Forest and land fires, toxic haze and local politics in Indonesia

H. PURNOMO[a,b], B. OKARDA[a], B. SHANTIKO[c], R. ACHDIAWAN[a], A. DERMAWAN[a,d], H. KARTODIHARDJO[b] and A.A. DEWAYANI[e]

[a]*Center for International Forestry Research (CIFOR), Bogor, Indonesia*
[b]*Faculty of Forestry, IPB University (Bogor Agricultural University), Bogor, Indonesia*
[c]*United Nations Industrial Development Organization (UNIDO), Jakarta, Indonesia*
[d]*Public Administration and Policy Group, Wageningen University*
[e]*University of Missouri, USA*

Email: h.purnomo@cgiar.org, b.okarda@cgiar.org, b.shantiko@gmail.com, ramadhani@agimpact.org, a.dermawan@cgiar.org, hakabgr@gmail.com, adeayudewayani@gmail.com

SUMMARY

Forest and land fires are among the major catastrophic events that occur in Indonesia. They are a major cause of deforestation and greenhouse gas emissions. Their multiple sources are most diverse and root in nature and society. The immediate fire effects directly and the long-term landscape ecosystem degradations indirectly cause major and persisting and serious problems of public health and ecosystem service. Smoke haze from the forest and land fires in Sumatra and Kalimantan in 2015 caused significant environmental and economic losses in Indonesia, Singapore and Malaysia. We describe the different types of land uses and land cover where fires and smoke haze took place, and how local politics have affected fire use from 2001 to 2017. We calculated hot spots from satellite imageries as proxies for fire occurrences and applied regression analysis to understand the link between fire and local politics in Sumatra and Kalimantan. The results show that the greatest frequency of hot spots occurred in wood and oil palm plantations and logging concessions (47%), followed by conservation areas (31%) and community land (22%). Local elections involve land transactions, and fires were used as a cheap way to increase the land value. The use of fire as means of land clearing was strongly influenced by local politics. Their frequency and abundance obviously increased about a year prior to local elections. The reasons behind the correlation need to be understood so that appropriate incentives and sanctions can be put in place and deter political leaders from using fire as an incentive to their advantage.

Keywords: organized networks, power structure, oil palm and wood plantations, *adat,* gazetted law

Feux de forêts et incendies, brumes toxiques et politique locale en Indonésie

H. PURNOMO, B. OKARDA, B. SHANTIKO, R. ACHDIAWAN, A. DERMAWAN, H. KARTODIHARDJO et A.A. DEWAYANI

Les incendies et feux de forêts comptent parmi les évènements les plus catastrophiques en Indonésie. Ils sont une cause majeure de la déforestation et de l'émission de gaz à effet serre. Leurs origines multiples sont très diverses et puisent leurs racines dans la nature et la société. Les effets immédiats des feux affectent directement la dégradation de l'écosystème et du paysage à long-terme et, indirectement, des sérieux problèmes majeurs et persistants de santé publique et des services d'écosystème. La brume toxique provenant des incendies à Sumatra et au Kalimantan en 2015 causèrent des pertes environnementales et économiques importantes en Indonésie, Malaisie et à Singapour. Nous décrivons les différents types d'utilisation de la terre et de couvert du sol dans les lieux d'où les incendies et la brume toxique émanèrent et comment les politiques locales affectèrent l'usage du feu de 2001 à 2017. Nous avons calculé les points chauds en utilisant l'imagerie satellite comme procuration et en appliquant une analyse régressive pour essayer de cerner le lien entre les incendies et les politiques locales à Sumatra et au Kalimantan. Les résultats indiquent que la plus forte fréquence de points chauds se centrait dans les plantations, particulièrement d'huile de palme, et les concessions de coupe (47%), suivies par les zones de conservation (31%) et les terres communautaires (22%). Les élections locales comprennent des transactions de terres, et les incendies étaient utilisés comme moyen non onéreux de faire apprécier la valeur du terrain. L'utilisation des feux comme moyen de dégager le terrain était fortement influencée par les politiques locales. Leur abondance et leur fréquence augmentait évidemment un an environ avant les élections locales. Les raisons sous-tendant cette corrélation doivent être comprises, afin que des encouragements tout comme des sanctions puissent être mis en place et décourager les politiciens d'utiliser les feux à leur avantage.

Incendios forestales y agrícolas, neblina tóxica y políticas locales en Indonesia

H. PURNOMO, B. OKARDA, B. SHANTIKO, R. ACHDIAWAN, A. DERMAWAN, H. KARTODIHARDJO y A.A. DEWAYANI

Los incendios forestales y agrícolas son una de las principales catástrofes en Indonesia. Constituyen una de las principales causas de la deforestación y de las emisiones de gases de efecto invernadero. Sus múltiples causas son muy diversas y están arraigadas en la naturaleza y la sociedad. Los efectos inmediatos del fuego, tanto directamente como indirectamente en la degradación a largo plazo del ecosistema del paisaje, causan problemas importantes persistentes y graves a la salud pública y a los servicios del ecosistema. La neblina de humo de los incendios forestales y agrícolas en Sumatra y Kalimantan causó en 2015 importantes pérdidas ambientales y económicas en Indonesia, Singapur y Malasia. Se describen los diferentes tipos de usos de la tierra y de la cobertura del suelo donde se produjeron los incendios y las neblinas de humo, y cómo la política local ha afectado el uso de los incendios entre 2001 y 2017. Se calcularon los focos principales a partir de imágenes satelitales como indicadores sustitutivos para los casos de incendios y se aplicó un análisis de regresión para entender el vínculo entre el fuego y la política local en Sumatra y Kalimantan. Los resultados muestran que la mayor frecuencia de focos ocurrió en las plantaciones de madera y de palma aceitera y en las concesiones madereras (47%), seguida por las áreas de conservación (31%) y las tierras comunitarias (22%). Las elecciones locales suscitan transacciones de tierras, ya que los incendios se han utilizado como una forma barata de aumentar el valor de la tierra. El uso del fuego como método para el despeje del suelo estuvo fuertemente influenciado por la política local. Su frecuencia y abundancia aumentaron obviamente alrededor de un año antes de las elecciones locales. Las razones detrás de la correlación deben ser entendidas para que se pueda establecer incentivos y sanciones apropiadas y disuadir a los líderes políticos de usar el fuego como un incentivo para su propio beneficio.

INTRODUCTION

The smoldering of burning peat, open land-surface fires, and the gaseous and particulate haze they create have affected the health of many people in Southeast Asia. Fire releases substantial quantities of volatile organic compounds that regulate the production and destruction of atmospheric oxidants and may be important to the ecosystem carbon balance and an essential regulator of the protective functions of the ozone layer (Sommer *et al*. 2004, Crutzen *et al.* 2016). In Indonesia, the National Disaster Management Agency recorded that the fire disaster of 2015 caused the recorded death of 24 children and adults by December 2015 (Fitri and Putri 2015). In Sumatra, Kalimantan and Papua, it caused environmental damage and substantial losses in terms of assets and economic and social activities. Traffic, tourism and education suffered badly throughout the whole region. The rate of premature death was much higher than previously, estimated at 100,300 people (Koplitz *et al.* 2016). The provinces in Indonesia that were severely affected by haze were: Riau, Jambi, South Sumatra, West Kalimantan and Central Kalimantan (Kementerian Kesehatan 2015). Singapore, Malaysia, Thailand and the Philippines were also affected by the haze (Heilmann 2015).

Scientists at the US National Aeronautics and Space Administration (NASA) proved and quantified that the haze caused by forest and land fires in Indonesia in 2015 was equivalent to that of 1997/1998, which followed an El Niño event (NASA 2015). In 1997/1998, economic losses were estimated at USD 9.2 billion (Applegate *et al.* 2002) or 4.3 percent of the 1997 GDP; and in 2015, losses were estimated at USD 16.1 billion or 1.9 percent of the GDP (World Bank 2016). These losses consisted of water resource damage, carbon emissions, flora impairment, biodiversity loss, health expenses, business travel disruption and the cost of ecosystem restoration.

In 2015, about 2.6 million ha of forest and land in Sumatra and Kalimantan were burned both on the state forest zones (SFZ, *kawasan hutan*) and non-state forest zones (NSFZ, *Area Penggunaan Lain*) (Khoemaeni 2015). Mizuno *et al.* (2016) describe the complexity and dynamics of land use and ownership inside the SFZ. SFZ are administered by the government, although they do not necessarily have tree cover. NSFZ are located out of the state forest zones and is allocated for other purposes. Corporate concession holders obtain licenses to manage large-scale concessions for a certain time for commercial purposes. Depending on the crop, corporate concessions can be located inside the SFZ or NSFZ. Communities inside SFZ can have pre-existing right to the land. However, there are cases where a person, group of people, and/or small- or medium-scale companies occupy lands in the forest zones to manage areas for private benefits illegally.

For tropical countries such as Indonesia, Field *et al*. (2016) and Schmidt (2016) argue that El Niño is a key factor that affects the severity of fires. However, fires were not ignited because of dry climatic conditions. Fires in Indonesia were mostly intentional and man-made and were amplified by the biophysical and atmospheric conditions (Tacconi 2003, Saharjo 2007, LSE 2016). The fires in 2015 were set alight by humans and exaggerated by dry climatic conditions due to El Niño (World Bank 2016). Forest and land fires in Indonesia under drought conditions would contribute to significant global atmospheric CO_2 emissions (Field *et al.* 2009). Burning peat is caused by surface fires that transition into the peat under specific conditions (Stracher *et al*. 2015). In the absence of controlled burning measures or sufficient law enforcement, the fires grew out of control, and were exacerbated by drought caused by El Niño (World Bank 2016). Spessa *et al.* (2015) stated that seasonal fires in Kalimantan, Indonesia, is influenced by El Niño years. Due to the continued use of fire to clear and prepare land on degraded peat, the Indonesian fire environment continues to have nonlinear sensitivity to dry conditions (Field *et al.* 2016). Wooster *et al*.

(2012) support the hypothesis that the El Niño phenomenon is a primary, large-scale and short-term climatic factor that occurs every 5–7 years; it influences the magnitude of the fire activity resulting from numerous land cover changes, agricultural preparation practices and human-caused ignitions that occur annually across Indonesia. However, Gaveau *et al.* (2014) find that fires in non-El Niño periods are important, which indicates that there could be human factors that affect the fires. Both biophysical and anthropogenic factors influence the magnitude of the fires that are ignited.

Fire has been used to clear forest land for native land use throughout human history. More recent is the use of fire to increase its market value. Forests were logged and the slash burned to make the land commercially cultivatable, especially for industrial fibre and oil palm plantations. Purnomo *et al.* (2017), in a case study of Riau Province, show that illegal land claims and land transactions had occurred in the SFZ. Land claims were usually followed by a process of slash and burn. This illegally claimed land was valued at USD 665 per ha. The value increased to USD 856 per ha if it was burned, and the value increased further to USD 3077 per ha if it was already planted with 3-year-old oil palm.

Fires in company concession areas were the largest contributors to smoke haze in Riau Province. Twelve pulp wood plantation company areas (both small and large) were burned (Syukur 2015). Oil palm plantations used fires illegally to clear land cheaply and quickly and to rejuvenate plants. In pulp wood plantations, fires were also used in a similar way (Putri 2014). This method costs 20–50% less than the normal cost of USD 200–600 per ha for land clearing and plant rejuvenation. Gaveau *et al.* (2017) reveal that as many as 82% of fire occurrences took place on 'idle' land. Idle land is land that lies inside and outside concessions and that is not secure from grabbing by different actors, i.e. farmers, who may be local community or mid-sized investors, and companies. Those are the actors connected to burning of land that is idle.

Our objective in this paper is to determine the connection between land uses, local politics and fires in Sumatra and Kalimantan Islands, Indonesia. Our three research questions are as follows:

- *How were land and forest fires distributed over different land uses?*
- *How were local politics connected to forest and land fires?*
- *Which future policy options can reduce land and forest fires?*

This paper focuses on the connection between fires and political and economic issues in Sumatra and Kalimantan, Indonesia. This paper will contribute to understanding the connection between local politics and fire occurrence.

APPROACH AND METHODS

Political economy and social–ecological system research into the causes and underlying issues relating to fires in Indonesia has been carried out for a long time, generating many technical, economic, social and political recommendations (Dennis 2009). The failure to understand the political economy (Dauvergne 1998) in relation to actors and their patronage has resulted in difficulty in overcoming forest fires (Varkkey 2013). The key *patrons* of forest fires consist of the ruling elites in business and politics at local, national and global levels (Varkkey 2016).

In Indonesia and Brazil, the importance of the sociopolitical issues in driving the fires has been acknowledged; however, the solution has been to prioritize technical research in firefighting, such as the identification of alternative agricultural (land clearing) practices other than fire and better fire identification capabilities. This has hampered efforts to overcome forest fires (Carmenta *et al.* 2011).

Political economists view politics as a crucial factor in determining economic outcomes (Drazen 2000, Purnomo *et al.* 2012a). The political economy focuses on how power and resources are distributed and contested in different contexts (DFID 2009). Policy change and the politics of "who gets what, when, and how" are closely related (Lasswell 1958). Many studies on the political economy of natural resources management in Indonesia highlight the importance of good governance of land and forests to improve forest sustainability and the livelihoods of people (Barr *et al*. 2009, Purnomo *et al.* 2012b). The political economy and good governance approaches are often used in national development transformation based on natural resources (Barma *et al.* 2012). Good governance is indicated by transparency, voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption (Kaufmann *et al*. 2007).

Studies on the drivers of deforestation invariably highlight the absence of good governance and socially acceptable policies, the predominance of market and investment failures, as well as a host of minor sociopolitical issues as underlying causes of deforestation (Contreras-Hermosilla 2000). The underlying causes drive the proximate causes of deforestation, which include agricultural expansion to produce food, wood extraction and infrastructure development (Geist and Lambin 2001). In the context of Indonesia, many studies show weak governance have driven deforestation. Poor licensing procedures and bribery have cleared the pathway to open the forests for other purposes. About half of oil palm expansion areas in Malaysia and Indonesia have gone through prior deforestation (Koh and Wilcove 2009, Miettinen *et al*. 2011, Busch *et al*. 2014, Margono *et al*. 2014, Vijay *et al*. 2016) by the plantation corporations as part of the financing scheme. The rapid development of oil palm has had adverse effects on Indonesia's forests, including production forests and protection areas (Casson 2002).

In a mosaic landscape, agriculture commodities such as rubber, oil palm and sweet corn usually provide greater financial benefits than forest. This benefit gap drives conversion from forest to agriculture (Suyanto 2006, Chomitz 2007). Moreover, land clearing for oil palm often goes hand in hand with legal or illegal transactions. Actors obtained enormous economic benefits from illegal forest and land transactions and conversion to oil palm using fire (Purnomo *et al.* 2017).

Land-use transitions contribute to atmospheric carbon emissions, including forest conversion for small-scale farming, cattle ranching, and production of commodities such as soya and palm oil. These transitions involve fire as an effective and inexpensive means for clearing land (DeFries *et al.* 2008). Dennis *et al.* (2005) confirm multiple direct and underlying fire causes that operate at any site, and wide differences in fire causes among sites. Gaveau *et al.* (2016) underline the role of various stakeholders, both of small-scale landholders and large industrial plantations, in causing fires. Colfer (2002) explains that the fires in Kalimantan were partly due to the government's uncoordinated response to land use issues. Perceptions of peatland fire and fire management are contested across scales (Carmenta *et al*. 2017).

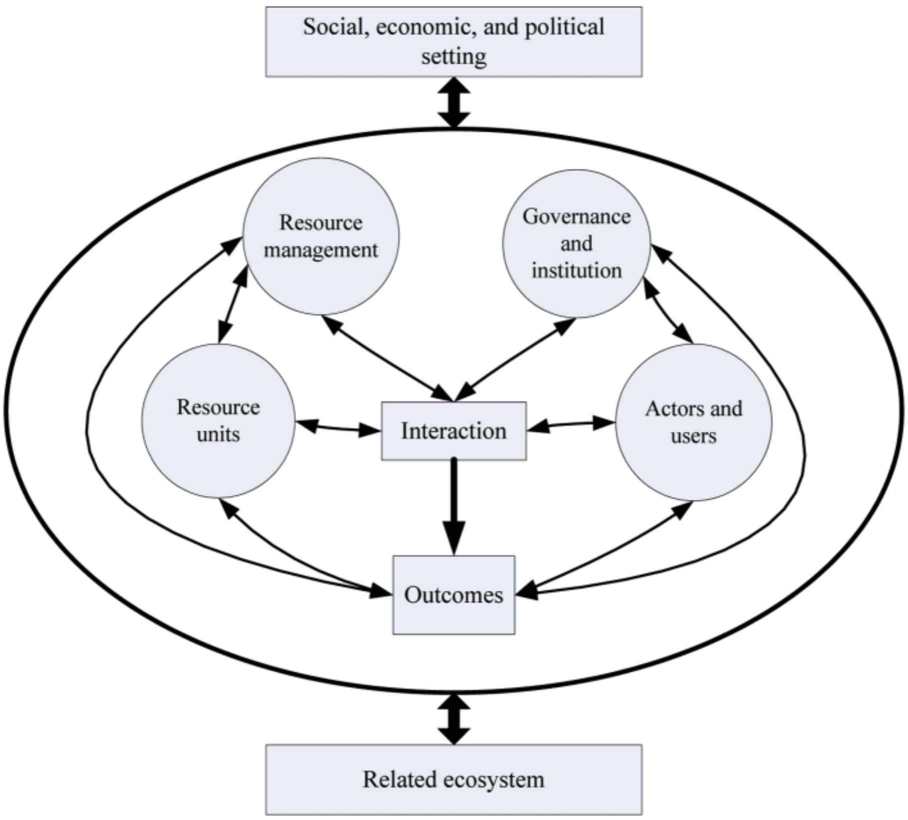
Ostrom (2007) describes the political economy as the interaction between humans as economic and social actors, and the ecological environment in the framework of a social–ecological system (SES). SES consists of four interacting components – resources, management, governance and users – that are influenced by the social, economic, and political settings and produce outcomes for the ecosystem (Figure 1). The SES framework is useful in understanding how the political economic settings influence the use of forests and land. SES helps identify factors that may affect the likelihood of policies enhancing sustainability (Ostrom 2009). The framework is useful to provides a broader view of the haze problem, which is not only caused by poor land use but by the political and economic settings at local and national levels. The SES framework was applied in cases of common-pool resources such as forests and climate (Purnomo *et al.* 2013).

Methods

The research questions are as follows: (a) How were land and forest fires distributed over different land uses? (b) How were local politics connected to forest and land fires? (c) What are the future policy options to reduce land and forest fires? As such, the research method is comprised of the following steps: (a) data collection of spatial maps and hot spots and descriptive analysis between hot spots and land uses by various actors; (b) analysis on the links between hot spots and local elections (PILKADA) in terms of the number of hot spots; and (c) SES analysis.

Fire occurrences include fires in peatland and mineral soils. Data on hot spots were recorded on maps and hot spots were overlaid on land used by various actors. Concession maps of pulpwood plantations, oil palm plantations and logging concessions were generated from the World Resources Institute (WRI) database (WRI 2018). Hot spot data were generated from the Fire Information for Resource Management System (FIRMS) of NASA (2018). Forest land maps were generated from maps sourced from the Ministry of Environment and Forestry (MoEF) in 2015. Hot spot locations were produced by fire detection sensors of the MODIS satellite using the infrared spectrum band. Fire detection is performed using a contextual algorithm that exploits the

FIGURE 1 *Framework of a social–ecological system (SES), (adapted from Ostrom 2007, 2009)*



strong emission of mid-infrared radiation produced by fires. The algorithm examines each pixel of the MODIS swath and excludes missing data, clouds and water. What remains are pixels representing the land; these are potential fire pixels. A series of contextual threshold tests are used to perform relative fire detection. These look for the characteristic signature of an active fire in which both the 4-μm brightness temperature and the 4- and 11-μm brightness temperature difference depart substantially from that of the non-fire background. Additional specialized tests are used to eliminate false detections caused by sun glint, desert boundaries and errors in the water mask (Giglio 2015). Each active fire location represents the center of a 1-km pixel that is flagged by the algorithm as containing one or more fires within the pixel. The accuracy level of this detection system has improved since the year 2000. For our analysis, we used hot spots with a confidence level of ≥80% – the same confidence level used by the MoEF for the same purpose. Although most hot spots can be attributed to fires, on rare occasions, artefactual hot spots might result from reflections off vehicles left in the sun or off pools of water.

The number of hot spots represents how often a land use area experiences fires at the same or various locations each day. They do not linearly represent the extent of fire over an area. If fire occurs at the same location on two consecutive or different days, then it will be recorded as two hot spots. In other words, two hot spots can occur at two locations that each experience fire on 1 day or in one location that experiences fire two times in 1 day. We used the number of hot spots as a proxy for how particular areas were burned.

We aimed to outline land use and hot spots on 102.8 million ha in Sumatra and Kalimantan by overlaying data from WRI, NASA and MoEF according to land use types. Overlaying the land use and hot spot maps for the last 17 years generated a distribution of hot spots in each land use type in corporate concessions, i.e. logging concessions, wood plantations, oil palm plantations and areas outside the corporate concessions (government-managed SFZ and NSFZ).

The land and forest zone data that were analyzed in this article came from various sources. Spatial maps of corporate concessions, logging concessions, and wood and oil palm plantations came from WRI; forest zone data were derived from the MoEF; and hot spot data were derived from FIRMS NASA. The various data sources were not calibrated against each other and were expected to produce asynchronous information. For example, corporate area maps derived from WRI did not entirely match up with forest zone maps from the MoEF. Instead, we used overlapping maps of logging concessions and wood and oil palm plantations (see Table 1). Forest and corporation maps often change from year to year. The issuance of new concession areas and the revocation of current concession areas are among the major factors that contributed to any inaccuracy. The problem of various incoherent data will not be solved soon in Indonesia. Indonesia has a program of a one map policy that is supported by the World Bank, but would require some time to reconcile the different maps. This is the limitation of this article that should be stated explicitly, as suggested by Mensh and Kording (2017).

Local politics was assessed in connection with the number of local elections (PILKADA) in Sumatra and Kalimantan during the same fire time-series observation. PILKADA is a way of electing the head of the local government at the district level. Local government elections occur every five years. Political parties or groups of political parties nominate candidates to be elected by the voters, who are citizens of Indonesia aged 17 years or older.

Regression analysis was carried out to determine the correlation between the number of hot spots and the number of PILKADA. It was hypothesized that a fire event in year ‘t’ is affected by a fire event. Hence, the time-series regression model used to estimate the fire event was autoregressive. Autoregressive models use the regression of a dependent variable by using the same variable from earlier in the same time series as the independent variable (Cryer and Chan 2008). The lag time of the autoregression (AR) function of the fire event was explored using a partial autocorrelation function. After the best AR function had been defined, another independent variable was included in the model; the model is thus called AR-X (i.e. an autoregressive model with X as the additional independent variable). The independent variables were tested through a stepwise process. The data were explored using the statistical software Minitab 15 (Minitab 2007). This result is described in the context of the SES framework (Figure 1). As explained by Ostrom (2009), SES shows the relationships among four subsystems of an SES that affect each other as well as linked social, economic, and political settings and related ecosystems. The subsystems are: (i) resource systems (e.g. a designated protected park encompassing a specified territory containing forested areas, wildlife and water systems); (ii) resource units (e.g. trees, shrubs and plants contained in the park, types of wildlife, and amount and flow of water); (iii) governance systems (e.g. the government and other organizations that manage the park, the specific rules related to the use of the park and how these rules are made); and (iv) users (e.g. individuals who use the park in diverse ways for sustenance, recreation or commercial purposes). Each core subsystem is made up of multiple second-level variables (e.g. size of a resource system, mobility of a resource unit, level of governance and users’ knowledge of the resource system).

RESULTS

Land use and hot spots

The location of hot spots or fire spots shown by satellite images from January to December 2015 in Sumatra and Kalimantan is given in Figure 2. While hot spots were identified throughout the islands of Sumatra and Kalimantan, most of the hot spots were found in southern Sumatra and Central Kalimantan. According to Tacconi (2016), major sources for 2015 haze were fires on oil palm concessions, food crops, and in natural forests.

FIGURE 2 *Hot spot distribution in Sumatra and Kalimantan, Indonesia, from January to December 2015 (NASA 2015)*

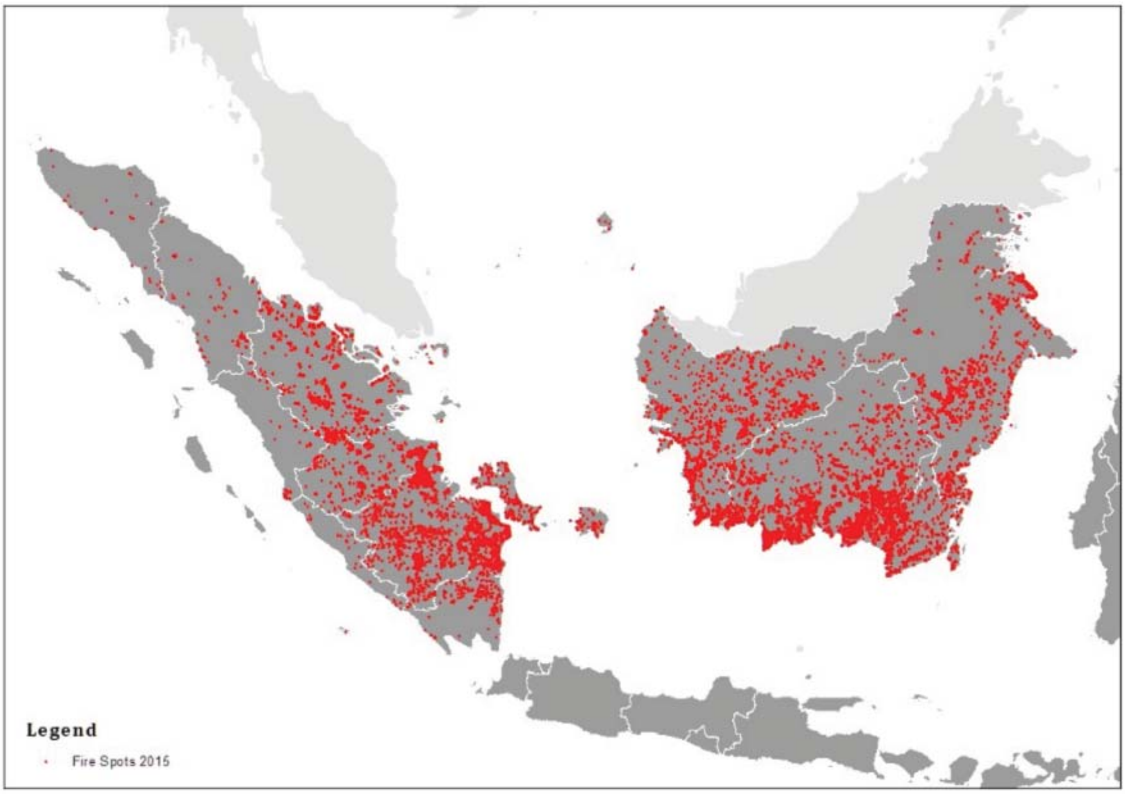


Table 1 shows two main land use types and the hot spots distribution for 2001–2017. Amounting to 34.7% of the areas were corporate concessions. There are four types of concessions: logging concessions, pulpwood plantations, oil palm plantations and an overlapping area among the three of them. Corporate-managed oil palm plantations were in NSFZ (8.8%) and converted SFZ (2.6%). Non-corporate concessions in the NSFZ were 30.2% and in SFZ were 35.1%.

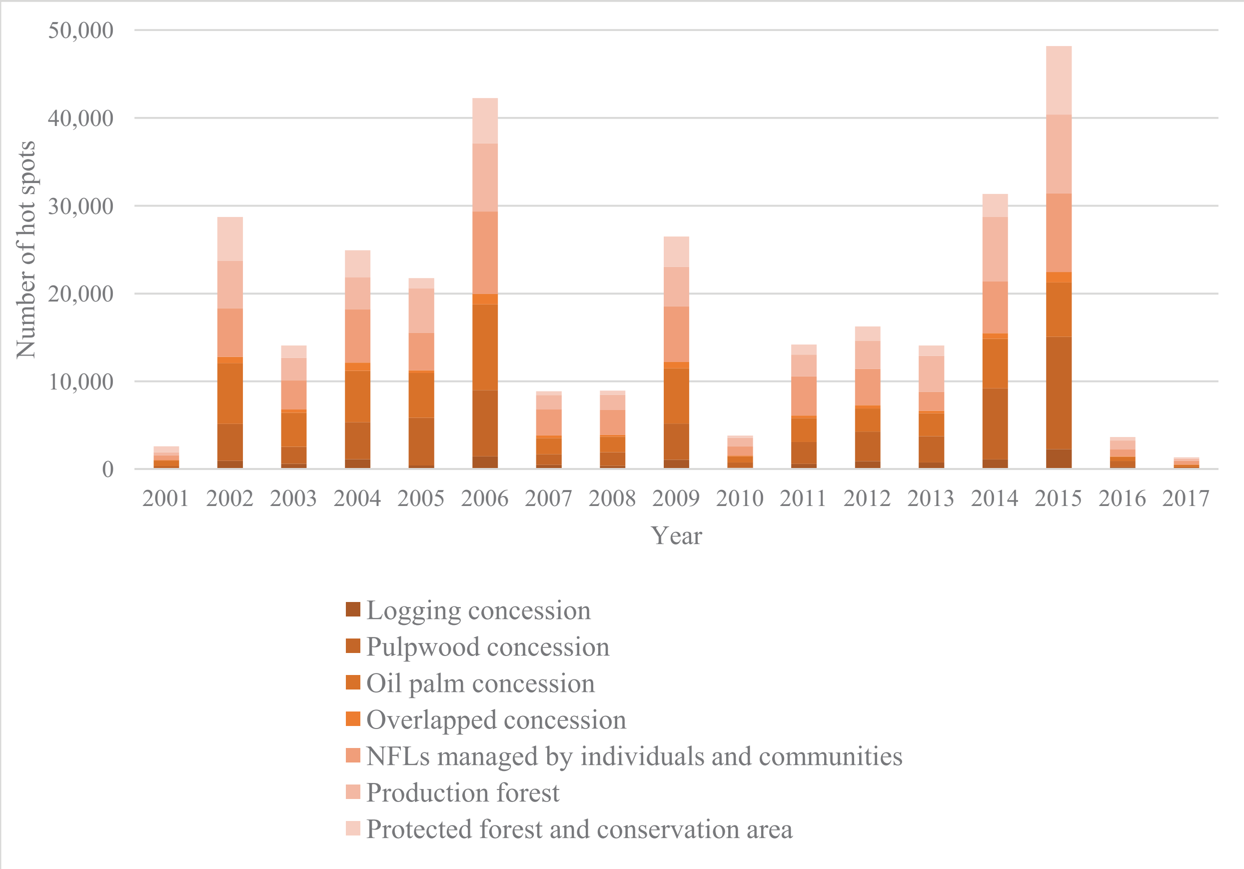
Over the last 17 years, the hot spot locations were distributed in corporate areas of logging concessions, wood plantations, oil palm plantations and non-corporate areas. On average, annually as much as 46.7% of hot spots occurred in corporate areas (4.1% in logging concessions, 19.8% in pulpwood plantations, 20.2% in oil palm plantations and 2.5% in overlapped areas) and 53.3% was in non-corporate concession areas (31.1% in SFZ and 22.2% in NSFZ).

Figure 3 shows a graphical presentation of annual hot spot data. The highest number of hot spots occurred in 2015. In 2015, hot spots were noted in 45% of corporate areas (13% oil palm plantations, 27% pulpwood plantations, 5% logging

TABLE 1 *Average annual hot spot data, 2001–2017*

Land use		**Extent**		**Hot spot**	
		Area (ha)	**%**	**Number**	**%**
Corporate concessions	Logging	12,419,328	12.1	750	4.1
	Pulpwood plantations	8,912,829	8.7	3,636	19.8
	Oil palm plantations				
	- in SFZ	9,041,398	8.8	2,410	13.1
	- in NSFZ	2,710,634	2.6	1,307	7.1
	Overlap	2,441,110	2.4	459	2.5
	Subtotal	35,525,299	34.7	8,562	46.7
Non-corporate concessions	NSFZ	30,968,208	30.2	4,063	22.2
	SFZ	35,968,208	35.1	5,708	31.1
	Subtotal	66,936,416	65.3	9,771	53.3
Total		102,461,715	100.0	18,333	100.0

FIGURE 3 *Land uses and occurrences of hot spots in Kalimantan and Sumatra*



concessions and 2% overlapped areas) and 53% were in areas outside the corporate concessions. The areas with the highest number of hot spot occurrences in Sumatra and Kalimantan for the last 17 years, i.e. more than 20,000 hot spots/year, happened in: 2002, 2004, 2005, 2006, 2009, 2014 and 2015.

Table 2 shows the hot spot density in the period 2010–2017. The hot spot density is defined as the number of hot spots per area extent (in our case, the area extent is per 1 million ha). The density of hot spots varied across different land use types. Corporate-managed pulpwood plantations had the highest hot spot density (437.28 hot spots/year/1 million ha), followed by non-corporate-managed production forest (256.04 hot spots/year/1 million ha) and oil palm plantations (225.49 hot spots/year/1 million ha). The lowest hot spot density was in corporate-managed logging concession areas (62.30 hot spots/year/1 million ha), followed by non-corporate-managed protected forest and conservation areas.

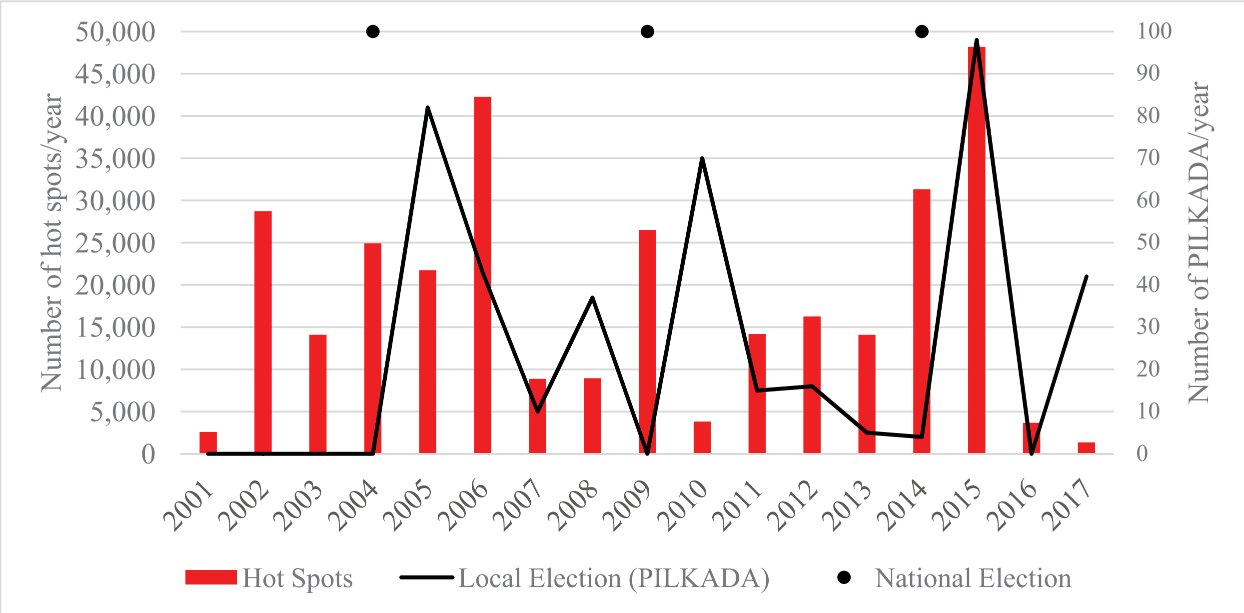
Hot spots and local elections

The number of regions that conducted PILKADA in Sumatra and Kalimantan for the last 17 years peaked in 2005, 2010 and 2015. Those years coincided with 1 year after the national general elections, which were held in 2004, 2009 and 2014.

TABLE 2 *Distribution of hot spots per 1 million ha of land in the period 2010–2017*

	Land use	**Area (M ha)**	**Hot spots, average (2010–2017)**	**Hot spot density/M ha/year (2010–2017)**
Corporate-managed lands	Logging concession	12.4	774	62.30
	Pulpwood plantation	8.9	3,897	437.28
	Oil palm plantation	11.7	2,650	225.49
	Overlapped concession	2.4	376	156.00
Non-corporate-managed lands	NSFZ managed by individuals and communities	30.4	3,478	114.19
	Production forest	13.8	3,540	256.04
	Protected forest and conservation areas	22.1	1,900	85.80

FIGURE 4 *Number of hot spots, local elections and national elections*



The greatest number of hot spots occurred in 2004, 2006, 2009, 2014 and 2015, which coincided with the year prior to each PILKADA year (except for 2006), as shown in Figure 4.

A high hot spot density occurred in Sumatra and Kalimantan and was hypothesized as being correlated with local politics (Figure 1). To verify this observation, we developed a regression model between the number of hot spots and PILKADA occurrences in Sumatra and Kalimantan. We found that the number of hot spots in year t was a function of the number of hot spots in year t–2 and of PILKADA that occurred in the year after year t+1 or $Y_t = f(Y_{t-2}, X_{t+1})$.

$$\text{Log } Y_t = 0.937 \log Y_{t-2} + 0.0219\, X_{t+1}$$

In the above, Y_t = the number of hot spots in year t, Y_{t-2} = the number of hot spots in year t–2 (hot spot occurrence from 2 years prior), and X_{t+1} = PILKADA occurrence 1 year after the hot spots recorded in year t. The mean absolute percentage error (MAPE) of the model is 9%, which means the model is sufficiently strong (See Annex 1 for more details).

There are other variables, such as precipitation, temperature, atmospheric moisture and El Niño that affect the occurrence of fire events (Flannigan and Harrington 1988). For example, there were very strong El Niño events in the 1997/98 and 2015 fires. However, in this model, they are not presented. The purpose of this model is to find the link between fire occurrence proxied by the number of hot spots and PILKADA. This model has shown a statistical connection between these two parameters.

DISCUSSION

Fire distribution and actors

Fire occurrence, proxied by hot spot numbers (Table 1), was found on land managed or administered by: corporations (46.7%) and non-corporate concessions i.e. communities and governments (53.3%). Among the corporate-managed lands, oil palm plantations both in SFZ and NSFZ were the biggest contributors to fires (20.2%), followed by pulpwood plantations (19.8%) and timber logging (4.1%). These three types of actors (i.e. corporation, community and government) should be responsible for fire occurrences in their managed areas. This provides new understanding, since in most cases, only communities and companies are blamed for fire occurrences. Communities live scattered inside all land uses legally and *illegally* and contribute to fire occurrences (Table 2). These communities are local communities and migrants coming from other areas. They can occupy land for their own purposes as well as be workers for rich people from nearby cities.

The highest density of hot spots on corporate-managed land was found on pulpwood and oil palm plantations, while that on non-corporate-managed land was in the SFZ i.e. production forest (see Table 2). This production forest is managed by the government. Our findings corroborate those of Gaveau *et al.* (2017), who reveal that idle land in either corporate- or non-corporate-managed lands is the location for fire occurrences. These lands were burnt to give economic benefits (Purnomo *et al.* 2017). The key role of big corporations in fire and haze in Indonesia and Southeast Asia was highlighted by Varkkey (2013, 2016). Prabowo *et al.* (2017) and The Gecko Project (2018) provided evidence of how oil palm plantation corporations accumulated power that enabled them to control productive and protective forest land in Kalimantan and Sumatra, Indonesia (see also in Mizuno, K. *et al.* (eds). 2016).

It is important to note that very limited use of fire by indigenous people is allowed by Law 32 of 1999 on Environmental Management and Protection. However, fires are illegal beyond that. Land and forests were burned illegally to make them ready to plant, especially for oil palm plantations. Fires in pulpwood and industrial plantation areas were the largest contributors to smoke haze in Riau Province. In Riau, twelve wood plantation company areas (both small and large) were burned (Syukur 2015). Those burnt areas have not necessarily been planted, as in general, only 30% of plantation areas are actually planted. The rest can be under land conflict with local communities or allocated for protection area and *tanaman kehidupan* (trees for local livelihoods) zone for local communities. Local-level political economy hinders the capacity of local government to control the sustainability of forests in Indonesia (Burgess *et al*. 2012).

Fires and local politics

Analyses on the links between local elections and deforestation are not new. The number of permits granted for land opening significantly increased prior to PILKADA (Burgess *et al*. 2012). This paper's contribution is to elaborate the mechanism by which local actors use fire to secure access to land.

PILKADA, or elections for local political elites, often involve land transactions (The Gecko Project 2018). The candidates, comprising district heads (who are either incumbents or new candidates), can grant access to communities or migrants to manage a certain patch of land. Land politics may involve the use of power or money to bribe voters to vote for those candidates. Land areas given by the candidates are categorized as either 'open access' or 'idle land' inside or outside corporate concession areas that are not secured (intentionally or unintentionally) by the government or corporations. These lands are often claimed by local people through traditional use patterns that are potentially recognizable by the government due to Constitutional Court Ruling No. 35 of 2013 that recognizes 'traditional' claims. The court redefined the status of customary forest within SFZ, and moved customary forest from the SFZ category to private forest (Siscawati *et al.* 2017). However, the execution of this constitutional court is complicated; it takes a long time to resolve issues and produces uncertainty about land ownership.

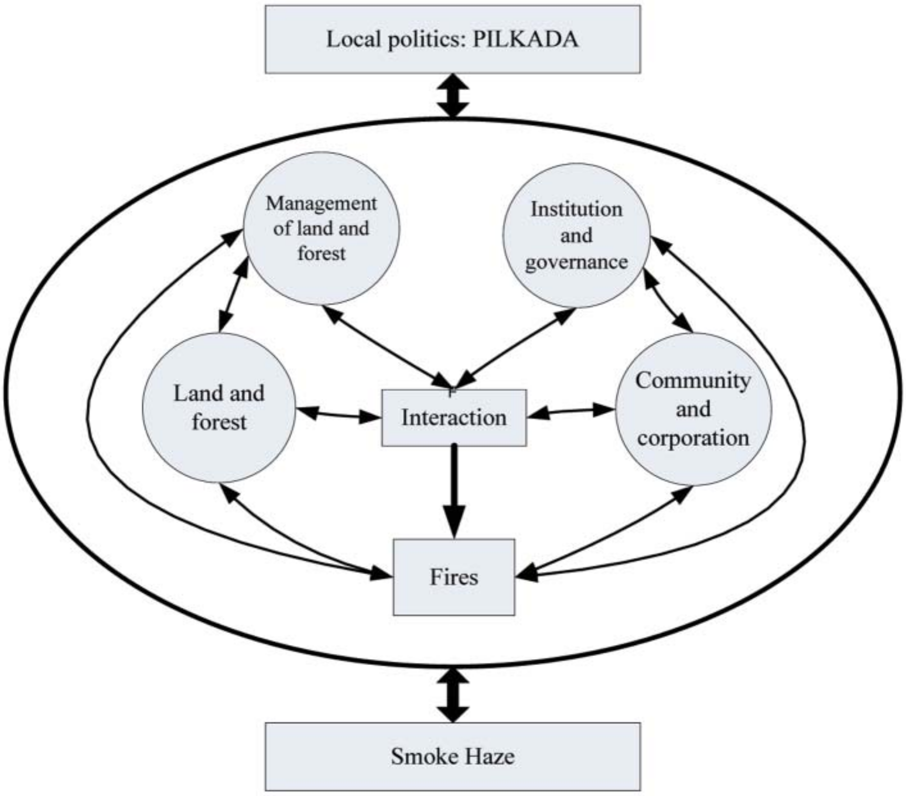
Prior to the local election, the incumbents issue permits to improve their chances of continuing in the second term. Meanwhile, the challengers make promises to allocate land in their campaigns. These permits are given due to political connections that lead to less control in using fire in land management. In Kalimantan, local elections were found to be an obstacle (not a solution) to the struggle in tackling forest fires and protecting Kalimantan's rapidly deteriorating environment (Berenschot 2015, Lang 2016).

Indonesia is a developing country with dynamic social, economic and political conditions. Decentralization that has been in place since 2000 has aimed to improve governance at the subnational level. PILKADA is a manifestation of decentralization in Indonesia (Barr *et al*. 2006). Despite the promise that decentralization would bring policy-making processes closer to the people, its success relies on the local governance leadership (von Luebke 2009). However, it has also brought the emergence of local elites (Barr *et al*. 2006) and increased the deforestation rate (Suwarno and Hein 2015). One of the manifestations of the failure of decentralization is the inability of PILKADA to produce strong and good leaders (Choi 2007, Aspinall 2014). A key storyline is that local elites give access – or promise to give access – to land to help them compete in the PILKADA, and the recipients use fire to establish their claim over the land. These local elites influence PILKADA through the access they give to land on which fire may be used. The interactions of natural resources, users/actors and land/forest governance are described in Figure 5. The interactions among the four elements of the social-ecological system (SES) produce outcomes in the form of fires and a hazardous haze that affects ecosystems, economic conditions and the health of millions of people in Indonesia and Southeast Asia.

PILKADA represents the political battle involving local elites that try to gain positions as local leaders, thereby influencing the SES. The elections of local leaders that involve land transactions were discovered in Riau. PILKADA encouraged the acquisition of open access land by local political elites, e.g. in the case of the Buol district head election in Central Sulawesi (Samad 2012). A similar case was also found in Central Kalimantan (EIA 2014). The correlation between local politics and deforestation has been addressed by previous researchers (Butler 2011, Burgess *et al.* 2012). PILKADA, as currently practiced, has not been able to bring about leaders that can implement good governance. Instead, Aspinall (2014) and Berenschot (2015) show that clientelism – the exchange of material benefits for political support – persists. The local system can produce fire and haze that badly affects the economy, ecosystem and environment. Corruption further weaken the institutions and system of governance were compromised. The existing institutions do not work and are replaced by extra-legal institutions that are controlled by local elites in crony-type relationships with powerful actors such as pulpwood and oil palm corporations (Kartodihardjo *et al.* 2015, Varkkey 2016). The ability of local and regional elites, often entrenched in patronage networks with plantation owners and policy makers, to curtail environmental policies, goes a long way towards explaining the continuation of forest fires in this area (Edwards and Heiduk 2015, Purnomo *et al*. 2018). These illegal institutions establish practices that are followed by various actors and that lead to deforestation and fires. They do not practice good land management as the best practice is not enforced. These 'bad' actors attempt to gain a larger benefit for themselves without considering the sustainability of forests and land (Monzón-Alvarado *et al.* 2014, Putra *et al.* 2019). They are supported by corporate bribery to influence the voters.

Some actors use fire to reduce the costs of land preparation and planting. Using fire in land management is a *private activity* that provides benefits to those who set the fires, whereas the haze resulting from that activity is *public goods* that affect the whole ecosystem and all the people under the patronage of business institutions such as corporations that produce wood fiber, industrial timber and palm oil. This haze phenomenon can be categorized as the 'publication of disaster and privatization of benefits,' which means that the beneficial product of land fires is enjoyed only by individuals

FIGURE 5 *Haze and the social–ecological system (SES) framework*



and corporate actors while the damages and losses from land fires are borne by the public. These free-riding and rent-seeking behaviors usually exist when local political leaders depend on the support of their patrons or business elites to continue ruling the regencies. The mutual benefit patronage (e.g. land, money, unenforced laws and votes) between local leaders and business elites is usually established before the former are elected as political leaders.

Options for future solutions

The important result of this investigative and analytical study is that it confirms the penetration of the social and political systems by an interactive network of profiteering commercial enterprises and benefiting political power players, who in this case steer the local electoral process in their favor by bribery. Evidence is provided by the close association among local elections, and hot spots and haze from forest and land burning. However, we have not looked at the effects of provincial- and national-level elections. PILKADA, which is a part of the democratic and political processes, must produce welfare for those citizens who are the voters. Resource plundering and abuse must be avoided. Those who profit financially or politically through the acquisition of power do not consider the impact derived from environmental factors such as hazardous haze that cause damage (Monzón-Alvarado *et al.* 2014).

Regulations that are not in accordance with sustainability or that allow fire use should be revoked. Only those regulations that truly allow fire use to be controlled and where the government has the capacity to localize and manage the fire use could be considered (Saharjo 1999). Presidential Instruction No. 11/2015 of 24 October 2015, Enhancing and Preventing Land and Forest Fires, should be implemented on the ground. The implementation of new Government Regulation No. 57/2016 on Protection and Management of Peatland Ecosystems and its subsequent regulations must be monitored. Some corporations and smallholders object to the implementation of this regulation since it jeopardizes their pulpwood and oil palm plantations on peatland (Hadrian 2017, Arumingtyas 2017). Local communities and land-based corporations with different land-management and benefit-sharing scenarios must collaborate and attempt to reduce or control fires and improve the livelihoods of local communities (Purnomo and Mendoza 2011, Purnomo *et al.* 2014a, Thondhlana *et al.* 2015). The elected leaders are key to ensuring that these regulations are in place for the benefit of the public.

The elected leaders must play key roles in enhancing the efficiency and transparency of bureaucracy to reduce rent-seeking behaviors of corporations, ruling elites or communities. The quality of governance will be improved if the elected leaders can reduce the patronage network, particularly between corporations and the ruling elites. Palm oil, and pulp and paper are Indonesia's most important agricultural commodities in the global market. For example, palm oil is the largest export commodity. In 2017, its export value was USD 18.5 billion (Bank Indonesia 2018), or 11% of Indonesia's total export. High demand for these commodities will give Indonesia a competitive advantage. More attention should be paid to ways to develop oil palm and pulpwood plantations in a sustainable way. The elected leaders must ensure that there is a better balance of power among various stakeholders in land allocation and use permits (van Noordwijk *et al.* 2014, Purnomo *et al.* 2014b). Indonesia can aim to attain the UN's Sustainable Development Goals (SDGs) No. 3 (ensure healthy lives and promote well-being for all at all ages), No. 13 (climate change mitigation) and No. 15 (sustainability of terrestrial ecosystems, which include forests) if Indonesia can reduce the number of fires on land and in forests, especially on peatlands, but also on wetland and dryland.

CONCLUSIONS

Hot spots occur on every type of land use and tenure. During 2001–2017 concessions, areas of corporate logging concessions, and pulpwood and oil palm plantations contributed to 46.7% of hot spots, while areas outside corporate concessions contributed to 53.3% of hot spots. During 2010–2017 pulpwood plantations had the highest hot spot density, followed by production forest and oil palm plantations. Forest and land managers who use fire as a management strategy trigger the occurrence of forest and land fires. Regulations that are rigid, impractical and often interest-biased, and the weakness of government institutions in developing and enforcing regulations, are the main causes of fire occurrence. Both technical and political economy approaches are important to effective fire prevention. Climatic factors such as El Niño exacerbate the risk of fires massively. The weakness of governance is caused by the patronage network in any social, political or economic sector and at every level. We conclude that PILKADA and fire occurrence are connected. The solution to land and forest fires should not only prioritize the technical management of land and forest, it should also be based on a political economy approach to building stronger governance.

ACKNOWLEDGMENTS

This work was supported by the Department for International Development of the United Kingdom (DFID UK) under the Rapid Response Mechanism (RRM), grant year 2015; International Forestry Knowledge (KNOWFOR) II, Grant No. MTO069018 year 2016–2017; the USAID-funded project, Governing Oil Palm for Landscape Sustainability (GOLS) 2016–2018; and The German Federal Ministry of Economic Cooperation and Development for Forest in the Global Bioeconomy project. We thank the seven manuscript reviewers for their valuable inputs, suggestions and argumentations so that we could significantly improve the focus and quality of the manuscript.

REFERENCES

APPLEGATE, G., SMITH, R., FOX, J.J., MITCHEL, A., PACKHAM, D., TAPPER, N., and BAINES, G. 2002. Forest fires in Indonesia: impacts and solutions. In: COLFER, C., and RESOSUDARMO, I.A.P. (eds) *Which way forward? People, forests, and policymaking in Indonesia.* RFF Press: Washington, DC. 293–308 pp.

ARUMINGTYAS, L. 2017. Ketika RAPP Tak Patuhi Aturan Gambut, Siti: Jangan Ajak-ajak Pekerja dan Ancam PHK. https://www.mongabay.co.id/2017/10/23/ketika-rapp-tak-patuhi-aturan-gambut-siti-jangan-ajak-ajak-pekerja-dan-ancam-phk/ (20 December 2018).

ASPINALL, E. 2014. When brokers betray: Clientelism, social networks, and electoral politics in Indonesia. *Critical Asian Studies* **46**(4): 545–570

BANK INDONESIA. 2018. Value of export by commodity. Retrieved from https://www.bi.go.id/id/statistik/seki/terkini/eksternal/Contents/Default.aspx on 30 August 2018.

BARMA, N.H., KAISER, K., LE, T.M., and VIÑUELA, L. 2012. Rents to riches? The political economy of natural resource-led development. The World Bank. Retrieved from http://www.imf.org/external/np/seminars/eng/2013/fiscalpolicy/pdf/rajaram.pdf on 1 June 2016.

BARR, C., RESOSUDARMO, I.A.P., DERMAWAN, A., MCCARTHY, J., MOELIONO, M., and SETIONO, B (Eds). 2006. Decentralization of forest administration in Indonesia: Implications for forest sustainability, economic development and community livelihoods. Bogor, Indonesia: Center for International Forestry Research (CIFOR). Retrieved from http://www.cifor.org/publications/pdf_files/Books/BBarr0601.pdf on 3 February 2018

BARR, C., DERMAWAN, A., PURNOMO, H., and KOMARUDIN, H. 2010. Financial governance and Indonesia's reforestation fund during the Soeharto and post-Soeharto periods, 1989–2009: a political economic analysis of lessons for REDD+. Occasional Paper 52. Center for International Forestry Research (CIFOR), Bogor, Indonesia. Retrieved from http://www.cifor.org/publications/pdf_files/OccPapers/OP-52.pdf on 5 January 2015.

BERENSCHOT, W. 2015. Haze of democracy. *Inside Indonesia*. Retrieved from http://www.insideindonesia.org/haze-of-democracy on 6 June 2016.

BURGESS, R., HANSEN, M., OLKEN, B.A., POTAPOV, P., and SIEBER S. 2012. The political economy of deforestation in the tropics. *Quarterly Journal of Economics* **127**(4): 1707–1754.

BUSCH, D., FERRETI-GALLON, K., ENGELMANN, J., WRIGHT, M., AUSTIN, K.G., STOLLE, F., TUIRUBANOVA, S., POTAPOV, P.V., MARGONO, B., HANSEN, M.C., BACCINI, A. 2014. Reductions in emissions from deforestation from Indonesia's moratorium on new oil palm, timber, and logging concessions. *Proceedings of the National Academy of Sciences* **112**(5): 1328–1333.

BUTLER, R.A. 2011. Election cycle linked to deforestation rate in Indonesia. *Mongabay*. Retrieved from https://news.mongabay.com/2011/04/election-cycle-linked-to-deforestation-rate-in-indonesia/ on 10 June 2016.

CARMENTA, R., PARRY, L., BLACKBURN, A., VERMEYLEN, S., and BARLOW, J. 2011. Understanding human-fire interactions in tropical forest regions: a case for interdisciplinary research across the natural and social sciences. *Ecology and Society* **16**(1): 53. Retrieved from http://www.ecologyandsociety.org/vol16/iss1/art53/ 9 August 2015.

CARMENTA, R., ZABALA, A., DAELI, W., PHELPS, J. 2017. Perceptions across scales of governance and the Indonesian peatland fires. Global Environmental Change **46**: 50–59. Retrieved from https://www.sciencedirect.com/science/article/pii/S0959378016304605 on 20 June 2018.

CASSON, A. 2002. The political economy of Indonesia's oil palm subsector. 2002. In: COLFER, C., and RESOSUDARMO, I.A.P. (eds) *Which way forward? People, forests, and policymaking in Indonesia.* RFF Press: Washington, DC. 293–308 pp.

CHOI, N. 2007. Local elections and democracy in Indonesia: The Riau Archipelago. *Journal of Contemporary Asia* **37**(3): 326–345.

CHOMITZ, K.M. 2007. *At loggerheads? Agricultural Expansion, Poverty Reduction and Environment in The Tropical Forests*. World Bank Policy Research Report. Washington, DC: World Bank.

COLFER, C.J.P. 2002. Ten propositions to explain Kalimantan's fires. In: COLFER, C., and RESOSUDARMO, I.A.P. (eds) *Which way forward? People, forests, and policymaking in Indonesia.* RFF Press: Washington, DC. 293–308 pp.

CONTRERAS-HERMOSILLA, A. 2000. The underlying causes of forest decline. Occasional Paper No. 30. Bogor, Indonesia: CIFOR.

CRUTZEN, P.J., HEIDT, L.E., KRASNEC, J.P., POLLOCK, W.H., SEILER, W. 2016. Biomass Burning as a Source of Atmospheric Gases CO, H2, N2O, NO, CH3Cl and COS. In Crutzen, P.J., and Brauch, H.G. (eds.) Paul J. Crutzen: A Pioneer on Atmospheric Chemistry and Climate Change in the Anthropocene. Mosbach, Germany: Springer. Pp. 117–124.

CRYER, J.D., and CHAN, K. 2008. *Time series analysis: with applications in R*. Springer. Second edition. New York. 491p.

DAUVERGNE, P. 1998. The political economy of Indonesia's 1997 forest fires. *Australian Journal of International Affairs* **52**: 13–17.

DeFries *et al.* 2008

DENNIS, R.A., MAYER, J., APPLEGATE, G., CHOKKALINGAM, U., COLFER, C.J.P., KURNIAWAN, I., LACHOWSKI, H., MAUS, P., PERMANA, R.P., RUCHIAT, Y., STOLLE, F., SUYANTO, TOMICH, T.P. 2005. Fire, People and Pixels: Linking social science and remote sensing to understand underlying causes and impacts of fires in Indonesia. *Human Ecology* **33**(4): 465–504.

[DFID] Department for International Development. 2009. Political economy analysis: How to note. DFID practice paper. Retrieved from https://www.odi.org/sites/odi.org.uk/files/odi-assets/events-documents/3797.pdf on 1 June 2016.

DRAZEN, A. 2000. *Political economy in macroeconomics.* Princeton University Press: Princeton, NJ. 792 pp.

EDWARDS, S.A., and HEIDUK, F. 2015. Hazy days: forest fires and the politics of environmental security in Indonesia. *Journal of Current Southeast Asian Affairs* **34**(3): 65–94.

[EIA] ENVIRONMENTAL INVESTIGATION AGENCY. 2014. Permitting crime: How palm oil expansion drives illegal logging in Indonesia. London: EIA.

FIELD RD, van der WERF GR, SHEN SSP. 2009. Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geoscience* **2**: 185–188.

FIELD, R.D., VAN DER WERF, G.R., FANIN, T., FETZER, E.J., FULLER, R., JETHVA, H., LEVY, R., LIVESEY, N.J., LUO, M., TORRES, O., WORDEN, W.M. 2016. Indonesian fire activity and smoke pollution in 2015 show persistent nonlinear sensitivity to El Niño-induced drought. *PNAS* August 16, 2016, **113**(33): 9204–9209.

FITRI, S., and PUTRI, W.D. 2015. BNPB Catat Kerugian Akibat Kebakaran Hutan 2015 Rp 221 Triliun. *Republika*. Retrieve from https://www.republika.co.id/berita/nasional/umum/15/12/20/nzms82359-bnpb-catat-kerugian-akibat-kebakaran-hutan-2015-rp-221-triliun on 12 June 2018.

FLANNIGAN, M.D., HARRINGTON, J.B. 1988. A study of the relation of meteorological variables to monthly provincial area burned by wildfire in Canada 1953–80. *Journal of Applied Meteorology* **27**: 441–452.

GAVEAU, D.L.A., SLOAN, S., MOLIDENA, E., YAEN, H., SHEIL, D., ABRAM, N.K., ANCRENAZ, M., NASI, R., QUINONES, M, WIELAARD, N., MEIJAARD, E. 2014. Four Decades of Forest Persistence, Clearance and Logging on Borneo. *PLOS ONE* **9**(7): e101654. Retrieve from https://doi.org/10.1371/journal.pone.0101654 on 10 August 2018.

GAVEAU, D.L.A., PIRARD, R., SALIM, M.A., TONOTO, P., YAEN, H., PARKS S.A., CARMENTA, R. 2017. Overlapping Land Claims Limit the Use of Satellites to Monitor No-Deforestation Commitments and No-Burning Compliance. *Conservation Letters* **10**(2): 257–264. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1111/conl.12256 on 5 May 2018.

GEIST, H.J. and LAMBIN, E.F. 2001. What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. *LUCC Report Series 4*. Belgium: LUCC. Retrieved from http://www.pik-potsdam.de/~luedeke/lucc4.pdf on 10 January 2015.

GIGLIO, L. 2015 MODIS collection 6 active fire product user's guide, revision A. Technical Report, University of Maryland (2015). Retrieved from URL: http://modisfire.umd.edu/files/MODIS_C6_Fire_User_Guide_A.pdf on 9 July 2018

HADRIAN, P. 2017. Gubernur Kalimantan Barat Bersurat ke Presiden Jokowi Perihal "Investasi" di Gambut, Maksudnya? https://www.mongabay.co.id/2017/05/20/gubernur-kalimantan-barat-bersurat-ke-presiden-jokowi-perihal-investasi-di-gambut-maksudnya/ (20 December 2018)

HEILMANN, D. 2015. After Indonesia's Ratification: The ASEAN Agreement on Transboundary Haze Pollution and Its Effectiveness as a Regional Environmental

Governance Tool. *Journal of Current Southeast Asian Affairs* **34**(3): 95–121.

KARTODIHARDJO, H., NAGARA, G., SITUMORANG, A.W. 2015. Transaction cost of forest utilization licenses in Indonesia. *Jurnal Manajemen Hutan Tropika (Journal of Tropical Forest Management)* **21**(3): 184–191. Retrieved from http://journal.ipb.ac.id/index.php/jmht/article/view/10793 on 9 August 2015.

KAUFFMANN, D., Kraay, A., Mastruzzi, M. 2007. Governance matters VI: Aggregate and individual governance indicators 1996–2006. World Bank Policy Research Working Paper No. 4280. Washington, D.C.: The World Bank.

KEMENTERIAN KESEHATAN. 2015. Masalah kesehatan akibat kabut asap kebakaran hutan dan lahan tahun 2015. Jakarta: Kementerian Kesehatan.

KHOEMAENI, S.A. 2015. Luas kebakaran huan di indonesia setara empat kali Pulau Bali. LAPAN. Retrieved from http://www.lapan.go.id/index.php/subblog/read/2015/2054/Luas-Kebakaran-Hutan-di-Indonesia-Setara-Empat-Kali-Pulau-Bali on 6 August 2016.

KOH, L.P., WILCOVE, D.S. 2009. Oil palm: disinformation enables deforestation. *Trends of Ecology and Evolution* **24**(2): 67–68.

KOPLITZ, S.N., MICKLEY, L.J., MARLIER, M.E., BUONOCORE, J.J., KIM, P.S., LIU, T., SULPRIZIO, M.P., DEFRIES, R.S., JACOB, D.J., SCHWARTZ, J., PONGSIRI, M., and MYERS, S.S. 2016. Public health impacts of the severe haze in Equatorial Asia in September–October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure. *Environmental Research Letters* **11**(9): 094023.

LANG, C. 2016. Illegal logging, palm oil and politics in Central Kalimantan. *REDD Monitor*. Retrieved from http://www.redd-monitor.org/2016/05/20/illegal-logging-palm-oil-and-politics-in-central-kalimantan/ on 25 May 2017.

LASSWELL, H. 1958. *Politics: Who Gets What, When, How.* Meridian Books: New Haven, CT. 264 pp.

LSE [The London School of Economics and Political Science]. 2016. No more forest fires in 2016? Good land use management is the key. Retrieved from http://blogs.lse.ac.uk/internationaldevelopment/2015/12/03/no-more-forest-fires-in-2016-good-land-use-management-is-the-key/ on 12 January 2017.

MARGONO, B.A., POTAPOV, P.V., TURUBANOVA, S., STOEEL, F., HANSEN, M.C. 2014. Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change* **4**: 730–735.

MENSH, B., KORDING K. 2017. Ten simple rules for structuring papers. *PLOS Computational Biology* **13**(9): e1005619. Retrieved from https://doi.org/10.1371/journal.pcbi.1005619 on 4 May 2018.

MIETTINEN, J., SHI, C., LIEW, S.C. 2011. Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology* **17**: 2261–2270.

Minitab 15 Statistical Software. 2007. [Computer software]. State College, PA: Minitab, Inc.

MIZUNO, K., FUJITA, S.M., SHUICHI, K. (editors). 2016. Catastrophe and Regeneration in Indonesia's Peatlands: Ecology, economy and society. Kyoto-CSEAS Series on Asian Studies 15. Singapore: National University of Singapore Press. 466p.

MONZÓN-ALVARADO, C., WAYLEN, P., and KEYS, E. 2014. Fire management and climate variability: challenges in designing environmental regulations. *Land Use Policy* **39**: 12–21.

NASA [National Aeronautics and Space Administration]. 2015. Fire Information for Resource Management System. Retrieved from https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data#tab-content-6 on 12 October 2015.

OSTROM, E. 2007. Sustainable social-ecological systems: an impossibility? Presented at the 2007 Annual Meeting of the American Association for the Advancement of Science, Science and Technology for Sustainable Well-Being, 15–19 February in San Francisco and Proceedings of the National Academy of Sciences (USA).

OSTROM, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* **325**: 419–422. http://www.eramx.org/biblio/Ostrom,%202009.pdf (accessed 1 July 2018)

PRABOWO, D., MARYUDI, A., SENAWI, IMRON, and M.A. 2017. Conversion of forests into oil palm plantations in West Kalimantan, Indonesia: insights from actors' power and its dynamics. *Forest Policy and Economics* **78**: 32–39.

PURNOMO, H. and MENDOZA, G.A. 2011. A system dynamics model for evaluating collaborative forest management: a case study in Indonesia. *International Journal of Sustainable Development & World Ecology* **18**(2): 164–176.

PURNOMO, H., SUYAMTO, D., ABDULLAH, L., and IRAWATI, R.H. 2012a. REDD+ actor analysis and political mapping: an Indonesian case study. *International Forestry Review* **14**(1): 74–89.

PURNOMO, H., ARUM, G.S., ACHDIAWAN, R., and IRAWATI, R,H,. 2012b. Rights and wellbeing: an analytical approach to global case comparison of community forestry. *Sustainable Development* **5**(6): 35.

PURNOMO, H., SUYAMTO, D., and IRAWATI, R.H. 2013. Harnessing the climate commons: an agent-based modelling approach to making reducing emission from deforestation and degradation (REDD) + work. *Mitigation and Adaptation Strategies for Global Change* **18**: 471–489.

PURNOMO, H., ACHDIAWAN, R., MELATI, IRAWATI, R.H., SULTHON, M.A., SHANTIKO, B., WARDELL, D.A. 2014a. Value-chain dynamics: strengthening the institution of small-scale furniture producers to improve their value addition. *Forests, Trees and Livelihoods* **23**(1–2): 87–101.

PURNOMO, H., GUIZOL, P., AWANG, S.A., WARDHANA, W., IRAWATI, R.H., and RENNALDI, D. 2014b. Communicative action to level the playing field in forest plantations in Indonesia. *Journal of Sustainable Forestry* **33**(4): 337–357.

PURNOMO, H., SHANTIKO, H., SITORUS, S., GUNAWAN, H., ACHDIAWAN, R., KARTODIHARDJO, H., and DEWAYANI, A.A. 2017. Fire economy and actor network of forest and land fires in Indonesia. *Forest Policy and Economics* **78**: 21–31.

PURNOMO, H., OKARDA, B., DEWAYANI, A.A., ALI, M., ACHDIAWAN, R., KARTODIHARDJO, H., PACHECO, P., and JUNIWATY, K.A. 2018. Reducing forest and land fires through good palm oil value chain governance. *Forest Policy and Economics* **91**: 94–106.

PUTRA, I.K., SAHARJO, B.H., WASIS, B. 2019. Tantangan kelembagaan pengendalian kebakaran hutan dan lahan pada tingkat tapak. *Jurnal Ilmu Pertanian Indonesia* **24**(2): 151–159. Retrieved from http://journal.ipb.ac.id/index.php/JIPI/article/view/25855/16838 on 9 August 2019.

PUTRI, T.A. 2014. Bakar hutan, pengusaha dapat untung besar. *Tempo*. Retrieved from https://bisnis.tempo.co/read/563809/bakar-hutan-pengusaha-dapat-untung-besar on 10 May 2016.

SAHARJO, B.H. 1999. *Pembakaran terkendali sebagai metoda alternatif dalam pencegahan kebakaran hutan di hutan tanaman acacia mangium* (prescribed burning as an alternative method for preventing forest fire in acacia mangium forest plantation). *Jurnal Manajemen Hutan Tropika* **5**(1): 67–75. Retrieved from http://journal.ipb.ac.id/index.php/jmht/article/view/2684/1664 on 1 August 2019.

SAHARJO, B.H. 2007. Shifting cultivation in peatlands. *Mitigation and Adaptation Strategies for Global Change* **12**: 135–146.

SCHMIDT, L.J. 2016. El Niño a key player in severe Indonesia fires. https://climate.nasa.gov/news/2489/el-nino-a-key-player-in-severe-indonesia-fires/ (20 June 2018).

SISCAWATI, M., BANJADE, M.R., LISWANTI, N., HERAWATI, T., MWANGI, E., WULANDARI, C., TJOA, M., SILAYA, T. 2017. Overview of forest tenure reforms in Indonesia. Working Paper 223. Bogor, Indonesia: CIFOR.

SOMMER, R., Vlek, P.L.G., Sá, T.D. de Al, *et al*. 2004. Nutrient balance of shifting cultivation by burning or mulching in the Eastern Amazon – evidence for subsoil nutrient accumulation. *Nutr Cycl Agroecosyst* **68**: 257–71.

SPESSA, A.C., FIELD, R.D., PAPPENBERGER, F., LANGNER, A., ENGLHART, S., WEBER, U., STOCKDALE, T., SIEGERT, F., KAISER, J.W. and MOORE, J. 2015. Seasonal forecasting of fire over Kalimantan, Indonesia. *Natural Hazards Earth System Science* **15**: 429–442.

STRACHER, G.B., PRAKASH, A., REIN, G. 2015. *Coal and Peat Fires: A Global Perspective Volume 4: Peat – Geology, Combustion, and Case Studies*. Amsterdam: Elsevier.

SUWARNO, A., and HEIN, L. 2015. Governance, decentralisation and deforestation: The case of Central Kalimantan Province, Indonesia. *Quarterly Journal of International Agriculture* **54**(1): 77–100.

SUYANTO, S. 2006. Underlying cause of fire: different form of land tenure coNSFZicts in Sumatra. *Mitigation and Adaptation Strategies for Global Change* **12**: 67–74.

SYUKUR, M. 2015. Kebakaran Hutan Tanaman Industri Sumbang Asap Terbesar di Riau. *Liputan 6 News*. Retrieved from http://news.liputan6.com/read/2310092/kebakaran-hutan-tanaman-industri-sumbang-asap-terbesar-di-riau on 8 August 2016.

TACCONI, L. 2003. Fires in Indonesia: Causes, Costs and Policy Implications. *CIFOR Occasional Paper* No. 38. Retrieved from https://www.cifor.org/publications/pdf_files/OccPapers/OP-038.pdf on 15 August 2018.

TACCONI, L. 2016. Preventing fires and haze in Southeast Asia. *Nature Climate Change* **6**: 640–643.

THE GECKO PROJECT. 2018. How corrupt elections fuel the sell-off of Indonesia's natural resources. https://thegeckoproject.org/how-corrupt-elections-fuel-the-sell-off-of-indonesias-natural-resources-c9ae7521d0ee (20 December 2018)

THONDHLANA, G., SHACKLETON, S., and BLIGNAUT, J. 2015. Local institutions, actors, and natural resource governance in Kgalagadi Transfrontier Park and surrounds, South Africa. *Land Use Policy* **47**: 121–129.

VAN NOORDWIJK, M., AGUS, F., DEWI, S., and PURNOMO, H. 2014. Reducing emissions from land use in Indonesia: motivation, policy instruments and expected funding streams. *Mitigation and Adaptation Strategies for Global Change* **19**(6): 677–692.

VARKKEY, H. 2013. Oil palm plantations and transboundary haze: patronage networks and land licensing in Indonesia's peatland. *Wetlands* **33**: 679–690.

VARKKEY, H. 2016. *The Haze Problem in Southeast Asia: Palm Oil and Patronage.* Routledge, Taylor & Francis: London. 228pp.

VIJAY, V., PIMM, S.L., JENKINS, C.N., SMITH, S.J. 2016. The impacts of oil palm on recent deforestation and biodiversity loss. *PLoS One* **11**(7): e0159668.

VON LUEBKE, C. 2009. The political economy of local governance: findings from an Indonesian field study. *Bulletin of Indonesian Economic Studies* **45**(2): 201–230.

WOOSTER, M.J., PERRY, G.L.W., and ZOUMAS, A. 2012. Fire, drought and El Niño relationships on Borneo (Southeast Asia) in the pre-MODIS era (1980–2000). *Biogeosciences* **9**: 317–340.

WORLD BANK. 2016. The cost of fire: an economic analysis of Indonesia's 2015 fire crisis. Indonesia Sustainable Landscapes Knowledge Note No. 1. World Bank, Jakarta. Retrieved from https://openknowledge.worldbank.org/handle/10986/23840 on 27 May 2016.

[WRI] WORLD RESOURCES INSTITUTE. 2018. Oil palm concessions (select countries) Year 2015. Retrieved from http://data.globalforestwatch.org/datasets/20398d4dc36e47bd92b559786670f270_1 on 20 October 2018.

ANNEX 1. THE REGRESSION BETWEEN THE NUMBER OF HOT SPOTS AND LOCAL ELECTIONS (PILKADA)

The relation between hot spots (Y) and PILKADA (X) is

$$\text{Log } Y_t = 0.937 \log Y_{t-2} + 0.0219\, X_{t+1}$$

Y_t = Number of hot spots in year t
Y_{t-2} = Number of hot spots in year t–2 (hot spot occurrence from 2 years prior)
X_{t+1} = PILKADA occurrence 1 year after a hot spot recorded in year t

Predictor	Coef.	SE Coef.	T	P	VIF
No constant					
$\log Y_{t-2}$	0.93702	0.04946	18.95	0.000	1.948
X_t	0.021854	0.009424	2.32	0.046	1.948

S = 1.06916; PRESS = 15.7433

Analysis of variance

Source	DF	SS	MS	F	P
Regression	2	947.59	473.79	414.48	0.000
Residual error	9	10.29	1.14		
Total	11	957.88			

Durbin–Watson statistic = 1.80315