

POLICY PERSPECTIVE

Overlapping Land Claims Limit the Use of Satellites to Monitor No-Deforestation Commitments and No-Burning Compliance

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Abstract

Worldwide many businesses have recently pledged to sourcing agricultural and timber products exclusively from deforestation and fire-free supply chains. Geoinvestigations—monitoring the activities of plantation companies using satellites and concession maps—are now applied to identify which companies breach their commitments and regulations. We investigate the limitations of geoinvestigations by analyzing land-use and fire in and around 163 Indonesian concessions of oil-palm and pulpwood, where recurring forest and peatland fires are a national and international concern.

We reveal a mismatch between de jure and de facto land occupancy inside and outside concessions. Independent farmers are present in concessions while some companies expand outside concessions. Thus, both actors may be responsible for deforestation and fire inside and outside concessions. On peatland, fire can start outside and spread into concessions, while draining in concessions may promote fire outside. These dynamics make attribution of fire and deforestation in Indonesian concessions impossible without detailed field investigations.

This study highlights the need to combine very high-resolution satellite data with extensive field investigations of de facto land ownership, claims and disputes inside and outside concessions. In Indonesia, such activities could fall under the One Map Policy, whose remit is to identify and resolve overlapping land claims.

Introduction

Many large agroindustrial companies have recently pledged to rid their palm-oil, pulpwood, soy and beef supply chains from deforestation and fire in supply from tropical countries (CLUA 2014). In Southeast Asia, despite these private sector commitments and national laws restricting the use of fire, peatlands and natural forests burn every year, blanketing parts of Indonesia and its neighbors in a toxic smoke (Gaveau *et al.* 2014). Plantation companies, mostly oil-palm and pulpwood estates are under scrutiny because large fires regularly occur in the lands they manage (concessions), destroying forests

and degrading lands. There are now calls to closely monitor the activities of concession holders, particularly multinational companies (Chisholm *et al.* 2016).

Contemporary satellite and computer developments have enabled the monitoring of deforestation and fire in the world's forests in near real-time (Hansen *et al.* 2016; NASA-FIRMS 2016) and made this information available to the public by means of online mapping services (Reymondin *et al.* 2012; GFW 2015; SIIA 2015; ZSL 2015; Greenpeace 2016). Worldwide, governments, civil society and academia are increasingly developing and using online mapping portals to monitor corporate sustainability commitments, define culpability and design

incentives and enforcement measures more effectively. In Southeast Asia, geoinvestigations—monitoring the activities of companies with satellites and concession maps—are perceived as key to the implementation of Association of Southeast Asian Nations (ASEAN) policies, such as the Trans-boundary Haze Pollution Act (THPA) in which Singapore requests fire monitoring responsibilities in Indonesian and Malaysian concessions (Lee *et al.* 2016). NGOs are tracking deforestation in concessions which have committed to zero-deforestation and no fire (Greenomics 2015; Pirard *et al.* 2015). Geoinvestigations also serve scientific enquiry to estimate the contribution of extractive industries to forest loss, and air quality degradation (Abood *et al.* 2015; Marlier *et al.* 2015; Spracklen *et al.* 2015).

The assumptions are that activities within a concession can be ascribed to the company legally managing the land, and that activities outside are the actions of independent farmers, whether local or migrant communities. However, these assumptions will be challenged if there are overlapping land claims, which appear to be widespread in twelve emerging countries (de Leon *et al.* 2013).

In this article, we investigate the extent to which geoinvestigations are a sufficient and reliable tool for monitoring private sector *No-Deforestation* commitments and *No-Burning* compliance. We take Indonesia as a case study because it reports numerous overlapping land claims in remote frontier areas. We focus on recurring forest and peatland fires because these deforestation fires release large amounts of toxic fumes (Stockwell *et al.* 2014) and represent a priority environmental challenge for South-east Asian countries.

The causes and motivations of fire use and spread in Indonesian peatland concessions are complex (Dennis *et al.* 2005). First, companies may not control all of the land under their management for numerous reasons, including insufficient resources, overlapping concessions held by other companies, cooperatives and other businesses, or ownership claims by migrant and local communities (hereafter called independent farmers). This may result in discrepancy between official licenses and actual activities, and may lead to disputes over the control of the land (Scale Up 2010). Second, company managers may be faced with difficulties in controlling invasive fires that were started outside the concession for land clearing purposes. Third, some companies may claim and burn land outside concession boundaries (EIA 2014). For example, nearly a quarter of planted industrial oil-palm was found outside government-registered concessions in Indonesian Borneo (Carlson *et al.* 2013). These companies can include medium and large holders who operate medium to large plantations without formal company

status (hereafter called “companies” as well), and therefore without registered concessions—Indonesian law requires the formation of a company for plantations >25 ha (MoA 2013). Fourth, peatlands are swamps, and must be drained to allow for agriculture, but deep drainage canals increase flammability including up to several kilometers away (Konecny *et al.* 2016). The long-range effects of deep canals created by companies in concessions on peat can therefore promote fires immediately outside the concession.

We begin our analysis by testing the prevailing assumption that fires are lit to clear land to enable planting. If so, fires should only burn unplanted lands; that is, forest and unplanted nonforested lands (hereafter called “idle”), rather than planted areas. We then consider the complex realities on the ground and their implications for using geoinvestigations, by exploring a number of research questions: (i) How much burning occurs inside and outside of concessions? (ii) What percentage of concession area is occupied by independent farmers? (iii) Is there evidence for fires starting on land in concessions occupied by independent farmers? (iv) Is there evidence for fire starting outside of, and spreading into concessions? (v) Is there evidence of companies clearing and burning lands outside concessions?

We address these questions by analyzing burned area extent in and around 163 government-registered concessions (67 pulpwood and 96 oil-palm concessions) totaling 1.8 million hectares (Mha) in a 4.1 Mha region in Riau province, Sumatra (See inset in Figure 1). We chose this region because it was the epicenter of significant smoke-producing peat fires in 2013 and 2014 and has a high rate of peat-swamp forest conversion into plantations (Miettinen *et al.* 2011; Gaveau *et al.* 2014). In this region, oil-palm plantations are developed by either small holders (<25 ha), or companies (either medium or large, whether registered or not, >25 ha). In contrast, two multinational companies monopolize pulpwood plantations, mainly found on peat. We mapped fire progression, and estimated the area of burned forest, burned plantations, and burned unplanted nonforested land (idle land) using fire hotspots (MODIS), medium (30 m; LANDSAT), high (1 m or less; Digital Globe satellites) and very high-resolution (0.1 m; UAV) imagery. Second, we compiled the detailed boundaries of all the legal registered concessions (pulpwood: SK-IUPHK-HTI in Indonesian; oil-palm: HGU and SK-PKH) that have been issued in our study region in collaboration with the provincial office (Dinas Kehutanan Riau) of the Ministry of Environment and Forestry. Third, using LANDSAT, we determined land occupancy in concessions by disaggregating concessions into: (i) areas occupied (either already planted or under development) by companies; (ii) areas occupied (either

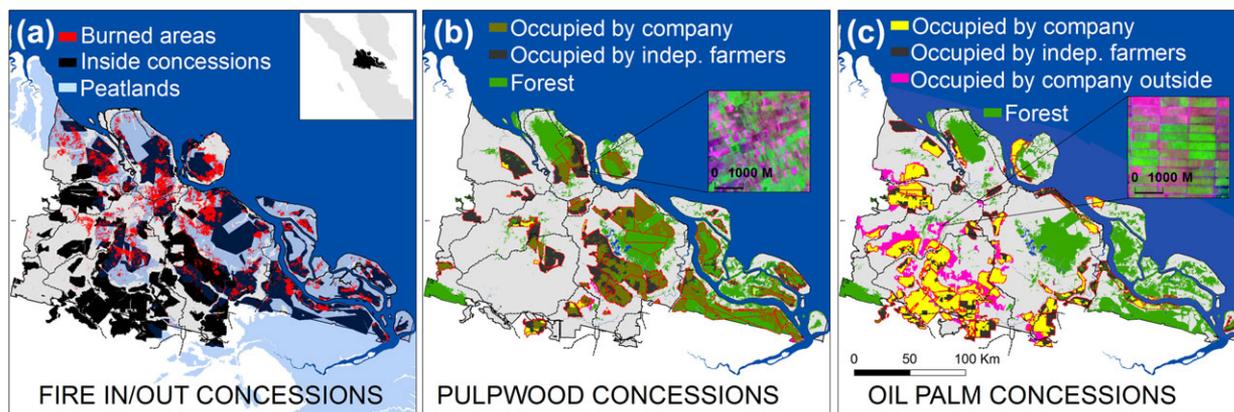


Figure 1 The 4.1 million hectare study area in Riau province, Sumatra (location see inset). (a) The 404,713 ha area that burned in 2013 and 2014 (red) on peatlands (light blue) inside (black) and outside pulpwood and oil-palm concessions. (b) Land occupancy in pulpwood (acacia) concessions. The small inset is a zoom on a LANDSAT image (03 November 2014) revealing clusters of land parcels having irregular shapes, varying sizes, and directions in a pulpwood concession. This spatial pattern characterizes lands occupied by independent farmers (either already planted or under development). (c) Land occupancy in oil-palm concessions. The small inset reveals regular grid-like land parcels outside concessions. This spatial pattern characterizes lands occupied by companies (either already planted or under development).

already planted or under development) by independent farmers; and (iii) undeveloped forest areas. For a complete account, see “Methods” section. We use the insights generated to speculate on improved ways of assessing performance, ways that utilize the monitoring capability of satellite data, while accounting for the complex realities on the ground.

Results and discussion

Idle peatlands are the target of fires, but planted lands are also burning

We find that 0.40 Mha burned in our study region in 2013–2014, including 0.33 Mha (84%) on peat (Figure 1 and Table 1). Seventy-five percent (0.30 Mha) of areas burned occurred on previously nonforest land, 82% of these burned nonforests were idle lands, that is, unplanted peatlands covered with shrubs and wood debris (Figure 2). Therefore, the assumption that fire was used to clear unused land before planting appears to be confirmed. In comparison, only 15% (61,078 ha) of burned areas were peat-swamp forests that had been degraded by selective logging before fire (Figures 1 and 2).

Planted lands were also affected by fire. Ten percent (38,451 ha) of all burned areas were mature *Acacia* tree stands before fire, and 18% (54,870 ha) of burned nonforests were oil-palm stands. Plantations in proximity to idle land are at risk of fire escape, especially on drained peat, where fires can easily propagate uncontrolled well beyond their targeted areas and also where fires may be the result of grievances over land rights (Scale Up 2010).

Therefore, escaped land clearing fires on peat can cause direct substantial financial losses for investors in plantations (loss of assets and agricultural production) both inside and outside concessions. Fires will likely re-occur in our study region, given the large amount of remaining idle lands (Figure S1), unless the Indonesian government and the private sector can enforce *No-Burning* regulations, or incentivize improved management on peatlands successfully.

Inside concessions: role of Independent farmers

We reveal a mismatch between land occupancy (*de facto*) and legal concession allocation (*de jure*). Although independent farmers cannot legally occupy land in concessions, we detect their presence in 160 of the 163 concessions—based on the presence of small land parcels of irregular shape, size, and direction (Figure 1b). Overall, an estimated 33% (0.59 Mha) of the total concession area (1.8 Mha) appears occupied by independent farmers (Table 1). These areas are a mosaic of idle land (55%) and planted oil-palm (44%) (Figure S1g).

Nearly half (48%; 0.19 Mha) of the total burned area was in concessions, and half of the burned area in concessions (95,835 ha, or 24% of total burned area) was occupied by independent farmers before fire (Figure 1 and Table 1). Fires in concessions occupied by independent farmers targeted idle land (82%), but also burned planted oil-palm (18%) (Figure S1i). Independent farmers are also present along concession borders, likely employing fire immediately outside boundaries, which may lead to some fire escape into concessions. This appears

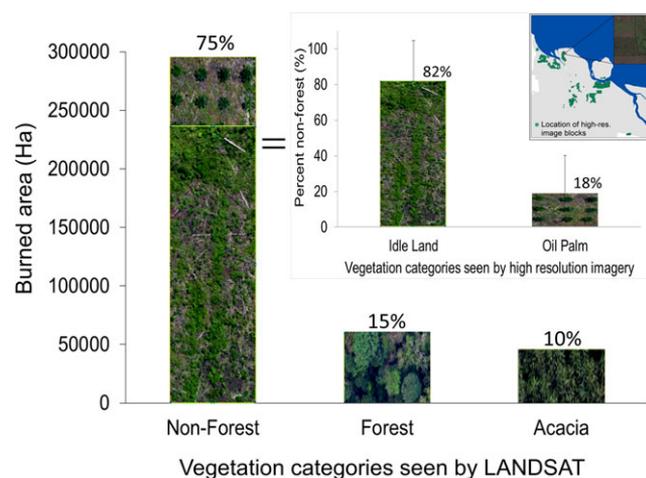
Table 1 Land occupancy and burned area statistics inside and outside concessions.

	Study Region	Inside concessions				Outside concessions			
		Company	Indep. farmer	Forest	All inside ^a	Company	Indep. farmer	Forest	All outside
Area (ha)	4,107,077	899,642	591,061	304,726	1,821,774	181,178	1,626,053	478,072	2,285,304
Burned area (ha)	404,713	60,461	95,835	29,274	194,719	7,956	168,827	33,210	209,994

Note: *Company* refers to land occupied by companies (generally planted or under preparation). *Indep. farmer* refers to land occupied by independent farmers (mainly local and migrant communities). *Forest* refers to unoccupied forested land.

^aWe note that there were 26,345 ha in concessions undisclosed in this table, which we could not attribute to *Company*, *Indep. Farmer* or *Forest*.

Figure 2 The vegetation type of the burned areas (404,713 ha) before the 2013–2014 fires. Burned nonforest, forest and standing acacia (pulpwood) plantations were mapped using medium-resolution LANDSAT imagery. A sample of 682 high-resolution (≤ 1 m) image blocks (mean block size: 213 ha), totaling an area of 144,960 ha (see inset for samples location in green) was used to separate the nonforest class into either idle land or land planted with oil-palm (see “Methods” section).



to be confirmed for the two largest burned areas (18,028 and 22,700 ha) in our study, straddling three pulpwood concessions, where fire had started outside (or in areas inside occupied by independent farmers), and which resulted in the destruction of 11,211 ha of planted acacia in pulpwood concessions (Figure 3).

These results suggest that independent farmers may be responsible for a substantial number of burning inside concessions by clearing idle land with fire for oil-palm inside and immediately outside concessions. However, companies may also use fire as a deterrent and burn land already planted by independent farmers to regain control of disputed areas. We still know too little concerning these specific fire events, but these findings imply that analyses of deforestation and fire data in concessions is not sufficient to prescribe attribution of fire event to concession owners without detailed field investigations.

Outside concessions: role of companies

We reveal another mismatch between land occupancy (de facto) and legal allocation (de jure) outside concessions. Although companies cannot legally operate outside their concessions, we detect their presence in these areas.

Over 28% (193,535 ha) of the total land occupied for oil-palm plantations by registered companies (695,695 ha) was found immediately outside of the legal concession boundaries—based on the presence of regular grid-like land parcels (Figure 1c). This estimate is conservative because it does not include land occupied by unregistered medium-sized land owners who operate like companies, but without formal company status, and adopt a diversity of planting patterns that are difficult to detect on the imagery.

Over half (52%; 209,994 ha) of the total burned area was outside of concessions (Figure 1 and Table 1). The majority of these (73%) were on State Forest Land (including 9,700 ha in protected areas) (Figure S2) for which there is no Land Registry because the development of agriculture in State Forest land is illegal. In addition, 82% (55 of 67) of pulpwood concessions are located on peat domes and over 59% (123,343 ha) of the burned area outside concessions occurred within a five kilometer buffer bordering these pulpwood concessions (Figures 1a and b), validating the need to explore (e.g., with advanced hydrology models) whether deep peat draining in pulpwood concessions indirectly increases fire susceptibility immediately outside.

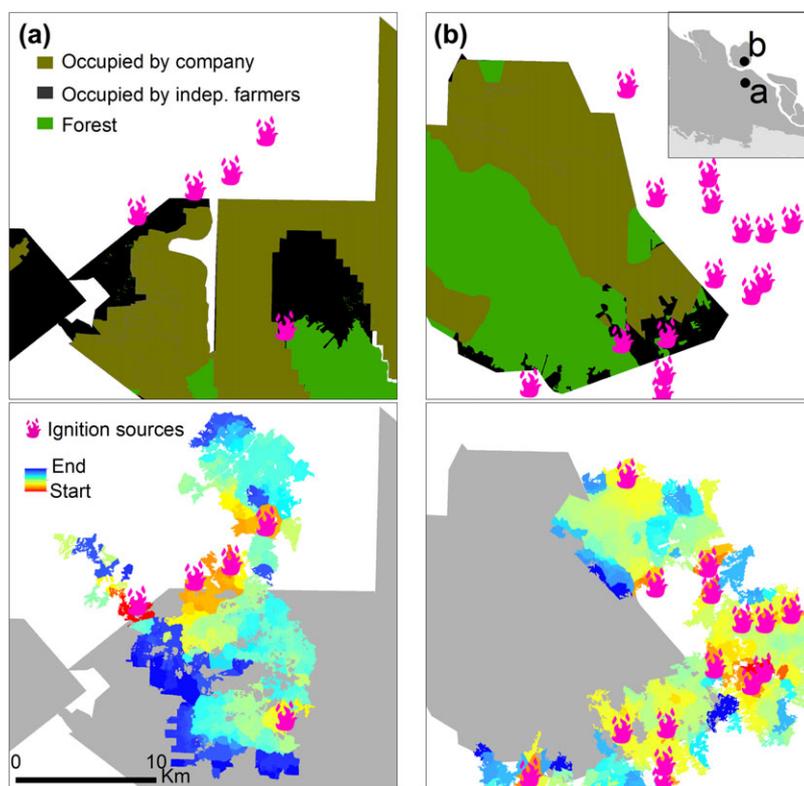


Figure 3 Propagation of two the largest burned areas (18,028 and 22,700 ha) in pulpwood concessions on peat. Fire ignited immediately outside concessions or inside on land occupied by independent farmers (disputed land) and spread well into the interior of the concessions where fire eventually ended. Independent farmers likely ignited a number of fires inside and immediately outside these two pulpwood concessions to clear idle land before planting oil-palm. Companies may have also used fire as a deterrent to regain control of disputed areas, and may have indirectly promoted fire spread by increasing fire susceptibility in the wider area with the use of deep drainage canals in these peatland concessions.

These results suggest that a substantial number of fires lit outside concessions are the actions of companies, whether duly registered or not, whether directly or indirectly. Scrutiny of activities by companies inside concessions alone is therefore insufficient and demonstrates a valid need to investigate fire contagion within a larger landscape, and with detailed field investigations.

Conclusion

While previously considered marginal for agriculture, Indonesian peatlands are now a primary target for agricultural expansion, resulting in annual fires associated with episodes of extreme air pollution (Gaveau *et al.* 2014). Registered companies are in the spotlight because concessions under their management can now be investigated via publically available online mapping services (Reymondin *et al.* 2012; GFW 2015; SIIA 2015; ZSL 2015; Greenpeace 2016), which indicate that concessions on peatlands are burning. We demonstrate that geoinvestigations, as currently employed, are not sufficient to ascribe culpability of Indonesian peatland fires due to the mismatch between *de jure* status and *de facto* land ownership inside and outside concessions. In Indonesia, land use and tenure in remote frontier areas are governed by a tangle of national, provincial, and customary laws that

often compete and overlap with each other, resulting in confusion over who owns what, and in disputes over land control (Shivakumar *et al.* 2015). This tenorial issue is not unique to Indonesia. An estimated 31% of all concession land in twelve emerging economies overlap documented community land claims (de Leon *et al.* 2013). This complexity is so far largely uncaptured by current online mapping services. In Indonesia, our analysis indicates while some companies may suffer from encroachment, also a number of companies are responsible for fires and deforestation outside their concessions, some of whom do not possess concession rights because they are not registered. As governments seeks to design incentive and enforcement measures to mitigate fire and deforestation more effectively, improved knowledge on *de facto* land ownership of individual land parcels is needed. We suggest that detailed maps of *de facto* land ownership (inside and outside concessions) can be created by combining very high-resolution (<1 m) satellite imagery (for the identification of size and limits of land parcels and vegetation cover) with contextual social and tenorial information collected in the field (Dennis *et al.* 2005; Carmenta *et al.* 2011). Extensive field checks of millions of land parcels seen by satellites are necessary to identify *de facto* ownership, potential claims and disputes across the large remote frontier regions of Indonesia regularly affected by

fire. Field investigations may benefit from willingness by the private sector to collaborate with the public administration and with civil society. For example, major efforts by oil-palm and pulpwood groups in Indonesia already include detailed field assessments of land claims and conflicts in their concessions and could provide information on lessons learned, but are not generally available for public consultation. In Indonesia, these activities could be achieved in synergy with the One Map Policy, whose remit is to identify and resolve overlapping claims of land ownership in rural Indonesia (Salim 2014; BIG 2015) and feed in to Indonesia's centralized Land Registry. The reliable monitoring of corporate sustainability commitments and the definitive attribution of responsibility for fires and deforestation events requires a resolution of overlapping land claims.

Methods

Mapping burned areas and prior vegetation in the study area

We extended the method developed and described in Gaveau *et al.* (2014) to map burned areas. We mapped burned areas using LANDSAT OLI satellite imagery acquired shortly before and after fire. We employed multiple images to reduce areas obscured by clouds and haze. Burned and unburned areas were mapped using a tree-based supervised classification algorithm (Rulequest 2007). We evaluated the accuracy of the LANDSAT-based "2013 burned area" map with very high-resolution imagery (0.1 m) acquired with an Unmanned Aerial Vehicle (UAV, Skywalker Aero model with a camera Canon S100), 1 month after fire. We observed an accuracy of 85% (Gaveau *et al.* 2014). We assume a similar accuracy for the extended 2013–2014 burned area map presented in this study. We estimated the area burned on peat by intersecting the burned area map with a peatland map from Indonesia's Ministry of Agriculture (Ritung *et al.* 2011).

We employed a two-step process to characterize the types of burned vegetation. First, we mapped the area of forest, nonforest, and planted acacia (pulpwood) that existed in our study region before fire using the pre-fire LANDSAT imagery. Our definition of *Forest* includes any natural forest that has remained in sufficiently good condition to be seen as intact or nearly intact on the imagery – this includes old-growth forest (Dipterocarps and Kerangas, on dry mineral soils, and on fresh-water and peat swamps as well as mangrove forests), selectively logged forest, and possibly some forest mildly impacted by ground fires. *Forest*, *Nonforest*, and *Planted Acacia* can be mapped with high accuracy (>94%) using

LANDSAT (Gaveau *et al.* 2014). In contrast, a refined analysis of what constitutes *Nonforest* requires examining higher resolution imagery. We quantified the proportion of unplanted nonforested (idle) lands and planted lands present in the nonforest area in our study region (by analyzing a sample of high-resolution (≤ 1 m) image blocks ($n = 682$; mean size: 213 ha; total area: 144,960 ha) acquired a shortly after fire (UAV for 2013; Digital Globe satellite imagery for 2014 available in Google Earth). See inset in Figure 2 for location of the image blocks. We quantified the proportion of burned idle and planted lands by analyzing a subset from our image blocks where fire had occurred ($n = 440$; mean block size: 107 ha; total area: 47,018 ha). The error bar presented in Figure 2 is calculated as ± 1 SD.

Mapping fire progression

We identified where fires ignited and where they spread in our two largest burned areas by retrospectively mapping daily fire progressions. We used the methods developed by Parks (2014), where fire progression was estimated by spatially interpolating MODIS fire detection data (MCD14ML product, Collection 5). MODIS fire detection data depict the date and location (i.e., pixel centroid) of actively burning MODIS pixels, and although the spatial resolution is relatively coarse (1 km), the fine temporal resolution allows day-of-burning to be mapped at finer spatial resolution via interpolation. We used this approach to map fire progression, and hence identify the locations where fires ignited, because agency-generated fire progression maps were not available and interpolated MODIS data provide reasonable estimates (Parks 2014).

Land-use in concessions

Concessions (36% of our study area, or 1.8 Mha) were disaggregated into: (i) areas occupied by companies; (ii) areas occupied by independent farmers; and (iii) forest (not occupied). This partitioning was achieved by delineating the spatial arrangements of land parcels on the prefire LANDSAT imagery. Lands occupied by independent farmers exhibited clusters of irregular shaped plots, varying sizes, and arrangements. Lands occupied by companies exhibited organized and formulaic grid-like structures. We delimited the regions with grid-like structures by visual interpretation, and assigned them to either land occupied by oil-palm or pulpwood companies using the concession maps. When the grid-like structure occurred outside concessions, we assigned them to *Land Occupied by Companies Outside*. Areas within concessions that had irregular parcel arrangements were ascribed as *Occupied by Independent Farmers*. Areas in concessions with forest remnants were classified as *Forest (Not Occupied)*. We

then quantified the proportion of idle and planted lands present in nonforest areas inside and outside concessions by analyzing several subsets from our high-resolution image blocks.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

supporting figure

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