and geospatial analysis have been implemented through Global Forest Watch (GFW), an online forest monitoring and alert system. To complement the annual tree cover loss data from GFW, the Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland produces GLAD alerts, a deforestation alert product that details—through thousands of pixels every week—where tree cover loss has occurred and provides a breakthrough in potential for monitoring zero-deforestation commitments. Thus, the goal of this project is to automate a filtering process for near real-time deforestation occurring around oil palm plantations in Indonesia and Malaysia and soy-planted areas in South America to find areas that *if cleared and subsequently planted* with palm or soy, are likely to be in noncompliance with zero-deforestation commitments.

METHODS

Overview

Both Places to Watch (PTW) Palm and PTW Soy use a grid system for the basis of the analysis; however, they use slightly different methods to rank the top places to watch, due to the varying availability of information, commodity-specific criteria, and regulations regarding zero-deforestation policies and agreements in the palm oil and soy sectors. The majority of zero-deforestation commitments in the palm oil sector in Southeast Asia use specific criteria to define areas that are noncompliant, such as clearance on protected areas and on peatlands. The information provided by these commitments contributed to the creation of the Places to Watch Palm "importance score," which weights the grid cells used in the PTW Palm analysis. For soy, however, the broad range of land use regulations across the countries and biomes of production and the lack of a sector-wide consensus on land use and deforestation cut-off date criteria pose difficulties for the application of a continental-wide weighting system. Thus, the same method was applied across the entirety of the soy production area in South America.

Input Data

GLAD alerts: The Global Land Analysis and Discovery (GLAD) alert system is produced by Hansen et al. (2013) at the University of Maryland and provides a weekly assessment of global tree cover loss at 30 meter (m) resolution from 30°N to 30°S (Hansen et al. 2016).

Tree plantations (Brazil, Chile, Indonesia, Malaysia, Peru): Global Forest Watch has combined plantation data from a multitude of sources into a global plantation dataset separated by species and country (Harris et al. 2019).

PTW Palm

Peat: The two peat datasets used are the global peat distribution from the Center for International Forestry Research Tropical and Subtropical Wetlands Distribution, version 2 (Gumbricht et al. 2017), and a Southeast Asia–specific peat dataset (Miettinen et al. 2016). They are combined into one binary mask.

Protected areas: The World Database on Protected Areas provides spatial information on all categories of protected areas (IUCN and UNEP-WCMC 2016). The vector dataset is converted into a binary mask.

Protected peat: This category of peat is included as a separate layer from the other peat dataset because it carries high significance in terms of zero-deforestation commitments, on top of being illegal to plant on. This dataset comes directly from the Ministry of Environment and Forestry in Indonesia (MoEF 2017) and is also a binary mask.

Primary forests: The Global Land Analysis and Discovery Lab at the University of Maryland produced a 30 m pantropical primary forest layer for the year 2001 (Turubanova et al. 2018). This dataset is also a binary mask.

Palm oil mills: The Universal Mill List, created by Global Forest Watch in collaboration with Rainforest Alliance, is used to generate the 50 kilometer (km) road network extent from existing palm oil mills. This dataset is the most extensive and comprehensively verified palm oil mill dataset available (Global Forest Watch 2019).

PTW Soy

South America soybean extent: The South America soybean mapping and area estimation data were also provided by the GLAD laboratory (manuscript in preparation, following methods published in Song et al. 2017 and King et al. 2017). It shows areas of soy cultivation in 2017–18 in the following seven South American countries: Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, and Uruguay. The output PTW layer displayed on the GFW platform will incorporate updated soy data as they are made available from the GLAD laboratory. Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) imagery were used to create soy classifications during South America's growing season. The total area of soy cultivation in South America for the 2017–18 growing season was about 54 million ha.

Palm Grid

Grid

The PTW Palm method uses a grid and scoring system to filter tree cover loss alerts. A 5x5 km grid has been determined to parse out new areas of tree cover loss at a suitable level of detail (providing ~10 cells that are ranked significantly higher than the rest) without requiring an overly onerous processing burden. This grid is clipped to the land extent of Indonesia and Malaysia using GADM 3.6 country boundaries (GADM 2018). All known tree plantations are removed from the grid. For all the islands except the Indonesian province of Papua, the grid is further clipped to a 50 km road network extent from known palm oil mills, which is a conservative distance estimate for a day's travel on the known road network, and a 10 km buffer around known oil palm plantations, which hopes to capture expansion around plantations that do not have roads within the road network datasets. New oil palm plantations need to be within a day's travel to palm oil mills to ensure maximum oil production from fresh fruit bunches and are generally found near existing plantations and infrastructure. Papua is excluded from this step because of the lack of road and mill data in that area, though oil palm plantations are still emerging there (identified through high-resolution satellite imagery). Due to the clipping of this grid, not all grid cells may be the same size, but during the importance score assignment (described in the following section), the importance score is normalized by the area of the grid cell so that no small cells that have a large number of GLAD alerts on important areas are lost. It should also be noted that this grid will need to be updated when the input datasets are updated.

Score

There are six main raster datasets and three vector datasets (described above) used as input data for the importance score and creation of grid cells, which are then combined with GLAD alerts to identify the top places to watch. The peat, protected peat, protected areas, and forest layers are projected into geographic coordinate system WGS 1984, resampled to 30 m using the nearest neighbor method, and reclassified to a value of 1. Then, all the input data are added together, resulting in a single raster with values from 0 to 4, indicating the presence or absence of the input datasets, with a value of 0 meaning no datasets were present and a value of 4 meaning all four datasets overlapped. This raster is converted to a polygon based on the value, and the ESRI Tabulate Intersection tool in ArcMap is used to generate a table that shows the percentage of each grid cell that overlaps with a specific value (i.e., 0–4), or *the sum of proportions of each input layer in a grid cell* (as shown in the equation below).

$$\textit{Importance Score} = \frac{\textit{Area of Peat} + \textit{Area of Protected Peat} + \textit{Area of Wildlife Protected Areas} + \textit{Area of Primary Forest}}{\textit{Area of Grid Cell}}$$

The information is then joined to the grid as shown in Figure 1. This score ranges from 0 to 4 and indicates the likelihood that tree cover loss in a specific grid cell is going to be related to oil palm expansion in noncompliance with zero-deforestation commitments.

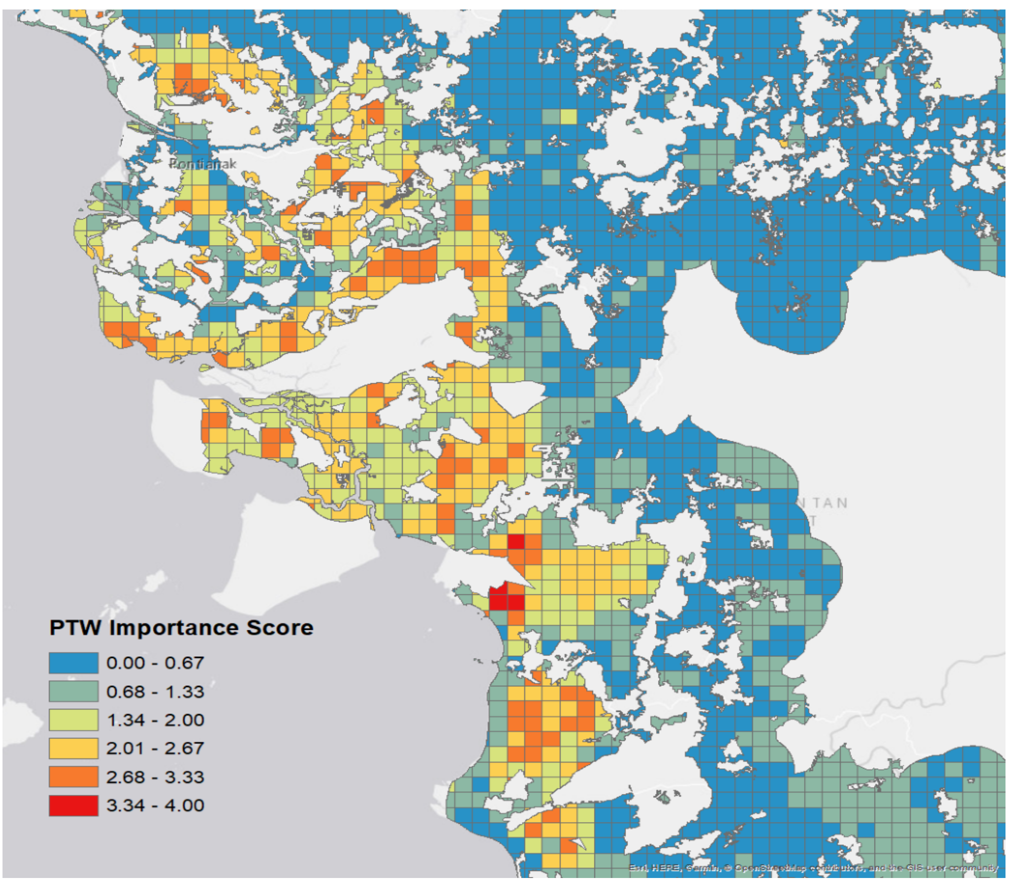
Soy Grid

Grid

For the PTW Soy analysis, a grid system is used to filter the alerts occurring around the soy extent in South America. The study area includes soy cultivation areas in the following six South American countries: Argentina, Bolivia, Brazil, Chile, Paraguay, and Peru.

A 5 km grid was created over the soy cultivated area in South America as shown in Figure 2. This 5 km grid includes grid cells that overlap the soy extent plus 5 km cells that are contiguous with the overlapping cells. Thus, the maximum distance from the current soy contained in the grid is 28 km. Each grid cell was assigned a unique identification (ID) number combined with the GADM

Figure 1 | **Example of PTW Grid with Importance Score Values**



Source: Places to Watch initiative, World Resources Institute. Using data from Global Forest Watch, a partnership convened by World Resources Institute.

administrative level 2 name associated with the grid's centroid to assist with additional filtering analysis. No importance score was used for the PTW Soy method to maintain consistency across all soy-producing regions.

Next, both the cultivated 2017–18 soy extent and tree plantations in Brazil, Peru, and Chile were removed from the 5 km grid around the soy extent, which resulted in 126,080 grid cells representing a modeled area of potential soy expansion in proximity to existing soy throughout South America.

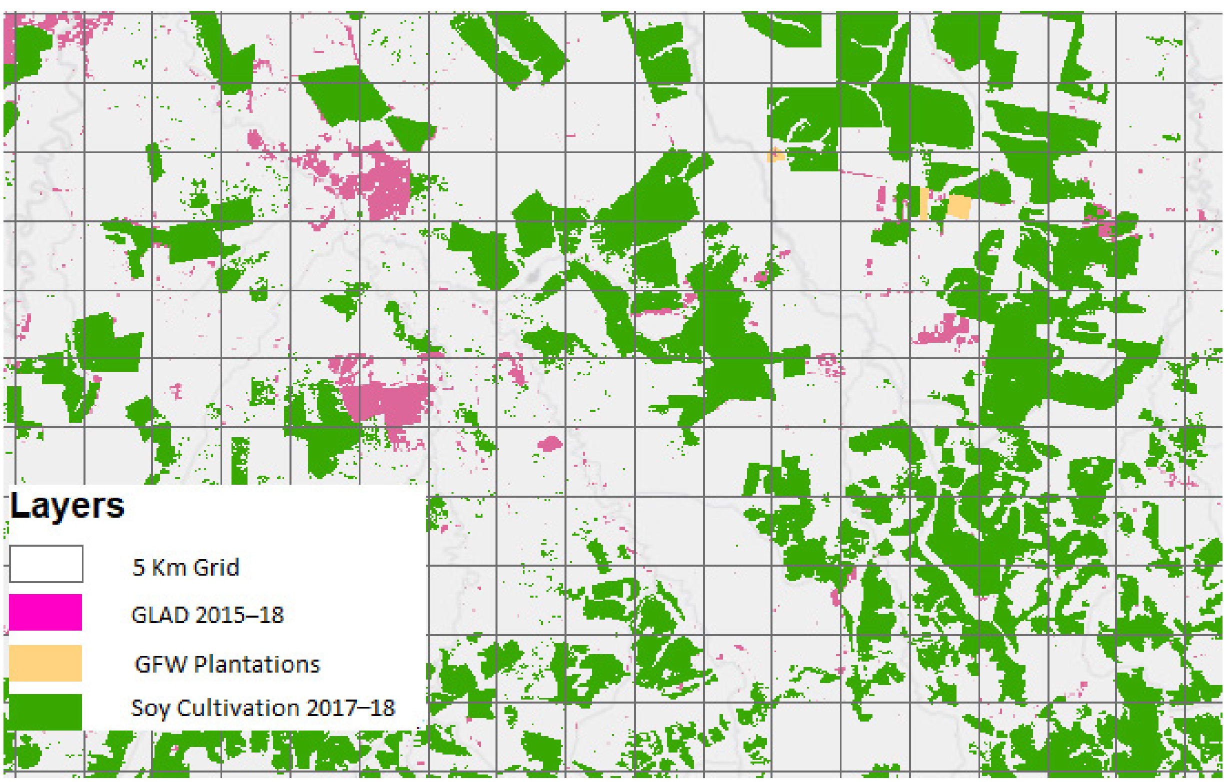
Filtering Criteria

To use the grids created by both methods to filter GLAD alerts, each month the number of GLAD alerts that falls within each palm grid cell is multiplied by the PTW importance score and the sum of GLAD alerts within each soy grid cell is taken at face value. The top 10 grid cells for palm and the top 10 grid cells for soy are visually inspected by an analyst with high-resolution imagery from Planet, Inc., to determine whether the results of the analysis are reasonable and to discard false positives (i.e., there are some roads or there is a clearing in a pattern known to be representative of plantations versus an area that is clearly still forest with no roads or recent clearing or the pattern of alerts is more likely attributable to shifting agriculture/fires). Any grid cells that do not show any clearing or that fall within an existing tree plantation (that were otherwise not present in the GFW data) will be removed from the final output layer.

Results

Results of this analysis will provide users with timely and contextualized GLAD alerts without having to run additional ad hoc or offline analyses. The user will be able to immediately zoom to locations on the map that are concerning and have the potential to be in noncompliance with zero-deforestation commitments. An example of newly cleared areas that would be identified by the PTWPS workflow can be seen in Figures 3 and 4.

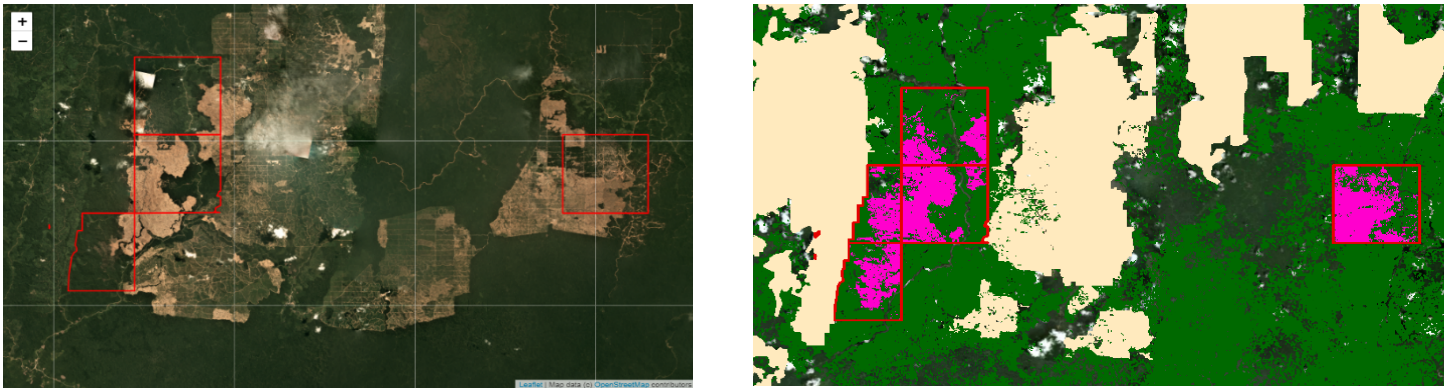
Figure 2 | **Study Area—GLAD Alerts (2015-18) Overlaid on Soy Cultivation Areas (2017-18) and Tree Plantations (2014) in South America with 5 Km Grid**



Source: Places to Watch initiative, World Resources Institute. Using data from Global Forest Watch, a partnership convened by World Resources Institute.

Figure 3 | **Behind-the-Scenes Output from PTW Palm Methodology**

A **B**

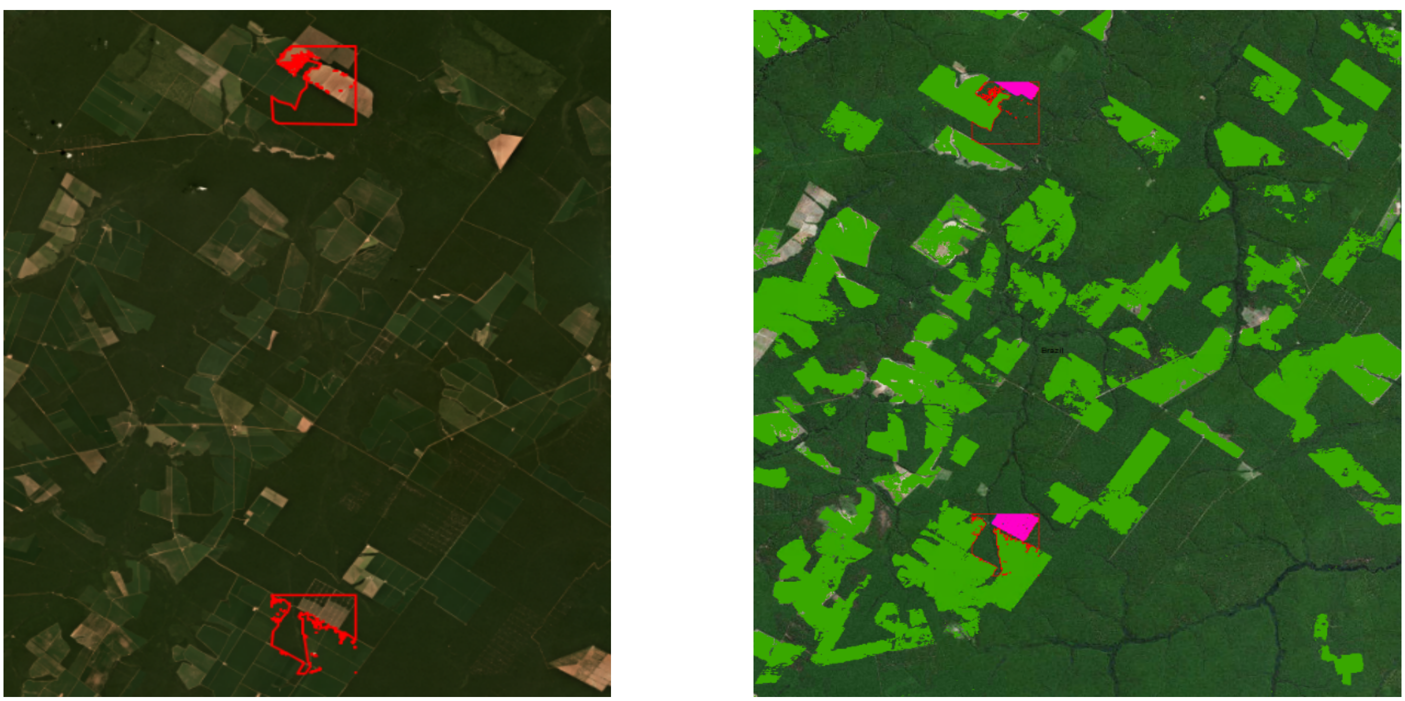


Note: An example of the results produced using PTW Palm methodology from a September 2018 (September 1–30, 2018) analysis, showing palm plantations (light tan areas in Figure 3a) and primary forest extent (dark green areas in Figure 3a) overlaid on DigitalGlobe Basemap imagery from 2014 in Kalimantan Timur, Indonesia. These grid cells had an importance score ranging from 0.91 to 0.98, due to almost full coverage by primary forest, which has been deforested since the creation of the primary forest dataset, as shown in Figure 3b. Figure 3b shows high-resolution Planet Basemap imagery from the fourth quarter of 2018, where there is visible evidence of the new clearing picked up in the PTW Palm analysis.

Source: Places to Watch initiative, World Resources Institute. Using data from Global Forest Watch, a partnership convened by World Resources Institute.

Figure 4 | **Behind-the-Scenes Output from PTW Soy Methodology**

A **B**



Note: An example of the results produced using PTW Soy methodology from a December 2018 (December 1–31, 2018) analysis with soy extent (light green areas, Figure 4a) overlaid on DigitalGlobe Basemap imagery from 2014 in Mato Grosso State, Brazil. Figure 4b shows high-resolution Planet Basemap imagery from the fourth quarter of 2018, where there is visible evidence of new clearing.

Source: Places to Watch initiative, World Resources Institute. Using data from Global Forest Watch, a partnership convened by World Resources Institute.

Curation and Distribution

This dataset will be available as a monthly layer on the GFW flagship interactive map, where users will be able to explore the results of the analysis as well as additional layers that may provide context for tree cover loss in these areas. The grid ID and PTWPS grid cells selected will not be shown to users on the web map, as they can be complex and confusing. Instead, users will be able to click on an icon at the center of the grid cell to zoom into the PTWPS area and see the GLAD alerts near the palm extent or soy extent for the chosen time period. A user will also be able to subscribe to this layer to receive a monthly email when a new layer has been published. Older layers will be archived for up to a year.

This will provide journalists, advocacy groups, and nongovernmental organizations a straightforward and timely way to review filtered GLAD alerts related to oil palm plantation or soy farm production, and alert forest watchdogs about areas of clearing that are potentially in noncompliance with zero-deforestation commitments.

DISCUSSION

Limitations and Assumptions

One limitation with this filtering method is that without combing through multiple companies' individual zero-deforestation commitments, and without knowing which companies are sourcing from each new plantation or production area, there is no clear mechanism to verify the noncompliance of each new plantation. In addition, there is no way at the time of publication to identify or verify the driver, or reliably predict subsequent land use as palm or soy. This method is strictly intended to help filter and contextualize the vast number of available GLAD alerts to find areas that are likely to be planted with oil palm and soybeans, and if so, are unlikely to be compliant with deforestation commitments. In particular, the PTWPS method will pick up large clearance events most likely due to industrial palm concessions or large soy farms. The input grid for this analysis will be updated on an annual basis. Future efforts to boost accuracy could focus on updating the grid every month as new plantations are identified, which is beyond the scope of the current project.

The PTWPS also makes additional assumptions to relate clearing to palm and soy production. The PTW Soy method uses a 5 km grid around soy cultivation from the 2017–18 growing season and the PTW Palm method uses oil palm plantations data published in 2019. This assumes both that future oil palm and soy expansion will be in the vicinity of current production areas and that the clearing occurring near oil palm and soy is more likely to be intended for oil palm and soy production. As a result, the GLAD alerts identified as PTW Palm and Soy cannot be directly attributed to their expansion.

In addition, unlike the PTW Palm method, the PTW Soy method contains no importance score. Thus, the PTW Soy method is based only on proximity to soy production and not contextualized with other layers like PTW Palm that might indicate potential sourcing policy or other violations. In addition, the PTW Soy method does not evaluate or indicate the likelihood of compliance with national, biome-specific, or local-land-use regulations such as the Brazilian Forest Code.

Comparisons with Other Methods

This method is aligned with the conceptual techniques of land use suitability mapping (i.e., overlaying criteria to find areas that are best suited for specific scenarios, like habitats, or construction sites) and has been used for almost 20 years for various geospatial analyses (Malczewski 2004). The Places to Watch quarterly analysis uses a similar method to filter global GLAD alerts, but it focuses on protected areas and intact forests globally instead of on peat and primary forests.

Other methods include using additional context layers and field validations to confirm that loss was due to a specific commodity. For example, to identify soy plantations in recently deforested areas mapped by PRODES (INPE 2017) in the Brazilian Amazon Biome, the area covered by the Soy Moratorium (a multi-corporation pledge to end soy planting in the Amazon forest) is limited to municipalities known to have planted more than 5,000 ha of soy in the most recent crop season. Soy sowing periods and vegetation indices were used to identify soy crop development using Landsat and MODIS imagery (Rudorff et al. 2011). In addition, protected areas, indigenous areas, and land reform areas were removed from the study area since the Soy Moratorium has its focus on private rural properties. Field work and aerial surveys were also used to validate the findings, and, more recently, soy monitoring within the context of the Soy Moratorium has been performed based on satellite imagery due to the higher temporal resolution of the current remote sensing satellites (Rudorff et al. 2011).

Areas for Future Work

Future improvements for both methods would involve updating the inputs as newer data become available, especially for recently expanded or established plantation and agricultural extents. There are a number of avenues to improve upon the PTW Soy method for future analysis by further filtering and contextualizing for a number of values and distinct geographies. The application of an ecological importance score using contextual data such as protected area and intact forest proximity would more accurately reflect the relative impact of potential expansion. Additionally, filtering the GLAD alerts for palm and soy production suitability based on altitude, slope, and soil type would further delimit potential areas of expansion to those considered most likely to grow soy. The method could also be refined to include commercially relevant supply chain sourcing criteria from major soy supply chain actors and more accurately contextualize land use change within legal regulations, such as by using nationally and biome-level relevant land use zoning, cadaster, and environmental registry data.

REFERENCES

Carlson, K.M., L.M. Curran, G.P. Asner, A.M.D. Pittman, S.N. Trigg, and J. Marion Adeney. 2013. "Carbon Emissions from Forest Conversion by Kalimantan Oil Palm Plantations." *Nature Climate Change* 3 (3): 283–87. https://doi.org/10.1038/nclimate1702.

CONAB (Companhia Nacional de Abastecimento/National Supply Company). 2019. "Acompanhamento da safra brasileira—Grãos/Follow-up of the Brazilian Crop—Grains. V.6. Crop year 2018/19, n.6, March 2019." Brasília. ISSN 2318-6852. http://www.conab.gov.br.

Freitas, R., and M. Mendonca. 2016. "Agricultural Expansion in Brazil and Soybean Participation: 20 Years." *Journal of Economics and Rural Sociology* 54 (3): 497–516.

Gomes, J.R. 2018. "Brazil Farmers Poised to Plant Record Soy Area in 2018–19: Poll." Reuters, August 21. https://www.reuters.com/article/us-brazil-grains-soybeans/brazil-farmers-poised-to-plant-record-soy-area-in-2018-19-poll-idUSKCN1L61X5.

Gumbricht, T., R.M. Román-Cuesta, L.V. Verchot, M. Herold, F. Wittmann, E. Householder, N. Herold, and D. Murdiyarso. 2017. "Tropical and Subtropical Wetlands Distribution Version 2." Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Hansen, M.C., A. Krylov, A. Tyukavina, P.V. Potapov, S. Turubanova, B. Zutta, S. Ifo, et al. 2016. "Humid Tropical Forest Disturbance Alerts Using Landsat Data." *Environmental Research Letters* 11 (3). Accessed through Global Forest Watch. https://www.globalforestwatch.org.

Hansen, M.C., P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, et al. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (6160): 850–53. https://doi.org/10.1126/science.1244693.

Harris, N., E.D. Goldman, and S. Gibbes. 2019. "Spatial Database of Planted Trees (SDPT Version 1.0)." Accessed through Global Forest Watch. https://www.globalforestwatch.org.

GADM. 2018. "Database of Global Administrative Areas, Version 3.6." University of California, Davis.

Global Forest Watch. "Universal Mill List." Last updated November 2019. https://www.globalforestwatch.org.

INPE (Instituto Nacional de Pesquisas Espaciais/National Institute for Space Research). 2017. "Monitoramento da floresta amazônica brasileira por satélite—Estimativas anuais de desflorestamento desde 1988 até/Satellite Monitoring of the Brazilian Amazon Rainforest—Annual Deforestation Estimates Since 1988." http://www.obt.inpe.br/prodes/dashboard/prodes-rates.html.

IUCN and UNEP-WCMC (International Union for Conservation of Nature and United Nations Environment Programme–World Conservation Monitoring Centre). 2016. "The World Database on Protected Areas (WDPA)." Cambridge, UK: UNEP-WCMC.

King, L., B. Adusei, S.V. Stehman, P.V. Potapov, X.P. Song, A. Krylov, C. Di Bella, et al. 2017. "A Multi-resolution Approach to National-Scale Cultivated Area Estimation of Soybean." *Remote Sensing of Environment* 195: 13–29.

Malczewski, J. 2004. "GIS-Based Land-Use Suitability Analysis: A Critical Overview." *Progress in Planning* 62 (1): 3–65. https://doi.org/10.1016/j.progress.2003.09.002.

Marti, S. 2008. *Losing Ground: The Human Impacts of Palm Oil Expansion*. Friends of the Earth, Life Mosaic, and Sawit Watch. https://friendsoftheearth.uk/sites/default/files/downloads/palmed_off.pdf.

Miettinen, J., A. Hooijer, D. Tollenaar, S. Page, C. Malins, R. Vernimmen, and C.L. Soo. 2012. *Historical Analysis and Projection of Oil Palm Plantation Expansion on Peatland in Southeast Asia.* White Paper 17. Washington, DC: International Council on Clean Transportation.

Miettinen, J., C. Shi, and S.C. Liew. 2016. "Land Cover Distribution in the Peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with Changes since 1990." *Global Ecology and Conservation* 6: 67–78. https://doi.org/10.1016/j.gecco.2016.02.004.

MoEF (Ministry of Environment and Forestry, Indonesia). 2017. "Fungsi Ekosistem Gambut Lindung/Protected Peat Ecosystem Function."

OSAS (Observatorio Socio-Ambiental de la Soja/Socio-Environmental Observatory of Soybeans). 2014. "Soy Cultivation in South America." Argentina, October. http://observatoriosoja.org/wp-content/uploads/2014/10/OSAS-fact-sheets-ENG.pdf.

Pye, O., I. Radjawali, and Julia. 2017. "Land Grabs and the River: Eco-Social Transformations along the Kapuas, Indonesia." *Canadian Journal of Development Studies 38* (3): 378–94. https://doi.org/10.1080/02255189.2017.1298518.

Rudorff, B., J. Risso, D. Aguiar, F. Gonçalves, M. Salgado, J. Perrut, L. Oliveira, et al. 2015. *Geospatial Analyses of the Annual Crops Dynamic in the Brazilian Cerrado Biome: 2000 to 2014*. Technical Report. Florianópolis, Brazil: Agrosatélite Applied Geotechnology Ltd. http://biomas.agrosatelite.com.br/img/Geospatial_analyses_of_the_annual_crops_dynamic_in_the_brazilian_Cerrado_biome.pdf.

Rudorff, B.F.T., M. Adami, D.A. Aguiar, M.A. Moreira, M.P. Mello, L. Fabiani, D.F. Amaral, et al. 2011. "The Soy Moratorium in the Amazon Biome Monitored by Remote Sensing Images." *Remote Sensing* 3 (1): 185–202.

Song, X.P., P.V. Potapov, A. Krylov, L. King, C.M. Di Bella, A. Hudson, A. Khan, et al. 2017. "National-Scale Soybean Mapping and Area Estimation in the United States Using Medium Resolution Satellite Imagery and Field Survey." *Remote Sensing of Environment* 190: 383–95.

Turubanova, S., P.V. Potapov, A. Tyukavina, and M.C. Hansen. 2018. "Ongoing Primary Forest Loss in Brazil, Democratic Republic of the Congo, and Indonesia." *Environmental Research Letters* 13 (7): 074028.

Wahid, M.B., S.N.A. Abdullah, and I.E. Henson. 2005. "Oil Palm—Achievements and Potential." *Plant Production Science* 8 (3): 288–97. https://doi.org/10.1626/pps.8.288.

ACKNOWLEDGMENTS

We are pleased to acknowledge our institutional strategic partners, who provide core funding to WRI: Netherlands Ministry of Foreign Affairs, Royal Danish Ministry of Foreign Affairs, and Swedish International Development Cooperation Agency.

We would like to acknowledge our fellow colleagues at the International Offices of Brazil and Indonesia, as well as our fellow GFW colleagues for helping modify the original PTW methodology for more specified analysis.

ABOUT THE AUTHORS

Ifeoma Collins, GIS Research Analyst I , World Resources Institute
Contact: ifeoma.collins@usda.gov

Thailynn Munroe, GIS Research Analyst II, Global Forest Watch
Contact: thailynn.munroe@wri.org

Anne Rosenbarger, Southeast Asia Commodities Manager, Global Forest Watch Commodities and Finance
Contact: anne.rosenbarger@wri.org

Ryan Sarsfield, Latin America Commodities Manager II, Global Forest Watch Commodities and Finance
Contact: ryan.sarsfield@wri.org

Caroline Winchester, Africa Commodities & Applied Solutions Manager, Global Forest Watch
Contact: caroline.winchester@wri.org

ABOUT WRI

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.