TITLE: Oil palm–community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives.

RUNNING TITLE: Oil Palm–community conflict

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ABSTRACT

Conflict between large-scale oil-palm producers and local communities is widespread in palm-oil producer nations. With a potential doubling of oil-palm cultivation in Indonesia in the next ten years it is likely that conflicts between the palm-oil industry and communities will increase. We develop and apply a novel method for understanding spatial patterns of oil-palm related conflicts. We use a unique set of conflict data derived through systematic searches of online data sources and local newspaper reports describing recent oil-palm land-use related conflicts for Indonesian Borneo, and combine these data with 43 spatial environmental and social variables using boosted regression tree modelling. Reports identified 187 villages had reported conflict with oil-palm companies. Spatial patterns varied with different types of conflict. Forest-dependent communities were more likely to strongly oppose oil-palm establishment because of their negative perception of oil-palm development on the environment and their own livelihoods. Conflicts regarding land boundary disputes, illegal operations by companies, perceived lack of consultation, compensation and broken promises by companies were more associated with communities that have lower reliance on forests for livelihoods, or are located in regions that have undergone or are undergoing forest transformation to oil-palm or industrial-tree-plantations. A better understanding of the characteristics of communities and areas where different types of conflicts have occurred is a fundamental step in generating hypotheses about why certain types of conflict occur in certain locations. Insights from such research can help inform land use policy, planning and management to achieve more sustainable and equitable development. Our results can also assist certification bodies (e.g. the Roundtable for Sustainable Palm Oil-RSPO, and the Indonesian and Malaysian versions, ISPO and MSPO), non-government-organisations, government agencies and other

stakeholders to more effectively target mediation efforts to reduce the potential for conflict arising in the future.

KEYWORDS:

Boosted regression tree modelling; Borneo; Mapping land use conflict; Oil palm expansion; RSPO; Sustainable development.

1. INTRODUCTION

Many regions of the world are undergoing rapid land use and land cover change to industrial-scale agriculture, especially in the tropics (Foley et al. 2005; Lambin & Meyfroidt 2011). From 2006 to 2009, 15 to 20 million hectares of land in developing countries were subject to negotiations and transactions for agriculture (von Braun & Meinzen-Dick 2009). In many of these areas, land has been historically controlled through indigenous governance systems (Larson & Bromley 1990), rather than through legislated systems of land and resource use rights (Redford & Sanderson 2000). However, power realignments over land and its resources is often driven by economic development, and challenge existing traditional systems and local peoples' values. In many countries this is leading to increased social tensions and conflict over land and land-use (Barron et al. 2004). Although such conflicts are found world-wide, we use Indonesia as an exemplary case study for highlighting the extent and type of land-use conflict related to agri-business developments, and demonstrate one method for understanding these at a landscape level.

In Indonesia, forest land-use related conflicts affected 12.3 to 19.6 million people (i.e. 5–9% of the country's population) from 1990 to 2000 (USAID 2006). More recently, in 2010 alone over 663 documented ongoing conflicts were identified, mostly located on the island of Sumatra and Kalimantan in Indonesian Borneo (Komnas & Sawit Watch 2010). Such conflicts have been largely due to tenuous indigenous or customary land rights for local communities in development agendas as forested lands have belonged to the State i.e. "under the Forest Estate" (Bartley 2010). This is of particular importance in relation to the countries expanding 'forest-frontier' oil–palm sector. Indonesia is globally the lead palm-oil producer country, with oil-palm plantations covering 8.4 million hectares in 2010 (Indonesian Ministry of Agriculture 2011). By 2009, 9.7 million hectares had already been licensed for oil-palm estates. However, 18 million hectares have been identified as suitable for this crop and targeted for future development (Jakarta Post 2009). With such current extent and future oil-palm expansion, instances of land-use conflicts are inevitable. For example, of the 232 agrarian conflicts documented in Indonesia in 2012, over half (119) were associated with the oil-palm industry (FWI, 2014).

Major environmental impacts (Abram et al. 2014b; Fitzherbert et al. 2008; Meijaard & Sheil 2013) and social disruptions by oil-palm plantations have been widely documented in Indonesia (Dhiaulhaq et al. 2014; Obidzinski et al. 2012). However, simply knowing where land-use conflicts are located is insufficient. It is also important to understand the types of conflicts that have occurred, and if possible the characteristics of the impacted communities and the root causes of these conflicts. Many conflicts are at local scales (i.e. one to several villages) (Meijaard et al. 2013); and at this scale, it is possible to identify such nuances in oil palm-community conflicts. Such conflicts can result from: a lack of appropriate consultation with local communities, land tenure issues where large land leases overlap with community areas, illegal operations, displacement of people from agricultural land (Patel et al. 2013; Yasmi et al. 2010); and inadequate provisioning by companies to communities for resettlement or compensation (Colchester 2010). Although most conflict occurs between large plantation companies and local communities, sometimes conflict arises between smallholders and other community members, especially regarding legitimacy and security of their land holdings (Vermeulen & Goad 2006). Mapping such nuances is challenging, yet necessary for improving land-use plans and sustainability in the oil-palm industry.

Approaches for creating sustainability within the oil-palm industry include the international certification body of The Roundtable for Sustainable Palm Oil (RSPO). The RSPO is a sustainable certification scheme aimed at mitigating negative impacts from oil-palm production on society and the environment, by improving agricultural production standards through specific principals and criteria (Traeholt & Schriver 2011). The RSPO's Principals and Criteria, amongst other things, incorporates community aspects such as rights to land, values of forested systems for livelihoods and culture, and receptiveness to development, through requiring High Conservation Value (HCV) assessments and obtaining Free Prior and Informed Consent (FPIC) from local communities (RSPO 2013). To-date such assessments and engagement have been at a plantation level. However, in 2015 district level commitments to a jurisdictional RSPO certification was given by government in Central Kalimantan (Indonesian Borneo), South Sumatra (Indonesia); and the State of Sabah (Malaysian Borneo). Mapping oil palm-community conflicts across landscapes is challenging, and one that a jurisdictional RSPO commitment will now need to address. Outside of the RSPO, understanding how to map land-use conflicts is important for informed land use planning and for targeting mediation and reconciliation efforts.

No single framework exists for studying conflict, but it is helpful to focus on actors of conflict, underlying causes of conflict, conflict management and conflict resolution (Dhiaulhaq et al. 2014; Yasmi et al. 2010; Yasmi et al. 2012). In this study we aim to contribute to the growing literature on conflict by applying a novel method for exploring spatial patterns of land-use conflict between local communities and a land-intensive industry. To do this we use conflict data derived through systematic searches of a georeferenced national database (of natural resource conflicts), and local newspapers. For one industry sector, oil-palm agriculture, we extract details on the type of conflicts that have occurred. Using boosted regression tree modelling we relate the types of conflict to a comprehensive spatial dataset of environmental and social variables that describes the characteristics of the locations where the conflicts have occurred and the local communities involved. This study is intended to better inform scientists, policy makers, oil-palm producers, and certification bodies to assist with reforming land use policy and implementing effective management to reduce the potential for different types of conflict and to better target mediation procedures in the future (e.g. Dhiaulhaq et al. 2015; Dhiaulhaq et al. 2014).

METHODS

2.1 Conflict data

We collected land use conflicts reports from the Geodata Nasional (GDN) database (*n*=122) (http://www.geodata-cso.org/) and from articles in local newspapers (*n*=143). The GDN database compiles information on natural resource conflicts in Indonesia collected by the following organizations: *Jaringan Kerja Pemetaan Partisipatif* (JKPP), *Perkumpulan Untuk Pembaharuan Hukum Berbasis Masyarakat dan Ekologi* (HuMA), *Perkumpulan Sawit Watch*, *Konsorsium Pembaruan Agraria* (KPA), *Konsorsium Pendukung Sistem Hutan Kerakyatan* (KpSHK), and *Jaringan Advokasi Tambang* (JATAM). We obtained the newspaper articles through online archive searches of the Rakyat Kalbar, Harian Equator, Radar Banjarmasin, Balikpapan Post, Kaltim Post, Samarinda post, Banjarmasin Post, Tribun Kalteng, Radar Tarakan, Tribun KalTim, and Kalimantan news.com; using keywords related to land use conflicts (e.g., *konflik lahan*, *sengketa lahan*).

Overall, 265 conflict reports were collected. Information extracted from these reports included: village names, sub-district, district and province information, general conflict type (i.e., agriculture, forestry, mining), status of conflict (i.e., if underway or finished/resolved), start and end dates of conflict and whether the conflict was still underway at time of the report, conflict descriptions, impacted local communities, major ethnic groups and livelihoods, industry or government bodies involved, and whether companies involved were national or international and company names, along with how companies had handled the situation.

For each conflict incident we extracted location information based on named village(s). Locations were georeferenced by searching for the village name (and any subdistrict or other administrative information) in gazetteers and online place name databases (Google Earth, Geographic Names http://www.geographic.org/geographic_names/ and Wikimapia), and assigning the geographic co-ordinates if a confident match could be made. See Appendix S1 in the Supporting Information for full methodological details. To determine the accuracy of the georeferenced villages we cross-referenced this dataset with three others, as outlined in Appendix S1.

2.1.1 Village level oil-palm conflict data

To enable spatially explicit statistical analyses of our conflict data we refined the data set by: (1) removing entries for villages on three small islands, because many of the spatial variables for statistical analysis did not cover these islands; (2) identifying villages with multiple conflict incidences, and merging entries to eliminate duplicate data (while retaining any information on distinct conflicts affecting the same village); and, (3) by selecting those reports that were marked as ongoing as per time of publication. The resulting dataset comprised 238 villages with conflict under differing industry sectors (forestry, mining, agriculture and fishing). We then separated the dataset into the corresponding industry sectors and extracted the data relating to oil palm in the agricultural sector. This resulted in 187 spatially referenced conflicts relating to industrial scale oil palm (Fig. 1).

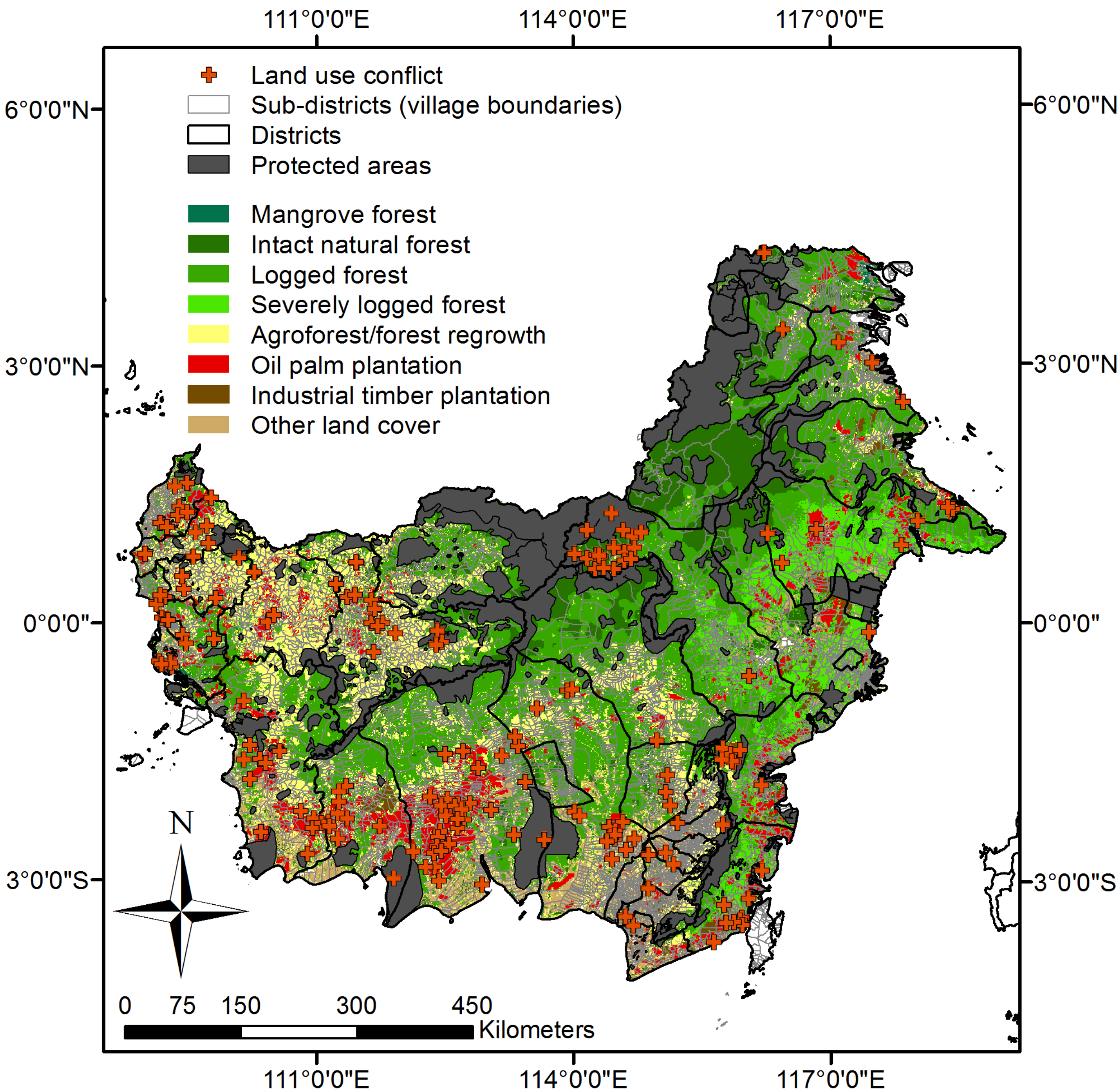

Fig. 1 Location of villages (n=187) with land use (oil palm) conflict occurrence in Kalimantan, Indonesian Borneo, with sub-district (grey lines) and district (black lines) information, with protected areas (grey) and 2010 land cover types (from Gaveau et al. 2014).

We grouped the 187 reports into five non-exclusive categories of conflict type: (a) All conflict occurrences (187 villages); (b) Conflict where communities oppose a company (89 villages), e.g. communities oppose the company, and question the integrity of the company; and, (c) Conflict over land boundaries and illegal operations by companies (102 villages) e.g. claims by one local community that the oil-palm company took 50 ha of their land, reports of companies holding meetings with communities and making promises when they did not have an operating license; (d) Conflict over negative impacts on the environment and people's livelihoods, arising from oil-palm developments (62 villages), e.g. reports of company destroying sacred sites, companies polluting rivers and lakes so much that the water cannot be used by the local people; (e) Conflict over a lack of consultation by oil palm companies/government bodies with local communities, and/or broken promises and lack of compensation from concession owners (70 villages), e.g. claims of falsification of companies in regards to impact assessments, companies forging signatures of local community members in documentations, and companies planting on community lands with no compensation pay out. Villages were allowed to have more than one type of conflict.

These five conflict types formed the response variables for the statistical modelling. The variables were modelled as binary outcomes, with a 'presence' of conflict at a location defined as at least one occurrence of the specific conflict type, and pseudo-absences defined as follows.

2.1.2 Pseudo absence oil palm conflict data

We generated 374 pseudo-absence points, giving a sample size equal to twice the number of observed conflict presences. The population frame comprised the centre-points of 1-km grid cells covering Kalimantan (612,230 points) and the sampling frame was confined to those points that spanned similar ranges of population density, impervious surface cover, and elevation as the observed presence points, and fell within the 46 districts for which our data sources have coverage (46 of Kalimantan's 54 districts). This gave a sampling pool of 460,016 points (75% of the population frame), from which the 374 locations representing 'absence of conflict' were randomly sampled.

It is acknowledged that the absence dataset may have included true, but unreported occurrences of conflict, but we were not able to establish this in this study. Moreover, we reasoned that any misclassified conflicts would have been too small to be reportable in any of the three databases from which the conflict information was extracted.

2.2 Environmental and socio-economic spatial variables characteristics of conflict

We used a spatial data framework of 43 variables describing the environmental and social characteristics of the landscape (Abram et al. 2014a; Davis et al. 2013; Meijaard et al. 2013). These variables fell into the broad categories of: (1) Land-use and land cover types; (2) Topographical variables; (3) Accessibility; (4) Socio-economic variables; and (5) Community perceptions of ecosystem services and land cover change (see Table 1 for brief descriptions and codes with further details in Appendix S2). The variables were extracted at 1 km^2 grid cell resolution for the whole of the target region (n = 85,759 pixels).

Table 1 Summary table of the 43 spatial variables used within the Boosted Regression Tree models.

Category	Spatial explanatory variable layers	Abbreviations
Land use and land cover	Statistic of neighbourhood values of Intact natural forest	intact_s
	Distance to Intact natural forest	intact_m
	Statistic of neighbourhood values of Mangrove	mangrove_s
	Distance to Mangrove	mangrove_m
	Statistic of neighbourhood values of Logged forest	logged_s
	Distance to Logged forest	logged_m
	Statistic of neighbourhood values of Severely degraded logged forest	svlogged_s
	Distance to Severely degraded logged forest	svlogged_m
	Statistic of neighbourhood values of Agro-forests/forest re-growth	agroregr_s
	Distance to Agro-forests/forest re-growth	agroregr_m
	Statistic of neighbourhood values of Industrial timber plantation	indtim_s
	Distance to Industrial timber plantation	indtim_m
	Statistic of neighbourhood values of Other land cover	otherlc_s
	Distance to Other land cover	otherlc_m
	Statistic of neighbourhood values of Oil palm plantations	oilpalm_s
	Distance to Oil palm plantations	oilpalm_m
	Statistic of neighbourhood values of Protected Area	pa_s
	Distance to Protected Areas	pa_m
	Distance to oil palm concessions	op_concess_m
	Distance to Peat	peat_m
Deforestation	Probability of deforestation	Prob_deforest
Carbon	Statistic of neighbourhood values of Carbon	carbon_s
Hydrology	River density	river_d
	Distance to Rivers	river_m
Topography	Ruggedness	ruggedness
	Elevation	elevation
Accessibility	Accessibility sum (road, river, foot)	access_sum
	Accessibility 10 (road, river, foot)	access_10
Infrastructure	Impermeable surface area (%)	impervious
	Road density	road_d
	Settlement density (2011)	pop_2011_n
Wealth	Poverty Index	poverty
Culture	District population (%) who follow Islam	Islam
	District Population (%) who follow Christianity	christian
	Ethnic groups	ethnic_gp
Communities perceptions	Perception of largescale forest clearance for oil palm agriculture	lgscalbd
	Perception of smallscale forest clearance for oil palm agriculture	smscalgd
	Uses of 7 specific forest products	uses7
	Uses of 29 other forest products	uses29
	Cultural and/or spiritual values of forests	cultural_ben
	Direct benefits from the forest to peoples lives	direct_ben
	Benefits from forest to peoples health	health_ben
	Benefits from forest to peoples environments	environ_ben

2.3 Modelling and mapping oil palm conflict

We used Boosted Regression Tree (BRT) modelling to relate the environmental and socio-economic spatial variables to the presence of each of the five conflict types. BRTs are a statistical method for grouping observations, based on a set of explanatory variables (in this case, grouping types of conflict, based on the associated environmental and socio-economic variables). The grouping is achieved by a series of binary splits of the explanatory variables, where the selection and ordering of variables, and the location of the binary splits, are all determined by the statistical model and based on the data. The BRT creates many possible series of splits based on random subsets of the data, and then combines them via a boosting algorithm, whereby the trees are developed sequentially to improve the model's accuracy, stability and predictive performance. This approach provides a relative weight for each variable based on its contribution to the full ensemble of models. BRTs can thus be used to determine the most important variables for grouping types of conflict, as well as the important levels of these variables.

BRTs were selected because they impose few assumptions on the distribution of the data or the relationships between the variables. Moreover, they accommodate complex nonlinearities and interactions between the explanatory variables and with the response (Elith et al. 2006; Elith et al. 2008). Each model was fitted using the relevant conflict occurrence data (presences) and the pseudo-absence data (absences) as binary responses, and the values of the 42 spatial variables at each of the response locations. Cross-validation is also employed to optimise bias-variance trade-offs (Friedman & Meulman 2003).

The BRT models were fitted in R version 2.15.0 (R Core Team 2013) using the functions 'gbm' and 'gbm.step' in the 'dismo' package (Hijmans et al. 2013), with the following specifications: a Bernoulli distribution for the response variable; maximum 5,000 trees with an interaction depth of 3 (allowing for multi-way interactions between primary explanatory variables); bagging fraction of 0.5 (50% random samples used for fitting the trees); training fraction of 0.8 (20% data reserved for independent model testing); and five-fold cross-validation (for model robustness).

The predictive performance of the models was assessed through goodness of fit plots between observed and predicted values, and by calculating the proportion of correctly predicted presences and absences, respectively. To better understand the underlying relationships between the spatial variables and the conflict type, fitted function plots were created for the top nine most influential spatial variables for each of the five BRT models.

In order to visualise the spatial pattern of conflicts, each BRT model was applied to the full spatial set of explanatory variables and used to generate a likelihood of conflict occurrence across the landscape. These were input into ArcGIS 10.1 (ESRI), converted to a raster grid (based on a 1 km^2 grid-mask), and then classified into quartiles (equal number of observations in each class) to delineate areas of low, medium, high and very high likelihood of the five different types of conflict.

RESULTS

3.1 Descriptive statistics

Of the 265 incidences of land use conflict (in 238 villages) reported in online media in mainland Kalimantan: 75% (199 incidences) were associated with conflicts between communities and oil-palm companies (with 92% of these corporations being Indonesian registered); 11% of incidences were associated with the forestry sector (with 97% of companies being registered in Indonesia); 10% of villages had conflict with mining companies (81% of which were Indonesian registered); and, 4% of villages had conflicts involving unknown actors or sectors.

Those conflicts associated with oil palm, as per time of media report, occurred in 187 villages. Villages occurred in all four provinces in Kalimantan, with 63 villages (34%) in West Kalimantan, 65 villages (35%) in Central Kalimantan, 42 villages (22%) in East Kalimantan, and 17 villages (9%) in South Kalimantan.

As part of the exploratory analyses, the correlations between the 45 explanatory variables were calculated using the full spatial dataset (n = 85,759 pixels). The results are reported in Appendix S3 and Table S1.

3.2 BRT models of oil-palm conflict

3.2.1 Conflict occurrence

The conflict occurrence model had a positive predictive accuracy of 93% and a negative predictive accuracy of 98% (Fig. 2). The occurrence of conflict between oil-palm companies and local communities was strongly correlated with the probability of deforestation, explaining 34% of the model variance. Fig. 3a shows the nine most important predictive variables for conflict occurrence, according to the BRT model. These are: the probability of deforestation (prob_deforest), distance to mangroves (mangrove_m), distance to severely degraded logged forest (svlogged_m), distance to oil palm concessions (op_concess_m), distance to oil palm plantations (oilpalm_m), communities' uses of the 7 specific forest products asked about in the survey (uses7), neighbourhood values of carbon (carbon_s), road density (road_d), and distance to agroforests (agroregr_m).

More specifically, there have been fewer conflicts in areas with a low probability of deforestation, and a near-linear positive trend in conflict with increased probability of deforestation (Fig. 3a). Conflicts have also occurred in locations nearer to mangrove forest (i.e., coastal areas) or far away from them i.e., approximately 230 km from mangrove forest with more conflicts occurring with increasing distance from the coast, and fewer conflicts far from roads (Fig. 3a).

(a) (b) (c)

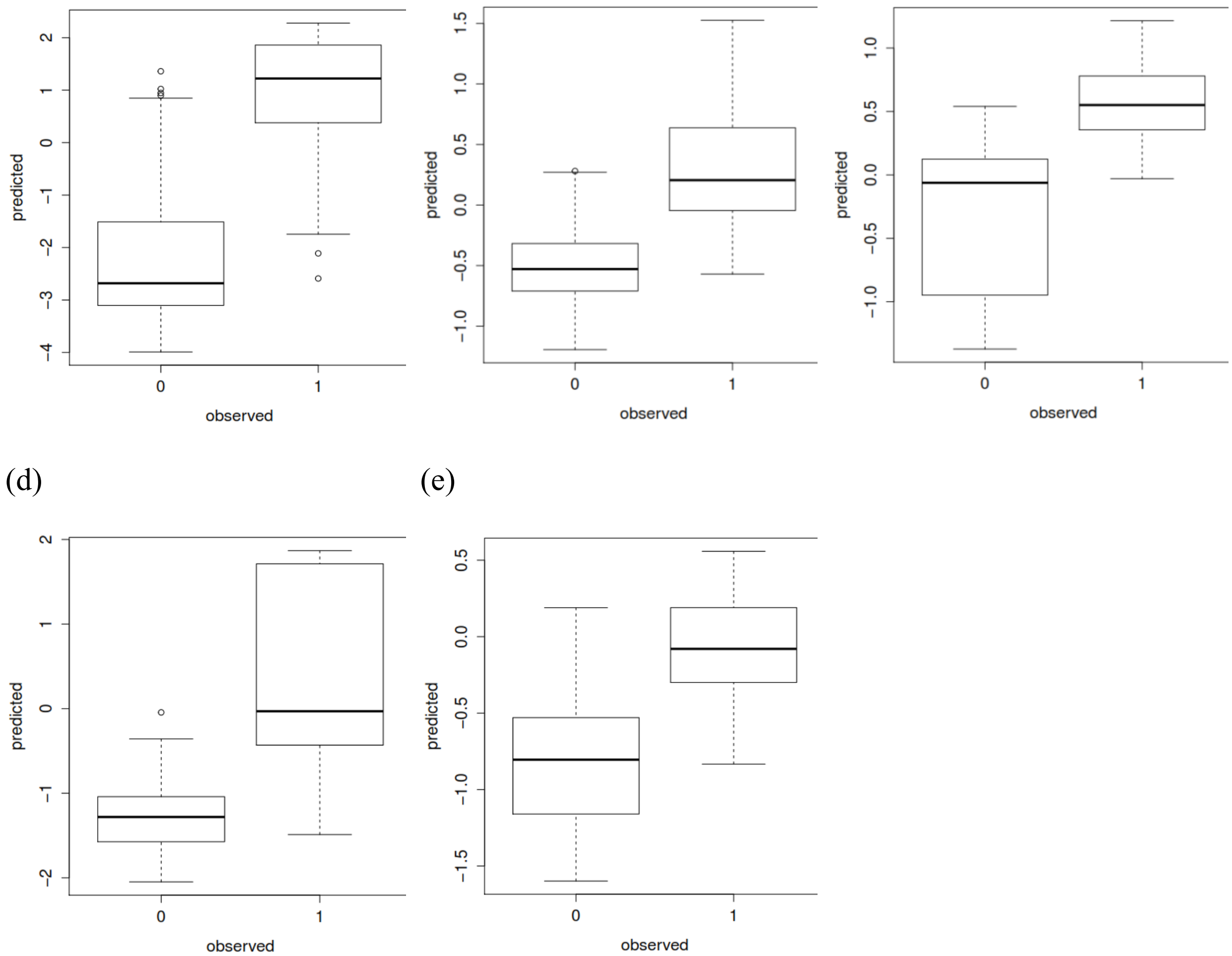

Fig. 2 Goodness of fit plots between observed and predicted responses for five boosted regression tree models for the following: (a) Conflict occurrence; (b) Conflict where communities oppose company; (c) Conflict over land boundaries and illegal operations by companies; (d) Conflict over negative impacts arising from oil palm on the environment and peoples livelihoods; (e) Conflict over a lack of consultation with communities, broken promises and lack of compensation.

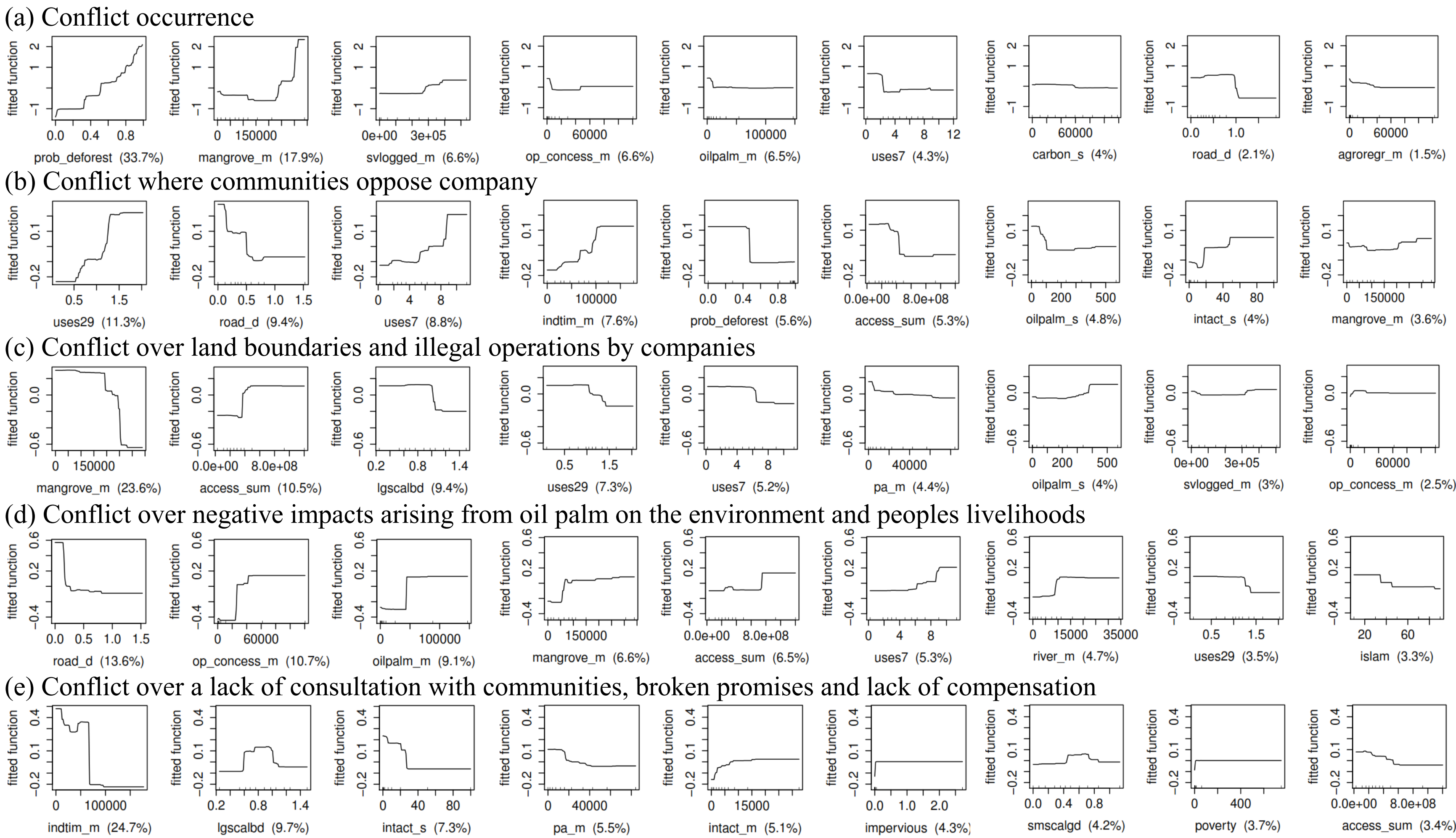
(a) Conflict occurrence
fitted function
prob_deforest (33.7%)
mangrove_m (17.9%)
svlogged_m (6.6%)
op_concess_m (6.6%)
oilpalm_m (6.5%)
uses7 (4.3%)
carbon_s (4%)
road_d (2.1%)
agroregr_m (1.5%)
(b) Conflict where communities oppose company
uses29 (11.3%)
road_d (9.4%)
uses7 (8.8%)
indtim_m (7.6%)
prob_deforest (5.6%)
access_sum (5.3%)
oilpalm_s (4.8%)
intact_s (4%)
mangrove_m (3.6%)
(c) Conflict over land boundaries and illegal operations by companies
mangrove_m (23.6%)
access_sum (10.5%)
lgscalbd (9.4%)
uses29 (7.3%)
uses7 (5.2%)
pa_m (4.4%)
oilpalm_s (4%)
svlogged_m (3%)
op_concess_m (2.5%)
(d) Conflict over negative impacts arising from oil palm on the environment and peoples livelihoods
road_d (13.6%)
op_concess_m (10.7%)
oilpalm_m (9.1%)
mangrove_m (6.6%)
access_sum (6.5%)
uses7 (5.3%)
river_m (4.7%)
uses29 (3.5%)
islam (3.3%)
(e) Conflict over a lack of consultation with communities, broken promises and lack of compensation
indtim_m (24.7%)
lgscalbd (9.7%)
intact_s (7.3%)
pa_m (5.5%)
intact_m (5.1%)
impervious (4.3%)
smscalgd (4.2%)
poverty (3.7%)
access_sum (3.4%)

Fig. 3 Fitted function plots for the nine most influential spatial variables within each boosted regression tree model. One row is presented for each model (each type of conflict, a-e). Plots show the bivariate effect of each spatial variable on the response variable. Spatial variables and abbreviations are explained in Table 1. Relative importance values for each variable are shown in parentheses.

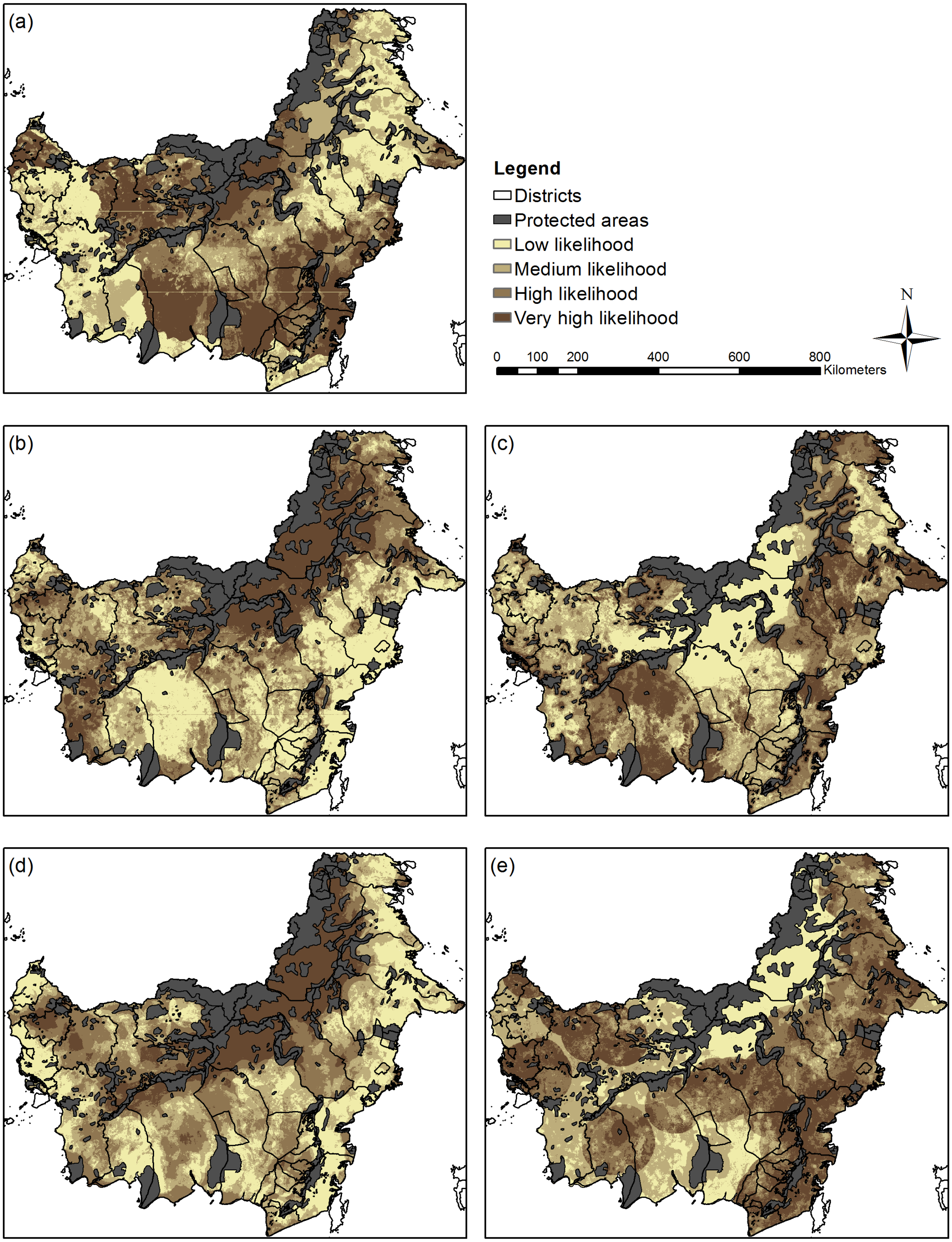
(a)
Legend
Districts
Protected areas
Low likelihood
Medium likelihood
High likelihood
Very high likelihood
N
0
100
200
400
600
800
Kilometers
(b)
(c)
(d)
(e)

Fig. 4 Mapped outputs from five boosted regression tree models on conflicts between oil palm companies and local communities from online data sources and local newspaper reports, overlaid with protected areas (grey) and district level boundaries (black lines). Maps show the likelihood of various types of conflicts (mapped as quartiles) for the following: (a) Conflict occurrence; (b) Conflict where communities oppose company; (c) Conflict over land boundaries and illegal operations by companies; (d) Conflict over negative impacts arising from oil palm on the environment and peoples livelihoods; (e) Conflict over a lack of consultation with communities, broken promises and lack of compensation.

3.2.2 Communities oppose company

The model for conflict where communities strongly opposed oil-palm companies had a positive predictive accuracy of 76% and a negative predictive accuracy of 89% (Fig. 2). This type of conflict was strongly influenced by the two variables that indicated greater usage of forest products by local communities i.e., 7 specific forest products (timber, rattan, hunting, traditional medicine, mining, honey and aloes wood) and 29 other forest products (e.g. fish, fire wood, fruit and vegetables, tree sap) (Fig. 3b). This type of conflict has also been more strongly associated with areas that have a lower road density (Fig. 3b). The probability of deforestation was also important but unlike the general conflict occurrence model, opposition-type conflicts have been more likely to occur when there was a lower probability of deforestation (Fig. 3b). Based on the observed relationships, the regions with a high likelihood of community opposition to oil-palm development are in locations that are more extensively forested (within the core of Borneo island) (Fig. 4b).

3.2.3 Land boundaries and illegal operations by companies

The model for conflicts over land boundary disputes and illegal operations of companies had a positive predictive accuracy of 94% and a negative predictive accuracy of 84% (Fig. 2). This type of conflict has predominantly occurred in locations within 250 km of mangrove forest (Fig. 3c). Land boundary disputes and/or conflict over illegal actions by companies have also occurred in areas where forests were more accessible by more people; where people had moderate to indifferent perceptions of negative impacts from large-scale oil-palm agriculture; and where there was moderate to little use/dependency on provisioning services from forest (Fig. 3c). Based on these observed relationships this type of conflict has a greater likelihood in coastal areas (Fig. 4c).

3.2.4 Negative impacts on the environment and livelihoods

The model for conflicts over negative environmental and social impacts from oil palm had a positive predictive accuracy of 92% and a negative predictive accuracy of 83% (Fig. 2). This type of conflict has occurred in areas with very low road density and in areas >25 km from oil-palm concession areas (allocated, under title, oil-palm areas that may or may not yet have oil palm) and >40 km from existing oil palm cultivations (Fig. 3d). This type of conflict has also been more common away from the coast (>50 km from mangrove forest) (Fig. 3d). Those areas where forests were more accessible to people and where communities had a higher use/dependency of forest products have experienced more environmental and social conflict (Fig. 3d). Similar to the model for people opposing companies, these environmental and social conflicts are more likely to occur in areas where there is more 'intact' forest in the core of the island (see Figs. 1 and 4d).

3.2.5 Lack of consultation and compensation and broken promises

The model for conflicts associated with lack of community consultation, broken promises, and lack of compensation, had a positive predictive accuracy of 83% and a negative predictive accuracy of 74% (Fig. 2). Conflicts of this type have been strongly associated with areas within 70 km from industrial timber plantations (which accounted for 25% of model variance) (Fig. 3e) and with some surrounding intact forest (Fig. 3e). Thus these types of conflict have occurred in regions that have gone through or are going through forest transformation to oil-palm or industrial- tree plantations (see Fig. 4e and Fig. 1 for land cover types).

DISCUSSION

In Indonesia, land allocation is characterised by a complex political landscape that promotes the transformation of forest assets to other land uses, such as oil palm, often at the expense of traditionally managed lands and livelihoods of local communities (Brockhaus et al. 2012). Understanding characteristics of conflict locations and the communities that have experienced conflict, facilitates the understanding of why and where certain types of conflict has occurred. Such information can assist with conflict prevention and future resolution attempts (Dhiaulhaq et al. 2015). This is not only important for regional land-use planning in Indonesia, especially in view of emerging jurisdictional approaches to RSPO certification, but this methodology is relevant for mapping community conflicts associated with other land use types e.g. those related to other agri-business and mining sectors, for example.

4.1 Conflict occurrence

In this study we demonstrated innovative methods for assessing spatial patterns of land-use conflict across mainland Kalimantan, a region of rapid land-cover and land-use change (Gaveau et al. 2014). To better understand the interplay between local communities (at the village level) and oil-palm companies, we modelled conflict occurrence and found that conflict intensity increased (almost linearly) with higher probabilities of deforestation. Extensive lowland regions in Kalimantan have been converted to oil palm and other human land uses (Carlson et al. 2013; Koh et al. 2011); and our findings demonstrate that conflicts have occurred at a greater intensity in regions undergoing conversion of forest to agricultural (Gaveau et al. 2014). Our findings showed some general associations between land cover and conflict type between the models for communities opposing oil palm (3.2.2), and those associated with perceived negative social and environmental impacts from oil palm (3.2.4). These models demonstrated similar spatial patterns, with these conflicts dominating in interior forest areas. These types of conflicts likely occur when people anticipate negative impacts from oil-palm development will outweigh possible benefits. This finding matches community perceptions about large landscape-level clearing for oil-palm that we identified in a previous independent study (Abram et al. 2014a; Meijaard et al. 2013).

Conflicts arising from land boundary disputes, illegal actions, and perceived lack of consultation, on the other hand, seemed to dominate areas where oil palm was developed from the 1990s to 2000s (see Gaveau et al. in review). Areas where oil palm was already or in the process of being established were generally in flat and fertile coastal areas, with conflict types transforming from general opposition of the industry to more specific forms of disputes.

4.2 Oil palm conflict with forest dependent communities

Among the oil-palm related conflicts, 48% of villages strongly opposed oil-palm companies. Anecdotal accounts of opposition included reports of indigenous communities outright rejecting the presence of the oil-palm plantations. For example, as companies developed oil palm in what were considered as customary forests under local/traditional governance systems. Our results revealed that local opposition by communities was associated with regions where communities had high use of provisioning services from forests (e.g. for timber, rattan, and hunting), and with more remote areas with intact forests that had a lower likelihood of deforestation. These results and the mapped outputs from the model (Fig. 4b) suggest that forest-dependent communities more strongly oppose oil-palm development. Furthermore, the model that considered conflict due to negative impacts on the environment and on villager's livelihoods arising from oil palm occurred within 33% of villages. We found that a higher occurrence of this type of conflict was associated with areas with a very low road density that were away far from oil-palm concessions (25 km or more) or plantations (40 km or more), and more than 50 km from coastal areas. These areas were associated with accessible forested areas where communities still had high dependency on forest products. Indeed, spatial patterns for both these models were similar with higher occurrence of conflict generally associated with areas of more continuous forest e.g. north of Central Kalimantan and west of East Kalimantan (Fig. 4b and Fig. 4d). One account of conflict from our dataset was in Long Pahangai in Mahakam Ulu (previously under administration of Kutai Barat) in East Kalimantan, where villages were initially impacted by a timber company from the 1980s, but more recently by an oil-palm company which controls 80,000 hectares of land that overlaps with 21 villages. In this region, communities perceived that the oil-palm plantation had robbed them of their livelihoods, the sustainability of forest and water resources, without providing sufficient benefits in return. The appeal of the modelling approach presented here is that stories like these are no longer considered as individual cases, but are systematically aggregated to identify points of commonality.

An independent study based on a Borneo-wide questionnaire dataset undertaken in rural communities showed negative perception of benefits of large-scale oil-palm establishment in more remote areas where there was more intact forest and communities have higher resource use of forests (Abram et al. 2014a). This tendency is supported by other studies (Marti 2008; Orth 2009; Sirait 2009) and suggests that communities linked to forest-based livelihoods or forest-based cultural identity and traditions generally have negative perceptions about oil palm. In parts of Central Kalimantan, for example, oil-palm establishment has impacted on indigenous Dayak communities, shifting cultivation practises and causing food insecurity (Orth 2007). Similar findings have been shown in West Kalimantan where groups most impacted by oil-palm establishment have been former customary land users, who have experienced loss of livelihoods due to limited access to forest and ease of accessing land for swidden agriculture; as well as negative environmental impacts including flooding, polluted waterways and pest issues (Obidzinski et al. 2012).

On the other hand, if managed properly, socio-economic benefits from oil-palm establishment (by either companies or smallholders) have positively transformed many rural communities, providing livelihood improvements and poverty alleviation (Myers et al. 2015; Semedi 2014). For example, in Bungo District in Indonesia, smallholding farmers prefer planting oil palm compared to other agricultural land use options (e.g. rubber and rice) due to its high returns (Feintrenie et al. 2010), with similar findings throughout Indonesia (Rist et al. 2010) and elsewhere in the tropics (Pfund et al. 2011). However, often the benefits of oil palm are felt through the establishment of smallholdings rather than large commercial plantations (Abram et al. 2014a; Rist et al. 2010), and in these communities elites are likely to benefit most, to the detriment of non-elites (Colchester 2010). This inequality is particularly emphasised within indigenous groups, where case studies identify that non-elites in communities can often lose ancestral land and livelihoods, and are subsequently forced to migrate to urban centres to look for employment, often leaving behind women, children and elders and hence fracturing social systems (Li 2015; Sirait 2009). Oil-palm establishment in indigenous lands can therefore erode traditional customs, cultures and identity, ensuing the detachment of people from their natural environment and the collapse of customary systems of natural resource management (Achobang et al. 2013).

4.3 Oil palm conflict in transformed areas

Over half (55%) of the villages were noted to have conflict over land boundary disputes and/or illegal operations by oil-palm companies, primarily in areas less than 250 km from mangroves (generally low-lying coastal flats), with accessible forests (suggesting non-remote areas). Additionally, higher levels of this conflict type were associated with areas in which people were less dependent on provisioning services from forests, and where there was already extensive oil palm (Fig. 3c). These results suggest that land boundary and illegal operations of companies were mostly located in predominantly agricultural areas with some remnant forest, where oil palm was established and expanding, potentially displacing local people from their lands (Achobang et al. 2013; Colchester 2010). This is especially pertinent considering that land allocation in Indonesia is characterised by a complex political economic system which facilitates forest conversion to oil palm, often overriding rights or informal claims to land (Larson et al. 2013; Paoli et al. 2013). For example, caveats in law permit governors and ministers the right to override land use decisions made by districts (i.e., Government Regulation No. 26/2008) (Brockhaus et al. 2012). We also note that land speculation by communities in these agricultural areas can be significant, with many informal and formal land claims overlapping, leading to an increased likelihood of conflict (Dennis et al. 2005).

As expected, transformed areas also experienced conflicts associated with lack of community consultation, broken promises, and lack of compensation. Such conflicts can occur over companies failing their obligations to provide services such as technical assistance in plantation management, schools, or clinics (Sirait 2009). Such unfulfilled obligations to communities can occur not only with companies but also local government officials. Indeed, some local officials may have vested interest through corruption, financial support in electoral campaigns, and increasing district authority through tax revenues from oil palm, and as a result development agreements may be rushed, ill-considered and poorly executed (Adnan & Yentirizal 2007; Rist et al. 2010; Sirait 2009). However, conflicts can also occur within communities, for example if the head of the community smallholdings cooperative maximises personal gain through receipt of bribes to favour company interests over community interests (Rist et al. 2010; Sirait 2009).

4.4 Methodological strengths and limitations

There are obvious challenges in the conception, conduct and interpretation of studies on social issues such as conflict in communities, such as those in Borneo. Five main issues that arise in the study presented in this paper are discussed here.

First, this study has aimed to develop a quantitative assessment of conflict based on data derived from online media. This data source was chosen because it was publicly accessible and therefore auditable by others. Moreover, it covered the whole of the target region and presented current information in a somewhat uniform manner. However, the disadvantage of relying on media reports is that it induces potential bias due to simplification of the issues, selective reporting of certain types of conflict, and under-reporting in rural areas or of smaller scale conflicts (Gritten et al. 2011). This bias was ameliorated to some extent by the use of a wide search for conflict stories, including a national database on natural resource conflicts compiled by five major organisations and eleven local news sources. Moreover, the study focused on the most predominant reported issue, oil-palm agriculture, which affects a wide cross-section of the community in the region.

Second, the use of conflict reports based on online media has a further disadvantage in that the extracted articles did not provide information about communities that are happy with oil-palm development. This motivates a future study that includes both positive and negative stories about oil-palm development. However, in order to achieve the desired balance in such a study, arguably a wider search than online media alone would be needed to compensate for the potential bias towards negative stories in newspaper reports. More detailed studies on broader welfare changes in communities adjacent to oil palm would help build understanding about the conditions under which oil palm can deliver net societal benefits.

Third, although one of the strengths of this study is the ability to derive a spatial understanding of conflict across the region, the validity of this approach is predicated to some extent on the accuracy of the geo-coding of the reported conflicts. An estimate of this accuracy was obtained by cross-referencing the conflict dataset with three separate sources. The results indicated acceptable accuracy with respect to the scale of the spatial variables used in the analysis. Furthermore, although a formal sensitivity analysis was not conducted, a review of the inferences from the statistical analysis suggested that they would be unlikely to be affected by movement of the villages within the average spatial range. While this does not completely resolve the issue, it does provide some confidence in the reported results.

Fourth, although the BRT models that were used in this study are able to flexibly model spatially correlated data, they may not have encompassed all of the spatial autocorrelation in the conflict response variables since records were derived from online sources and therefore no systematic sampling was undertaken. However, a wide geographic area is covered in the analyses, diversifying the environmental space within the models. Moreover, although the spatial explanatory layers invariably exhibit varying degrees of inaccuracy, every attempt was made to omit poor quality data from the spatial framework.

Finally, it is acknowledged that the models developed in this study were not intended to describe causal relationships between the spatial variables employed and the occurrence of conflicts. Rather, our study is an exploratory exercise aiming to understand the types of conflicts that are occurring, the characteristics of the communities that have been impacted by conflict and of the locations where these conflicts have occurred. As understanding causality was not the focus of this study, we do not assert that the models accurately predict the location of future conflicts. Rather our mapped outputs are intended to visualise where different types of conflict are more likely to occur, based on the relationships observed in the past and using the data on conflicts that we were able to access.

Notwithstanding these limitations in our methods, the data source and modelling approach demonstrate a robust approach to understanding the spatial trends and patterns associated with landscape level information on the environmental and social context and different types of conflict. These methods are applicable to other regions and industries that are conflict prone such as forestry or mining.

4.5 Scale of the problem

The Indonesian government maintains a village-level database on conflicts which is updated every 3 years in the *potensi desa* process. However, underreporting of conflicts by the government in Indonesia is common, meaning that community-oil palm conflict occurrence may indeed be much higher than suggested by government data (Barron et al. 2004). Nevertheless, in 2012, for Kalimantan, the Ministry of Agriculture stated that there were 439 land-use conflict cases for oil palm, with 250 cases in Central Kalimantan alone, 78 in East Kalimantan, 77 in West Kalimantan and 34 in South Kalimantan (Hadinaryanto 2014). This suggests that conflict is extensive and widespread. Moreover, land-use conflict will likely be exacerbated as oil palm and other human land uses continue to rapidly expand. For example in West Kalimantan, oil-palm covered 0.3 million hectares in 2000 (Sirait 2009), then expanded to over 1 million hectares in 2010, yet over 5 million ha have been granted in concession to around 390 companies (data from Gaveau et al. 2014). When we segment the size of the province (14 million hectares) into 3.7 million hectares under timber companies, 3.7 million hectares protected and 1.5 million hectares under mining permits, only 0.7 million hectares remain for 4.3 million people (Hadinaryanto 2014). The scale of existing and future conflicts becomes clear when considering the rapid and extensive land cover change occurring in the more rural areas (Gaveau et al. 2014) and that such large-scale transformation may work against the poor in these areas (McCarthy & Cramb 2009).

If, however, the transformation is successful and returns are managed equitably, high net revenue from oil palm can deliver significant economic benefits at local levels, providing such benefits accrue to rural people and outweigh the societal costs of oil palm (e.g. costs of increased flooding, costs of higher temperature associated with land clearing) (Abram et al. 2014a; Sayer et al. 2012). Indeed, one study on livelihood impacts of oil palm noted that in all of the four case study regions, most communities were eager for economic development and in remote regions villages compete for development investors (Rist et al. 2010). A desire for oil-palm development is due to its potential to enable households to lift themselves out of poverty, which appears most feasible where smallholdings are independent of companies (Feintrenie et al. 2010). However, whether local people directly benefit from oil palm is highly dependent on the local context, with the particular deals offered to communities varying widely with respect to land exchanges, loan conditions, and sale of lands (see Orth 2009; Rist et al. 2010). This is also influenced by the capacity of the local people to adapt to new management of land and alternative livelihoods (Sirait 2009). Other important issues include the extent to which oil palm displaces smallholder farming, especially for food staples such as rice, thus reducing community self-sufficiency, and also whether oil palm development requires the import of migrant labour, which can have significant social impacts (Anderman et al. 2014).

In some cases, initial conflict can be a starting point for positive change for communities, by allowing for cross-stakeholder dialogues, clarification of land tenure, and for potential development opportunities (Dhiaulhaq et al. 2014). Reducing the frequency of future disputes can be beneficial for all parties. For example, financial risk incurred by plantations when disputes arise can be significantly reduced. One large plantation estimated that, over a several year period, social disputes with local communities could easily cost USD 1,000,000 (Levin et al. 2012). Fires are also frequently used by communities in a conflict situation, causing significant crop losses to the company (Dennis et al. 2005).

4.6 Ways forward

Ensuring that local communities can benefit from development and that companies can limit risks associated with land-use conflicts with local communities (e.g. due to increased operational costs) underpins aspects of the RSPO's standards; and the less known mandatory Indonesian equivalent ISPO (Indonesian Sustainable Palm Oil). In regards to the RSPO, certification requires company compliance with applicable laws and regulations (Principle 2), for example, by demonstrating full rights to land which is not contested by local people, and being able to demonstrate Free and Prior and Informed Consent (Principle 7) (RSPO 2013). The RSPO is a voluntary certification scheme, however the new jurisdictional approach may see transformations in how its HCV assessments and FPIC procedures are rolled out across landscapes. Although the ISPO has similar requirements, it is regarded as substandard to RSPO. Nevertheless both schemes are under scrutiny for inadequate social and environmental safeguards (Caroko et al. 2011; Ruysschaert & Salles 2014). Nevertheless, there remains hope that such requirements will improve current practice and standards, in an industry with a poor reputation. Moreover, in contexts in which conflict already exists, mediation and conflict resolution efforts may prove useful tools for overcoming conflict.

Prior to establishment of oil palm by any company, willingness for the particular development should be better determined through engagement and incorporation into spatial plans (Paoli et al. 2013). This will help to reduce the negative impacts of oil-palm plantations on communities, and maximize the potential for oil palm to elevate local economies (Obidzinski & Dermawan 2010). Additionally, current and future development projects should consider the different types of conflicts they may encounter, given the spatial characteristics of the sites. Obviously, reconciling competing land uses and factoring in the desires and needs of stakeholders is complex (Sayer et al. 2013). Spatially explicit methods for decision analysis for conflict resolution in land use planning are available (e.g. de Groot 2006; Zhang et al. 2012), and despite requiring significant data gathering and analysis, the spatial distribution of social land use perceptions is possible (Abram et al. 2014a; Brown & Raymond 2014). This study underlines the need to involve local communities in local and district land-use decision making and the design of development strategies, to ensure their rights and livelihoods are not only considered but integrated into spatial management plans.

SUPPORTING INFORMATION

Appendix S1: Location accuracy of georeferenced villages

Appendix S2: Environmental and Socio-economic spatial predictor variables

Appendix S3: Correlations among the predictor variables

Table S1: Correlation matrix between 43 spatial (explanatory) variables. Moderately correlated variables highlighted in yellow, strongly correlated in orange and very strongly correlated in red.

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