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Exploring under-utilised low carbon land resources from multiple perspectives: Case studies on regencies in Kalimantan

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ABSTRACT

Mobilising under-utilised low carbon (ULC) land resources for future agricultural production can help reducing pressure on high carbon stock land from agricultural expansion, particularly for deforestation hotspots like Kalimantan. However, the potential of ULC land is not yet well understood, especially at regency level which is the key authority for land-use planning in Indonesia. Therefore, this study explored ULC land resources for all regencies in Kalimantan. By analysing information from six monitoring domains, a range of indicators were derived to provide insights into the physical area of ULC land from various perspectives. It was found that these indicators show largely different values at regency level. For example, regency Pulang Pisau has a substantial area of 'temporarily unused agricultural land' but a very limited area of 'low carbon land' – this implies that not all 'temporarily unused agricultural land' is ready for future exploitation when assessing from different aspects. As a result of such diverging indicators, using a single indicator to quantify available ULC land resources is risky as it can either be an over- or under-estimation. Thus, ULC land resources were further explored in the present paper by taking four regencies as case studies and comparing all the indicators, supported with relevant literature and evidence collected from narrative interviews. This information was used to estimate ULC land area by possible land-use strategies. For example, Gunung Mas was found to have a large area of low carbon land which is not occupied and might be suitable for oil palm deployment. However, the major limitation is that physical estimates cannot provide a complete picture of 'real' land availability without considering a broader range of socio-economic factors (e.g. labour availability). Therefore, physical land area indicators from different domains must be combined with other qualitative and quantitative information especially the socio-economic factors underlying land under-utilisation to obtain better estimates.

1. Introduction

The rate of terrestrial carbon stock loss in Kalimantan (the Indonesian part of Borneo) has grown substantially over the last two decades, largely driven by increasing global demand for timber and agricultural products. The annual emission from land-use change (LUC) has reached to about 52 Tg CO_2/year in 2006–2010 (Agus et al., 2013). Export-oriented agricultural activities, particularly oil palm expansion, are also often associated with carbon stock loss due to deforestation and peat loss (Agus et al., 2013). In 2005–2010, about half of the oil palm expansion (1.8 Mha) has occurred in Kalimantan (Gunarso et al., 2013). Mobilising less-productive lands with low carbon stock and insignificant ecological services may be a solution for increasing agricultural production and preventing further carbon stock loss. To achieve these aims, two general criteria can be employed to assess potential land resources: (i) its current agricultural productivity is insignificant or low compared to its optimal potential; and (ii) it has a low level of carbon stock so that utilisation of the land is unlikely to incur additional carbon stock loss and negative ecological impacts. Land that fulfils the two criteria may be broadly regarded as under-utilised low carbon (ULC) land. In case oil palm is to be cultivated on these lands, the threshold value of above-ground carbon stock can be set, for example, at 40 tC/ha, i.e. the average value of carbon sequestered in an oil palm plantation with a rotation period of 25 years (Khasanah et al., 2012). In terms of soil carbon, areas with potentially high carbon stock in the soil such as wetland should be directly excluded.

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Various names, e.g. 'abandoned', 'degraded', and 'marginal' land, have been proposed to quantify land available for future expansion but they do not necessarily fulfil both the ULC criteria. Furthermore, their definitions or criteria may be different and some are not entirely clear, e.g. abandoned land is not necessarily degraded, and vice versa (Smit et al., 2013; Suhariningsih, 2009). Ambiguous definitions may create unrealistic expectations and unintended consequences in policymaking. For example, in some cases the classification of degraded land was used as an excuse for forest clearing under the guise of reforestation programmes, although the 'degraded' land may still be rich in carbon stock and biodiversity (Barr et al., 2010; Obidzinski and Dermawan, 2010).

For Kalimantan, a number of top-down efforts have been initiated to identify ULC land based on remote sensing coupled with biophysical models, by both international (e.g. Gingold et al., 2012; Hadian et al., 2014) and national institutions (e.g. Mulyani and Sarwani, 2013; MoF, 2013). Most of these analyses focus largely on environmental constraints (e.g. avoiding biodiversity loss) and technical potential, but lack local socio-economic considerations, e.g. land occupancy by indigenous communities. Also, they were often performed between large time-intervals (up to several years) due to resource constraints. Thus, land-use dynamics may not be well captured and technical errors could be significant, e.g. it is difficult to differentiate abandoned land from land which may still be cultivated sporadically by local communities (Treitz and Rogan, 2004).

In addition to top-down efforts, also bottom-up approaches have been developed to identify ULC land resources. In contrast to the top-down approaches, the bottom-up approach integrates relatively more locally focused socio-economic information based on expert opinions and household surveys (e.g. BPS, 2013b; Lambin et al., 2013). For example, Lambin et al. (2013) have estimated the 'potentially available cropland' in several countries based on expert judgement. Such approaches may include more precise local information on a case-by-case basis. However, 'under-utilisation' is a normative notion that can be interpreted differently, e.g. based on socio-cultural values, economic values or legal perspective. For example, land claimed by local communities for certain purposes e.g. shifting cultivation, is not deemed 'under-utilised' by the occupants. Estimates of available land thus often lack consistency from one case to another (Lambin et al., 2013).

Since ULC land can be defined differently based on the different perspectives of land-use actors across scale, the immediate question is at what level relevant policy can be made to achieve the aim of preventing further carbon stock loss while increasing agricultural production. Among the authorities in the Indonesian hierarchy, regencies (*kabupaten*) and municipalities (*kota*) are the most influential decision makers in terms of land-use policies.[1] Since 2001, they are empowered to implement their own spatial planning policies (Thorburn, 2004). Deforestation in Kalimantan in the 2000's was largely driven by regency-oriented policies, which largely promoted (large-scale) oil palm expansion (e.g. Barr et al., 2006). Between regencies, rules and regulations on land-use can be quite different and are enforced with varying degrees of stringency (Fairhurst et al., 2010). Land-use patterns also interact with the wider socio-economic environment within a regency. Understanding and comparing the issues related to ULC land from a regency perspective is thus essential. But at present, most studies on Kalimantan either focus on island, provincial or village level. Quantitative and comparative studies on individual regencies are still rare and only cover a limited number of regencies (e.g. Tomich et al., 1997).

In addition to spatial and scale variations, the changes in land-use patterns across time, e.g. how long has the land been under-utilised or remained in a low carbon state also need to be accounted for when examining its potential for agricultural expansion. Some studies, e.g. Potter (2015), have specifically explored the history of agricultural land-use at regency level by assessing their underlying socio-economic causes, but not quantifying the area changes. Some other studies, e.g. van der Laan et al. (2015), have investigated the land-use trajectories in individual regencies based on land cover changes using spatially explicit methods. However, the interplay of local factors underlying these changes, e.g. land-use intensity and occupancy (whether it is really 'abandoned' or not), has not yet been explored in conjunction with the land-use patterns of ULC land.

This study aims to explore the availability of ULC land by combining information collected with different types of approaches. Firstly, information collected based on distinct perspectives and relevant aspects (e.g. ecological or socio-economic) for assessing ULC land resources are categorised into six monitoring domains and reviewed. Based on information collected from the six monitoring domains, relevant quantitative indicators are analysed and derived for 55 regencies and municipalities in Kalimantan. Finally, based on these quantitative indicators as well as relevant literature and evidence collected from narrative interviews, the potential of ULC land for possible land-use strategies was estimated for four regencies.

2. Study area

Kalimantan is the Indonesian territory that makes up about 73% of the total land area of Borneo Island. It is divided into five provinces. Throughout this study, the newly formed North Kalimantan province (in 2012) is considered as part of East Kalimantan to incorporate data before 2012, when Kalimantan was divided into 46 regencies and 9 municipalities (both are sub-divisions of provinces) (see the map in Fig. A1). The island has experienced serious (legal and illegal) logging and deforestation since the 1980's. Then, the 'oil palm boom' began from the 1990's, surging since 2006 (Agus et al., 2013). Kalimantan was a major transmigration[2] site alongside several large land-based projects, such as the Mega Rice Project (MRP)[3] in Central Kalimantan which planned to locate a large number of Javanese transmigrants. By 2011, the population had grown to >14 million with a 2.4% growth rate (BPS Kalbar, 2014; BPS Kalsel, 2014; BPS Kalteng, 2014; BPS Kaltim, 2014).

In addition to the analysis for all regencies, case studies were conducted in four regencies in Central Kalimantan with distinctive characteristics in order to assess the potential of ULC land for possible land-use strategies. First, Gunung Mas was chosen due to its vast low carbon lands and unusual average land area claimed by households. Next, Kotawaringin Timur was selected for its rapid industrial oil palm expansion. Palangka Raya, the capital of Central Kalimantan, was included for urbanisation and the formation of ULC land surrounding the city. Finally, Pulang Pisau, the former site of the MRP, was chosen for comparison due to its poor agro-ecological conditions.

[1] For convenience, the term 'regency' was used throughout the paper to represent all regencies and municipalities.

[2] The transmigration programme was a population-relocation programme that moved landless people mainly from the densely populated island of Java to less populous parts of the country, e.g. Kalimantan). It was especially active during the Suharto era and continued in a minor way after regional autonomy (Potter, 2012). President Widodo now plans to reactivate the scheme, especially in undeveloped areas such as North Kalimantan.

[3] The MRP, also called Peat Land Project or 'Proyek Lahan Gambut' (PLG), was a failed programme by the Indonesian Government to develop one million hectares of degraded peatland for rice production from 1996.

3. Review of monitoring domains

Relevant information for ULC land in Kalimantan can be gathered from six monitoring domains (Table 1) which employ different approaches and have their own advantages and limitations. From an ecological perspective, *land cover* is a key indicator to distinguish land with high carbon stock. Meanwhile, information about *land suitability* can be used to evaluate the technical agricultural potential. For socio-economic aspects, *land occupancy* by small farmers provides an indication for local land-use. In addition, *land-use intensity* can be used to identify land that is used in lower intensity in terms of agricultural activities. The *legal classification and concessions* is another important aspect when land is legally classified as the official 'forest zone' or granted for agricultural activities (which may not be the same as the actual land cover and land-use). Finally, *land degradation* is also monitored as changes in land characteristics from environmental, technical and economic perspectives. Each domain is further explained and described in the following sub-sections.

Publicly available data sources for quantifying these indicators are also listed in Table 1. The agricultural land statistics are collected on an annual basis, but most monitoring efforts are only performed once in several years (e.g. the household survey by BPS, (2013b) is only performed once in a decade). The data sources also have different levels of clarity in methodology as also explained below.

3.1. Land cover

Low carbon land cover can be identified using remote sensing (e.g. Gunarso et al., 2013, Hoekman et al., 2010; MoF, 2015). Land classes like forests and wetlands which potentially have high carbon stocks and ecological services, as well as other functional land classes like settlements, mines, existing industrial oil palm plantations and wet paddy fields, can be identified and excluded through examining land cover maps. The remaining land forms the maximum of ULC land area that can be mobilised.

The Ministry of Forestry (MoF, 2015) has publicly provided spatially explicit land cover maps of Indonesia for 2009 and 2011. Based on the land classification method used in these maps, land cover types which are of low carbon (excluding functional land classes like settlements) are (i) dry-field agriculture, (ii) dry-field agriculture mixed with grass (grassland that is suspected to have sporadic agricultural activities, e.g. shifting cultivation), (iii) dry-field shrub and grass and (iv) open land. The above-ground carbon stock values of these four land classes are reported to be below 40 tC/ha (i.e. less than the average carbon stock of oil palm as reported by Khasanah et al., 2012), and they do not contain peat (Agus et al., 2013). However, these four land classes do not necessarily represent land suitable for productive agricultural activities. Also, relying solely on land cover data at a single temporal point (or with a large time-step, e.g. 5 years) means that it is difficult to explicitly distinguish temporarily and permanently abandoned land. Some of these areas may be used for shifting agriculture (Agus, 2011). This is difficult to capture through land cover changes in a short period of time due to the continuous transition of land-use from one type to another (Gunarso et al., 2013). Discrepancies between spatially explicit maps also exist due to technical issues e.g. different interpretation from visual inspection (Treitz and Rogan, 2004). Nevertheless, the total area of the four aforementioned land classes can be deemed the upper limit for ULC land resources.

3.2. Land suitability

Land suitability, linking to agricultural productivity, is determined by a number of agro-ecological and topographical factors, such as soil suitability, elevation, and water availability (Gingold et al., 2012). In government policies, the term 'sub-optimal' is employed to describe land with lower quality (Haryono, 2013). Several monitoring activities have been conducted to assess the amount of sub-optimal land in terms of its agricultural potential (e.g. based on its acidity), as well as a number of case studies on technological aspects performed at regency or sub-regency level (Mulyani and Sarwani, 2013). Notably, degraded peatland is also included as one type of sub-optimal land, which is targeted for development but which is not low in carbon stocks. However, no spatially explicit information is freely available to the public.[4] BBSDLP (2014) also assessed the agricultural land resources of Indonesia in terms of acreage, distribution, and potential availability. Among the different types of land assessed, 'dry-field suitable for crops and livestock' is one indicator to estimate the technical potential of ULC land, but data is only publicly available at provincial level.

For oil palm establishment, two prominent studies on land suitability have been conducted by Gingold et al. (2012) and Hadian et al. (2014). Suitable lands are identified based on land cover maps, biophysical models as well as other ecological indicators to ensure agricultural suitability and sustainability. However, such large-scale mapping exercises are often fraught with high uncertainties (e.g. soil distribution is largely estimated through models with limited ground surveys) (Gingold et al., 2012; Sulaeman et al., 2013). Detailed agro-ecological surveys are conducted on plantation scale by companies, but this is very costly and labour-intensive and data is not generally available to the public. It is not realistic to be performed on a larger scale.[5]

While the accuracy has largely limited the data usefulness, the available spatially explicit information prepared by WRI (2012) nevertheless provides the best possible estimates for potentially suitable areas for oil palm in terms of agro-ecological properties while excluding areas with high carbon stock or conservation value.[6] However, it does not account for existing uses by local communities that are not easily recognised from maps. Hadian et al. (2014) has pinpointed that social and legal aspects such as local land-use and tenure are not taken into consideration, which is a major drawback of such studies.

3.3. Land occupancy

In Kalimantan, a substantial area of land is occupied by local communities for small-scale farming. These lands may largely consist of low carbon land, e.g. dry-field agriculture, but also a wide range of land classes, e.g. forests or peatlands. It is crucial to take this aspect into account when quantifying land availability because local perspectives on land-use, particularly the land claimed by local communities, may vary greatly. The land-use of small farmers in Kalimantan cannot be simply captured by remote sensing because many of them move and change their land-use from time to time, involving the transition of shrub-fallow-agroforests in irregular patterns (Fox et al., 2009), despite some having used their lands more intensively for e.g. oil palm. Although the performance of small farmers varies greatly, most small farmers Kalimantan gen-

[4] Personal communication with Yiyi Sulaeman, land specialist at Agency for Agricultural Research and Development (Badan Penelitian dan Pengembangan Pertanian) in Bogor, Indonesia in January 2015.

[5] Personal communication with S Paramnanthan, director of PA Soil Survey and Advisor of Malaysian Palm Oil Board in Kuala Lumpur, Malaysia in December 2014.

[6] This represents low carbon land with elevation <1000 m, soil depth >75 cm, soil acidity <pH 7.3, slope <30%, water resource buffers >100 m, and conservation buffer >1000 m. However, other climatic indicators, e.g. rainfall seasonality, were not included in this land suitability map.

Table 1
Monitoring aspects, domains, approaches, sources, spatial scale, types of data, year available and public availability.

Monitoring aspects	Monitoring domains	Monitoring approaches						Source	Types of data	Spatial scale				Year available	Public availability	
		Remote sensing	Stakeholder's survey	Agriculture statistics	Bio-physical models and field surveys	Expert's and official's opinions	Legal classification			Island	Province	Regency	Spatially explicit		Methodology	Data
Ecological	Land cover	●						MoF (2015)	Land cover maps				●	2006, 2011	No	Spatially explicit
								Gunarso et al. (2013)		●			●	1990, 2000, 2005, 2010	Yes	Aggregated at island level
Technical	Land suitability				●	●		WRI (2012)	Land suitable for oil palm				●	Processed in 2012	Yes	Spatially explicit
								Hadian et al. (2014)	Land excluding EU-RED zone[a]		●		●	Processed in 2014	Yes	Aggregated at provincial level
								BBSDLP (2014)	Dry-field suitable for crops and livestock		●		●	Processed in 2014	Yes	
Socio-economic	Land occupancy		●	●				BPS (2013b)	Land occupied by small farmers		●	●		2003 and 2013	Yes	
								DG Estate Crops (2012a, 2012b, 2014a, 2014b)	Area of oil palm and rubber small-holdings		●	●		2011–2013	No	Aggregated at regency level
Agri-cultural	Land-use intensity	●	●	●				BPS (2013a)	Agricultural land by utilisation		●	●		2008–2012	Yes but lacks clarity	
Legal	Legal classification and concessions					●	●	WRI (2012)	The 'forest zone', timber concessions and oil palm concessions				●	Processed in 2012	Yes	Spatially explicit
Multiple	Land degradation	●			●	●		MoF (2015)	Critical land				●	2011 (every 5 years)	Yes but lacks clarity	

[a] EU-RED zone is defined as the land area that has fulfilled the requirements of sustainability criteria set by EU-RED (European Union Renewable Energy Directive) for biofuel production.

erally have lower productivity compared to their counterparts in the other parts of the country.[7]

To further look into the land occupancy by local communities in Kalimantan, information from two sources can be used. BPS (2013b) has conducted household surveys on the area occupied by small farmers. The strength of the household survey BPS (2013b) is that it provides direct information from the local communities on land-use. The limitation is that it is only conducted once in a decade as such monitoring is labour-intensive. DG Estate Crops (2014a, 2014b), the second source, reported the area of oil palm and rubber smallholdings at regency level. But they do not distinguish between independent and plasma farmers.[8] Unfortunately, there is still no accurate spatial information over land tenure claimed by local communities, whether formal or informal. The best data available is only aggregated at regency level.

3.4. Land-use intensity

Distinguishing land by land-use intensity, i.e. identifying (temporarily) abandoned land, can be useful to improve the assessment on ULC land. In a legal context in Indonesia, land that has not been used according to its rights of cultivation (*Hak Guna Usaha*, HGU) is considered under-utilised land. The government can then withdraw the land-use right from the holders. The term 'under-utilised' land (*tanah terlantar*) is defined as land that has purposely not been used according to its condition, characteristics, or the purpose of its land-use rights (which is designed by the authority). Land will be considered as under-utilised when over a certain period it has become non-productive, not providing benefits to the land-right holders or local communities, and experiencing decrease in fertility. This also includes lands that have been purposely kept at low productivity (e.g. uncultivated land within oil palm concessions). Furthermore, selling land to non-locals who have no intention to develop the lands, namely 'absentee land' (*tanah absentee*), is actually forbidden under the Basic Agrarian Law (UUPA) to avoid land under-utilisation. In practice, the definition of under-utilised land is ambiguous, as there are no clear official criteria for determining the utilisation status as well as the effective time frame (Suhariningsih, 2009).

An indicator at regency level is 'temporarily unused agricultural land', which is available from the annual agricultural statistics collected by the Central Bureau of Statistics (BPS, 2013a). It consists of land that was used regularly but currently has not been used for 1–2 years, and also includes paddy fields that have been left unused for >2 years. The area for 'shifting cultivation' is also further distinguished. However, it is not entirely clear how these areas are identified by BPS (2013a), and both land classes also do not necessarily represent low carbon land. Although secondary succession in Kalimantan is more difficult to maintain due to ecological constraints (e.g. repeatedly damaged by wild fire especially in El Nino years) and human disturbance (e.g. salvage logging) (Tolkamp et al., 2001; van Nieuwstadt et al., 2001), some temporarily unused land may have already experienced considerable carbon stock regeneration (Yassir et al., 2010). Also, this land class may consist of land that is not suitable for regular agricultural use, e.g. peatland. Regency Kapuas of Central Kalimantan is a notable example – it has plenty of degraded peatland (previously developed under the MRP), which may be counted here as 'temporarily unused agricultural land' (McCarthy, 2001). Thus, while this monitoring domain is useful to understand the local land-use, it cannot be used solely to quantify land availability for future expansion or intensification.

3.5. Legal classification and concessions

At national level, MoF has classified about 70% of the total land area as 'forest zone' and the rest as 'other use zone (APL)'. However, the legal classification does not always correspond to the actual physical situation (i.e. the APL is not necessarily non-forested) (Gnych and Wells, 2014). Meanwhile, a vast area of land has also been granted as timber, oil palm and mining concessions. These concessions may overlap with each other and the 'forest zone'.[9] Companies wanting to grow oil palm must apply to the MoF to have their land excised from the 'forest zone', otherwise they are illegal. This has made monitoring of legal classification and concessions a complicated subject that involves a wide range of stakeholders. Furthermore, some concessions may not be used for their designated purpose and remain under-utilised for years at low carbon status, having been converted from forest to low carbon land decades ago. For oil palm concessions, the location permit (*izin lokasi*) is supposed to be withdrawn if the area has not been developed within three years, and it is only allowed to be prolonged for one extra year. But in reality, this has not been enforced (Fairhurst et al., 2010). These areas are largely locked away from productive use due to uncertainties in land-use rights.

Both legal classification and concession maps are available at WRI (2012). The mapping results under this domain can be combined with land cover maps to examine low carbon lands that are locked away from utilisation due to policy or legal constraints. A major drawback is that these concession maps are fraught with overlaps and uncertainties due to conflicting claims based on multiple concession issuances by different authorities from national to regency level (Rosenbarger et al., 2013).

3.6. Land degradation

The Land Degradation Assessment by FAO (LADA, 2009) defines land degradation as 'a reduction in the capacity of land to perform ecosystem functions and services that support society and development'. This is much broader than the two ULC criteria described in Section 1 because this may include land that is of high carbon stock or ecological services, e.g. degraded peatland. However, 'degraded' land is a term often used to represent low risk land for agricultural development especially in the context of biofuel development (Wicke, 2011).

A term with a similar definition, 'critical land (*lahan kritis*)' is used by the Ministry of Forestry (MoF) to refer to land which is severely damaged due to its loss of vegetation cover, and no longer functions as a medium for water retention and productive elements, but disrupting the ecosystem balance (MoF, 2013). Remote sensing, biophysical models and experts' or officers' opinions are employed to assess the level of criticality. Land is categorized by level of criticality based on four criteria: land cover, slope, soil erosion, productivity and level of management. The weight of each criterion is different for forest and non-forested area. Unfortunately, the methodology published by MoF (2013) is not detailed

[7] For oil palm, the productivity of smallholders (in 2013), which ranged from 0.7–4.0 tCPO/ha at regency level with an average of 1.6 tCPO/ha, is generally lower than the national average of 3.3 tCPO/ha for smallholders and 3.8 tCPO/ha for large private plantations (DG Estate Crops, 2014a). Medium-scale farming currently still rarely exists, except in West Kalimantan where cooperatives of oil palm smallholders are growing (Potter, 2015). Similarly for paddy, the average yield in Kalimantan is only half of the national average (8.5 t/ha) in 2013 (BPS, 2014). Meanwhile, the rubber productivity of the 55 regencies in 2013 ranges from 0.4 to 1.5 t/ha with an average of 0.8 t/ha, significantly lower than the national average of smallholders (1.0 t/ha) and private enterprises (1.5 t/ha) (DG Estate Crops, 2014b).

[8] Plasma schemes are outgrower schemes designed to assist small farmers by attaching them to large companies that provide technical and financial supports to them before they become independent plantation growers.

[9] The timber concessions are in the areas designated as 'production forest' or occasionally 'conversion forest'.

enough to understand how scores are given. Also, the actual carbon stock level is not explicitly accounted for in policymaking based on this monitoring domain. There were cases where degraded forests with substantial carbon stock were classified as 'critical land' and logged intensively under the guise of so-called 'rehabilitation' programmes (Barr et al., 2010; Obidzinski and Dermawan, 2010). Still, the indicator for land degradation can be seen as a warning signal – it gives an overview of how much land has undergone degradation and requires further actions.

4. Materials and methods

4.1. Deriving indicators at regency level

Table 2 shows the list of indicators defined for different monitoring domains and how they were derived. The year 2011 was employed as the base year since most information is available for this year (with few exceptions). In addition to indicators directly related to ULC land, other indicators, which could be relevant for investigation (e.g. area of paddy), were also included. For 'legal classification and concessions' and 'land degradation', instead of presenting the original data, the maps were further overlapped with land cover maps to derive new indicators. All GIS operations described in Table 2 were performed using ArcInfo© procedures.

4.2. Narrative interviews

Table A1 listed the 23 sub-regencies (*kecamatan*) visited. Local communities were invited for group discussions, with priority given to local leaders. Each group discussion or interview lasted 0.5–3 h, participated by 2–10 people. The discussions were about land-use characteristics and dynamics in relation to ULC land. They were conducted in a flexible and open way to avoid preconception and to allow unexpected hypotheses to emerge.

4.3. Estimating ULC land potential for four case studies

The ULC land potential in the four selected regencies was estimated by comparing indicators derived from the previous section, supported with literature and ground evidence collected through narrative interviews. Firstly, the proportion of land cover was compared with the percentages of land suitable for oil palm, oil palm concessions, and critical non-forested land per total regency area. Next, the land-use change (LUC) within and outside oil palm concessions was inspected by overlaying the land cover maps of 2006 and 2011 with the concession map using ArcInfo© procedures. This was then compared with the other indicators, considering their changes across several years whenever data is available. Particularly, the roles of small farmers and industrial oil palm corporations were inspected. Two socio-economic indicators, i.e. population and household income, were also included for the analysis. Based on these findings, possible land-use strategies (e.g. small- or large-scale oil palm establishment) to mobilising ULC land were generally identified with broad estimates of physical ULC area.

5. Results and discussions

Table A2 displayed the comparison of key indicators at provincial level. When comparing different indicators at provincial and island level, it can be seen that although some numbers reported may match well at island level, the numbers are quite different at provincial level (e.g. the land suitability indicators). The numbers become even more different when they are further disaggregated to regency level, for example as shown in Fig. 1 (see all other indicators in Figs. A2–A7). These figures clearly show that although regencies could be very different when compare between different aspects. For example, although Ketapang has nearly 1 Mha of low carbon land, only 0.6 Mha is deemed suitable for oil palm.

Based on the wealth of data presented in Figs. A2–A7, regency policymakers together with other stakeholders, e.g. national policymakers, NGO's, industry or others, may attempt to devise more appropriate land-use strategies at regency level. For example, large-scale establishments should be restricted in regencies with high rate of land occupancy by small farmers even if it has a substantial area of low carbon land. Instead, in the future these regencies might be prioritized for a more diversified portfolio of agricultural activities, e.g. agro-forestry, which may be more suitable in environmental aspect. Seruyan is a prominent example with a low percentage of land remained suitable for oil palm and a large area of critical land. In comparison, regencies in West Kalimantan, which have a large amount of low carbon land and land suitable for oil palm production, could be a better starting point to explore possibilities for large-scale establishment. At the same time, these regencies in West Kalimantan also show high amounts of critical land. This implies that they are degraded and that further expansion would have to take this into account and make sure that the situation is not further exacerbated. To demonstrate how strategies can be drawn based on these indicators, a more detailed investigation was made for four selected regencies in Central Kalimantan with distinctive characteristics as illustrated in the following.

5.1. Case study on Gunung Mas

5.1.1. Land-use characteristics and dynamics

Gunung Mas is a land-locked regency mainly covered with two distinctive land cover types, i.e. 56% of dry-field forest (611 kha) and 39% of low carbon land (416 kha) (see Fig. 2). Among the four regencies, Gunung Mas has the largest area of land considered suitable for oil palm (378 ha), but only a very small percentage of the regency is planted with oil palm (9 kha).

As shown in Fig. 3, which portrays the spatially explicit LUC in 2006–2011 in the four regencies, Gunung Mas has experienced relatively small LUC across 2006–2011 (only on 5% of the total regency area). This includes 41 kha of deforestation (without cultivation) and new establishment of 9 kha of oil palm plantation on both existing low carbon land and dry-field forest. The large area of low carbon land has existed already since before 2006.

Fig. 4 shows that land occupied by small farmers in Gunung Mas has increased 35 kha within 2003–2013 to a total of 77 kha, with about 42 and 1 kha are planted with rubber and oil palm, respectively. But, as illustrated in Fig. 5, only 4 kha is planted with permanent crops in 2012. It is likely that majority of the rubber owned by the small farmers is grown as 'jungle' rubber in a secondary forest, thus it is not easy to be traced without direct information from the farmers (EIA, 2014).

On average, the small farmers in Gunung Mas occupy the largest area of land (about 6 ha per household) among the 55 regencies (Fig. 5). The narrative interviews reveal a possible explanation for the exceptional high average area occupied by small farmers, i.e. claiming of deforested land remained in the timber concession. As Gunung Mas has undergone rapid deforestation at the hands of logging companies in recent decades, vast areas of former timber concessions have been turned into grassland or shrubs but are officially included in the 'forest zone' (see Fig. 6). For example in Tewah, about 6 kha of deforested land is locked inside a former timber concession. The villagers have announced their ownership on these areas, and attempted to free these areas up for large-scale oil palm plantation.

Table 2
List of indicators from different monitoring domains.

Monitoring domains	Spatial scale	Indicators	Source of raw data	Derivation methods
Land cover	Spatially explicit	Dry-field agriculture (excluding plantation) Dry-field agriculture mixed with grass Grass/Shrub Open land Low carbon land % Low carbon land per total land area of the regency Paddy[a] Oil palm plantation (large-scale)[a] Dry-field forests[a] Swamp and mangrove forest[a] Non-forested wetlands[a] Others[a]	Provincial land cover maps from MoF (2015)	Land classes used by the source were followed. Low carbon land was defined as the sum of the first four land classes. The map was further dissected to regency level by overlaying with the boundary map.
Land suitability		Land suitable for oil palm excluding existing plantation Low carbon land that is not suitable % Land suitable for oil palm excluding existing plantation per total land area of the regency	Suitability map from WRI (2012)[b], existing plantation from MoF (2015)	The map was further dissected to regency level by overlaying with the boundary map. Existing plantations were excluded. Low carbon land that was not considered suitable was calculated by subtracting suitable land from total low carbon land (which was derived for the land cover domain).
Land occupancy	Regency level	Land occupied by small farmers for paddy Land occupied by small farmers for non-paddy agriculture	BPS (2013b)	Directly reported by source.
		Total land occupied by small farmers for agriculture % Land occupied by small farmers for agriculture per total land area of the regency		Sum of the two above land classes.
		Land occupied by small farmers for oil palm Land occupied by small farmers for rubber Land occupied by small farmers for other non-paddy agriculture Total area of oil palm smallholdings reported by DG Estate Crops (2014a) Total area of rubber smallholdings reported by DG Estate Crops (2014b) Extra area of oil palm smallholdings reported by DG Estate Crops (2014a) Extra area of rubber smallholdings reported by DG Estate Crops (2014b)	BPS (2013b), DG Estate Crops (2014a, 2014b)	Areas of land occupied by small farmers for oil palm and rubber were adapted from DG Estate Crops (2014a, 2014b). If the total oil palm and rubber area of smallholdings reported by DG Estate Crops (2014a, 2014b) was smaller than area of 'land occupied by small farmers for non-paddy agriculture', the remaining land was assumed to be used for other non-paddy agriculture. Else, the extra area reported by DG Estate Crops (2014a, 2014b) was considered as extra oil palm and rubber area (distributed between the first two and last two indicators using the ratio of total oil palm and rubber area reported).
		Average land area occupied for agriculture per household	BPS (2013b)	Total land occupied divided by number of households.

Table 2 (*Continued*)

Monitoring domains	Spatial scale	Indicators	Source of raw data	Derivation methods
		Average agricultural income (from own land) per ha of land occupied for agriculture in 2013 (USD/ha)[d]		Directly reported by source.
		Average agricultural income (as labourer) per ha of land occupied for agriculture in 2013 (USD/ha)[d]		
		Average non-agricultural income per ha of land occupied for agriculture in 2013 (USD/ha)[d]		
Land-use intensity		Temporarily unused agricultural land[c]	BPS (2013a)	Directly reported by source.
		Shifting cultivation		
		Irrigated paddy field		
		Non-irrigated paddy field		
		Permanent crops (non-industrial)		
		Total agricultural land		Sum of the five classes above.
		% Land-use intensity		% Used agricultural land (i.e. agricultural land other than temporarily unused agricultural land) per total agriculture land.
Legal classification and concessions (overlapping with land cover)		Low carbon land inside timber concessions	Concession maps from WRI (2012) and land cover map from MoF (2015)	The concession maps (WRI, 2012) were overlaid with the land cover map (MoF, 2015) to distinguish low carbon land, and with the regency boundary map to be dissected to regency level. Some overlaps between concessions and 'forest zone' exist. For all overlaps with oil palm concessions, lands were included in oil palm concessions; for overlaps between timber concessions and 'forest zone', lands were included in timber concessions.
		Low carbon land inside oil palm concessions		
		Low carbon land outside the 'forest zone' and concessions		
		% Low carbon land inside the 'forest zone' and concessions per total low carbon land		
		% Low carbon land inside oil palm concession per total low carbon land		
Land degradation (overlapping with land cover)		Critical non-forested land	Critical land map of Kalimantan from MoF (2015)	The critical land map was overlaid with the land cover map (MoF, 2015) to distinguish forested and non-forested land that falls under categories 'very critical', 'critical' and 'moderately critical', and with the regency boundary map to dissect to regencies.
		Critical forested land[a]		
		% Critical non-forested land per total land area of the regency		
		% Forest in critical status per total forested land		

[a] These indicators are not directly related to ULC land, but were included here to provide overviews of land-use in the regencies.

[b] This represents low carbon land with elevation <1000 m, soil depth >75 cm, soil acidity <pH 7.3, slope <30%, water resource buffers >100 m, and conservation buffer >1000 m. However, other climatic indicators, e.g. rainfall seasonality, were not included in this land suitability map.

[c] Land that was regularly used but temporarily (1–2 years) unused, and paddy fields that have been left unused for >2years.

[d] These are socio-economic (non-physical) indicators, but were included here as they were also reported by BPS (2013b), and useful for comparison in case studies.

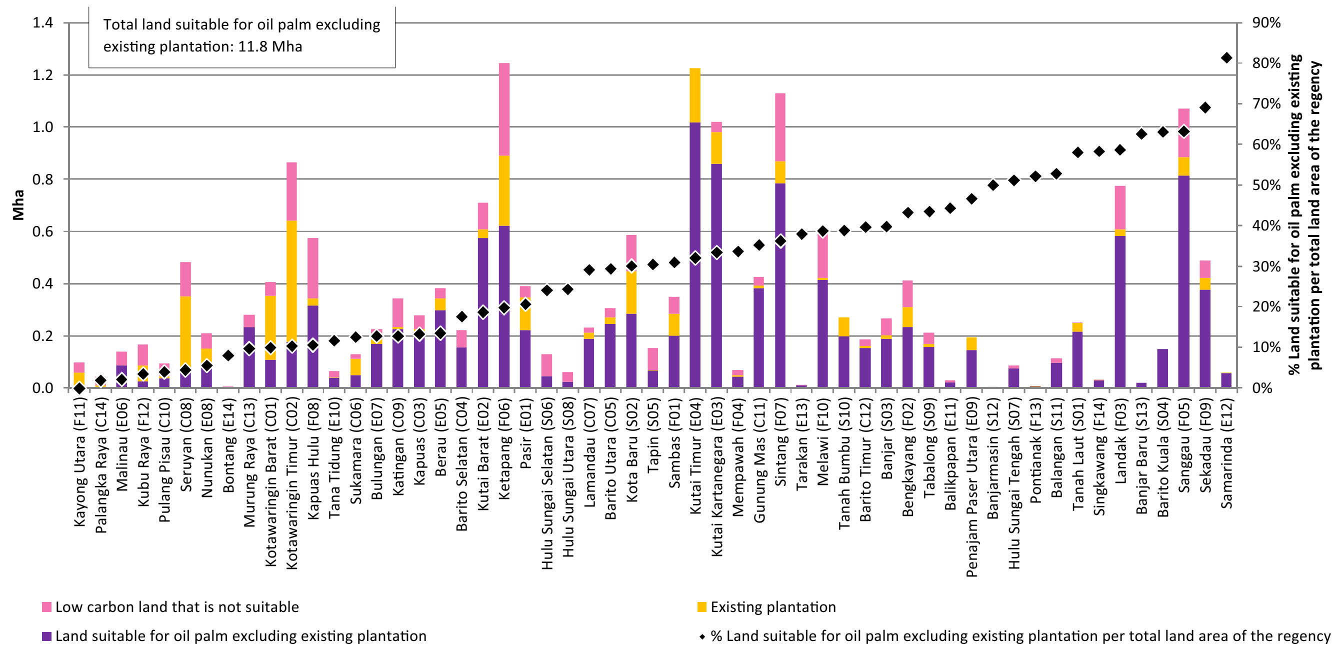

Fig. 1. Land suitability: Land suitable for oil palm in Kalimantan as identified by WRI (2012) in comparison to low carbon land and existing oil palm plantation identified by MoF (2015).
Suitability criteria are: low carbon land with elevation <1000 m, soil depth >75 cm, soil acidity <pH 7.3, slope <30%, water resource buffers >100 m, and conservation buffer >1000 m.

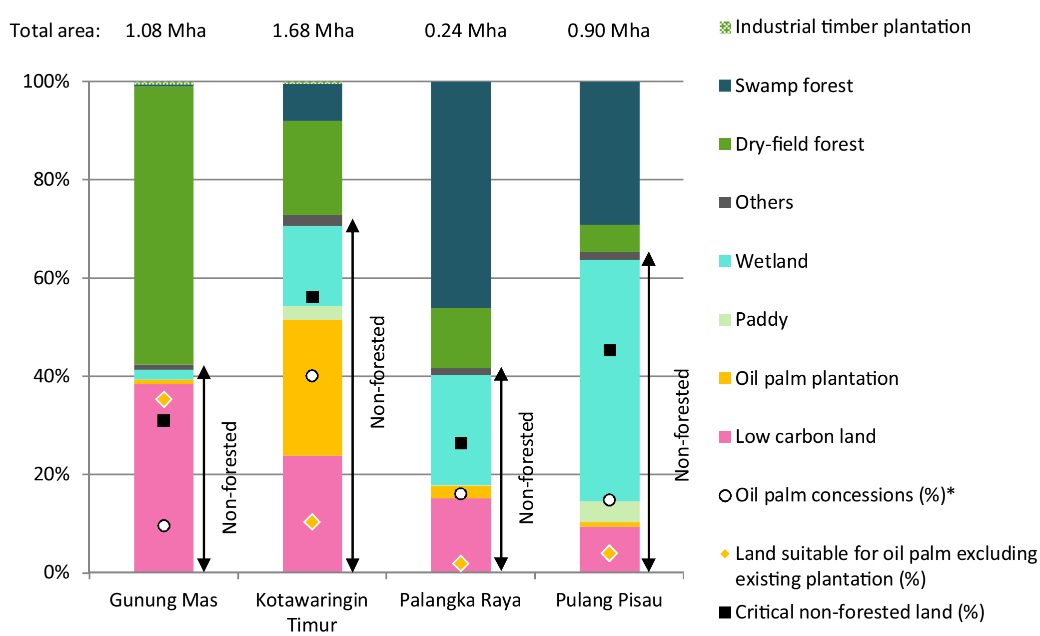

Fig. 2. Land cover types by proportion, % land suitable for oil palm, % oil palm concessions, and% critical non-forested land per total regency area in the four regencies in 2011.
*Some oil palm concessions are forested.

5.1.2. *Possible land-use strategies*

At first sight, Gunung Mas may be a potential candidate for the future establishment of industrial plantations in conjunction with plasma schemes. This is because up to 306 kha of low carbon land which is deemed suitable for oil palm cultivation may be still unoccupied with a rough assumption that another 76 kha is occupied by farmers (comparing Fig. 2 and Fig. 4). However, experiences with rogue firms that have routinely disregarded regulations and exploited local people (even though the number of companies is still small), may incur serious social consequences (also see EIA, 2014).

In this context, intensification of small farmers seems to be a suitable starting point for increasing agricultural production, as they have occupied relatively large areas of land. But, the large area occupied per household also implies that labour scarcity could be also an issue, not to mention the distraction from non-agricultural income opportunities (Fig. 6). Compared to other regencies, Gunung Mas has not experienced large influxes of trans-

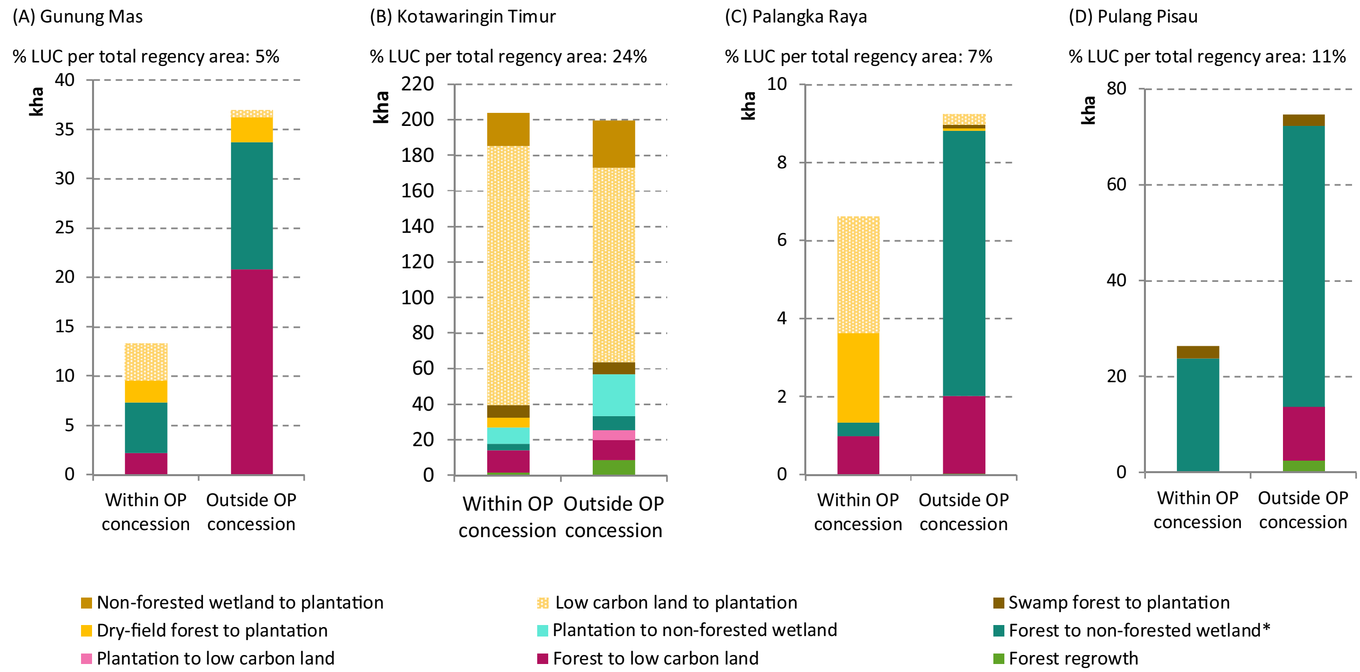

Fig. 3. Land-use changes in 2006–2011 in the four regencies.
*This includes some conversion of dry-field forest to wetland, which may be due to technical error in distinguishing dry-field forest and swamp forest.

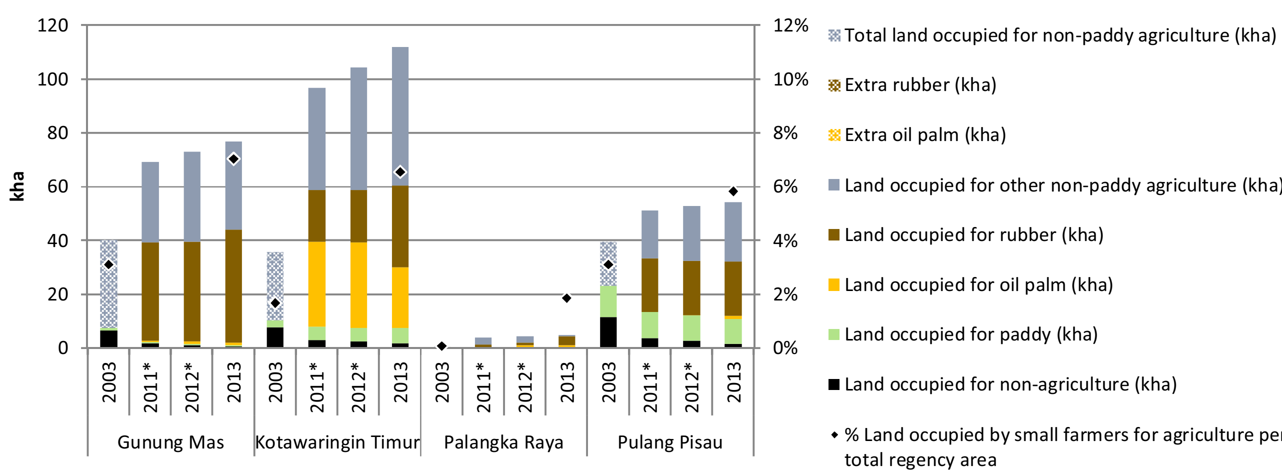

Fig. 4. Land occupancy by small farmers in 2003 and 2013. *Areas of land occupied are interpolated for 2011 and 2012 based on data of 2003 and 2013.

migrants, and the population growth has been slow and steady (Fig. 5) (see also the map of transmigration sites in Potter, 2012).

Overall, although Gunung Mas has a lot of potential in terms of physical land area, the socio-economic factors and continuing isolation (in terms of logistics) are likely to be the major constraints on future agricultural development in the regency. This requires further investigation beyond physical land area estimation.

5.2. Case study on Kotawaringin Timur

5.2.1. Land-use characteristics and dynamics

After decades of intensive logging throughout the 1980's and 1990's, Kotawaringin Timur has been undergoing rapid expansion of industrial oil palm plantations in the 2000's. By 2011, about one third of the regency was covered by oil palm (Fig. 2). Another one fifth of the regency remained low carbon (400 kha), but only less than half of that is suitable for oil palm.

Fig. 3 shows that the LUC has been rapid in 2006–2011 – about 24% of the regency has experienced changes in land cover. This is mainly caused by the cultivation of 255 and 45 kha of oil palm on low carbon land and wetland, respectively.[10] About 40% of the total new oil palm was planted outside oil palm concessions (133 kha in total, with 110 kha on low carbon land). Small farmers may partly contribute to the oil palm expansion outside concessions, i.e. under plasma schemes, which theoretically should account for 20% of the total plantation area. But as shown in Fig. 4, only 31 kha of oil palm area in 2013 was occupied by smallholders, either plasma (mainly transmigrants) or independents. This suggests that small farmers

[10] A strange situation is that 32 kha of plantation in 2006 is reclassified into unplanted wetland in 2011. One possibility is that some oil palm might be abandoned due to unfavourable agro-ecological condition like fire, but it could also be due to technical errors in the analysis of satellite images.

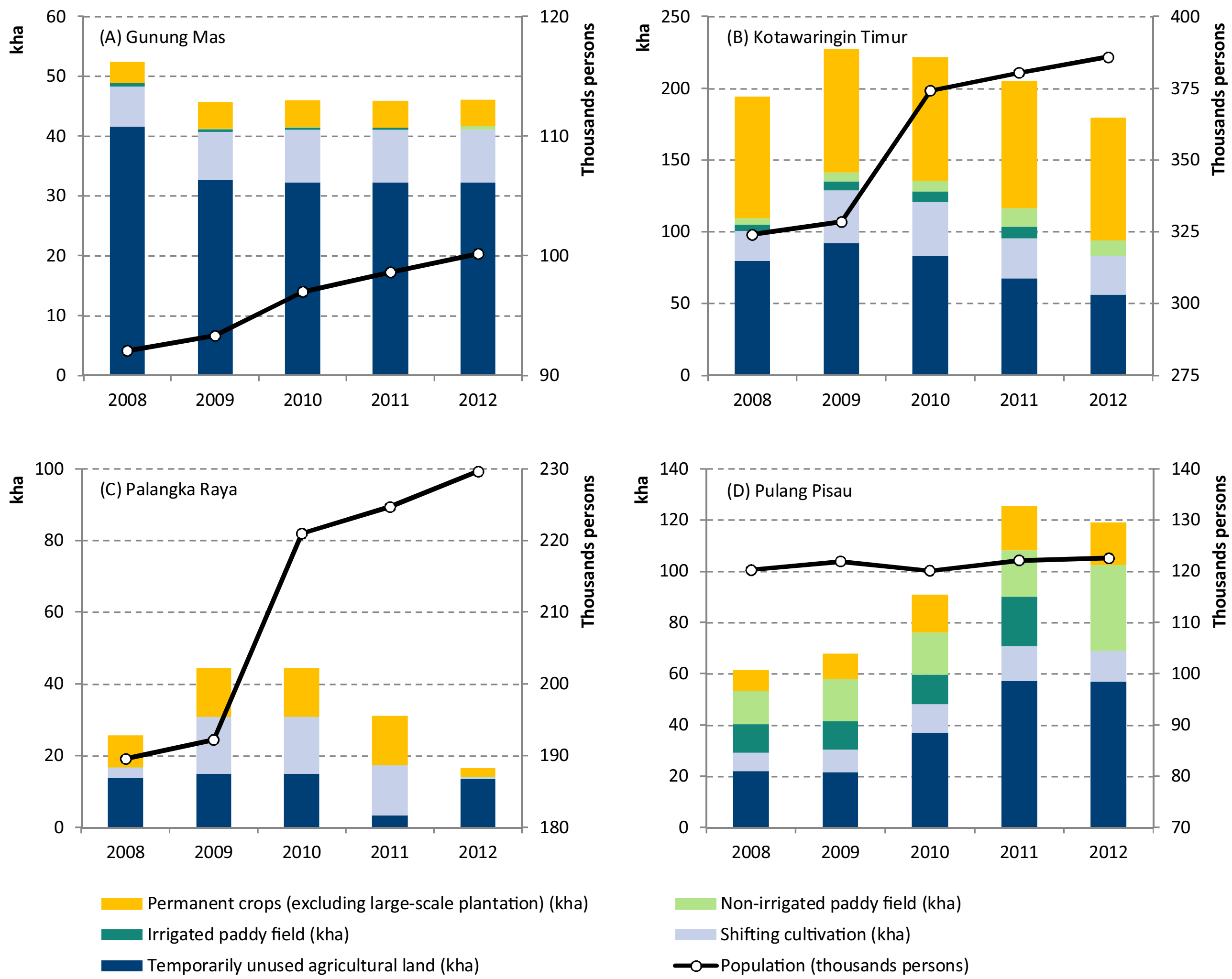

Fig. 5. Land classes by land-use intensity and population changes in the four regencies in 2008–2012.

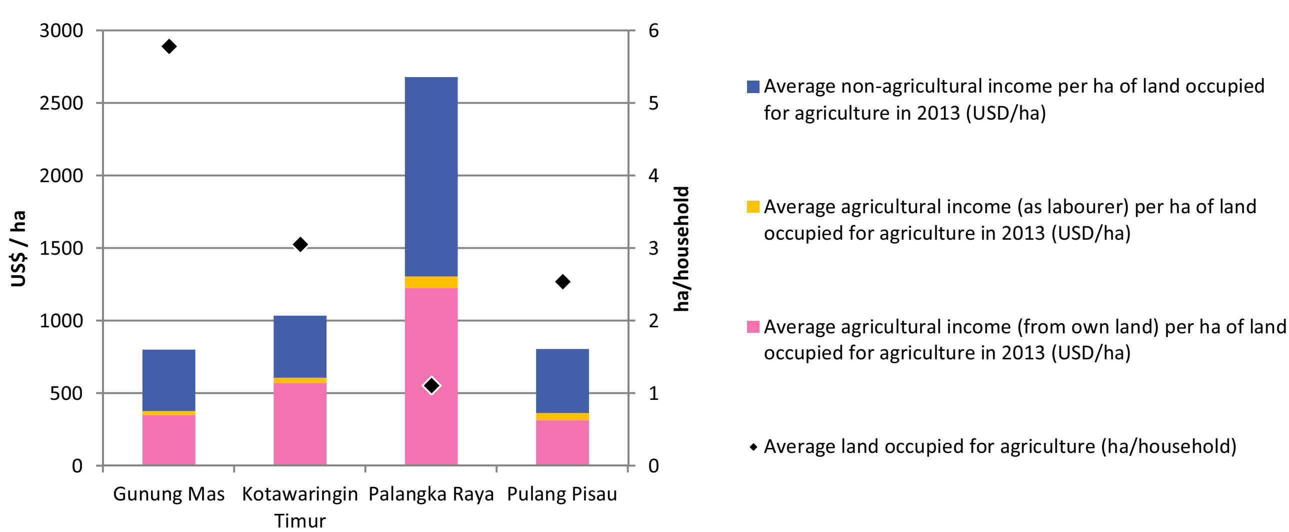

Fig. 6. Household income by activities in 2013.

were involved in oil palm expansion but in a much lower magnitude than industrial establishment. This also means that industrial plantations have largely expanded beyond the concessions. Also, the low share of land given to smallholders has made Kotawaringin Timur having the greatest number of disputes between companies and locals in any regency.[11]

Ironically, about 200 kha of oil palm concessions in Kotawaringin Timur still remain as uncultivated low carbon land until 2011 (Fig. 6). This consists of 50% of the total low carbon land in the regency. There are many cases where areas are abandoned after timber extraction although the land-use right was originally given for oil palm development (also reported by Sandker and Suwarno Campbell, 2007). Many of these could be part of the land banks of the large corporations.

Another notable change in the regency shown in Fig. 5 is the loss of 12 kha of irrigated paddy field in 2012. From the narrative interviews with villagers in the paddy-oriented villages in Teluk Sampit and Pulau Hanaut, poor water management has been indicated as a major problem for paddy cultivation. Not only productivity has become low due to absence of irrigation, but drought and flooding have also frequently destroyed their harvest.

5.3. Possible land-use strategies

As only less than half of the 400 kha of low carbon land in the regency is considered suitable for oil palm, a diversified strategy may be more suitable for this oil palm-oriented regency in the future. While oil palm plantation is the major agricultural activity, other crops such as paddy, rubber and coconut are widely grown. Also, the land-use intensity is comparatively high (i.e. the share of temporarily unused agricultural land is lower). Thus, an applicable strategy is to support small farmers to intensify and expand on the large area of low carbon land, depending on its suitability for different crops, e.g. paddy and rubber which are already widely grown, or to convert the low carbon land into agro-forestry. Meanwhile, further expansion of industrial plantation beyond the oil palm concessions should be prevented to reduce risk of future deforestation, but the vast area of low carbon land located in the concessions (200 kha) should be better utilised.

5.4. Case study on Palangka Raya

5.4.1. Land-use characteristics and dynamics

As the capital of the province, Palangka Raya actually spans a much larger area of land (240 kha) compared to other municipalities in Kalimantan. It is mainly covered by swamp forest (60%), and also a significant area of non-forested wetland (22%) and low carbon land (15%) (Fig. 2). The low carbon land is largely not suitable for oil palm, probably because most of the low carbon land is surrounded by wetland and swamp forest. However, the regency has 25% of its land granted for oil palm concessions.

Overall, about 7% of the municipality has undergone land cover changes in 2006–2009, which involved 9 kha of deforestation outside oil palm concessions (Fig. 3). About 5 kha of oil palm was cultivated within concessions, of which more than half were cultivated on low carbon land, but the rest involved conversion of dry-field forest.

The area of land occupied by small farmers is relatively low compared to the other three regencies – only 2% per total regency area (Fig. 4). The reasons could be land abandonment due to severe agro-ecological conditions (e.g. uncontrolled fire in Rakumpit and flood in Bereng Bengkel), coupled with massive speculative land trading (Rakumpit and Bukit Batu) where most of the land has been sold to outsiders and remained unproductive.

5.4.2. Possible land-use strategies

Since large-scale expansion is risky (only 2% of land remained suitable for oil palm), further agricultural intensification by small farmers could be a feasible strategy in Palangka Raya as they were able to generate relatively high income from agricultural activities compared to the other regencies (Fig. 6). This may be credited to their exposure to more information and infrastructure due to urbanisation. However, despite the presence of about 36 kha of low carbon land, most of this might be owned by (extra-local) speculators who do not intend to perform agricultural activities, as small farmers only occupy 1.1 ha per household. This will be a barrier for future mobilisation of ULC land.

5.5. Case study on Pulang Pisau

5.5.1. Land-use characteristics and dynamics

Pulang Pisau, one of the main sites where the MRP took place during the Suharto era, is rich in swamp forest and wetland (80%) and has rather limited dry-field that is suitable for large scale agricultural activities (9%) as illustrated in Fig. 2. Similar to Palangka Raya, about 19% of the regency is granted for oil palm concession despite the fact that only 4% is considered suitable for oil palm.

In the period 2006–2011, the deforestation rate was still high (Fig. 3). The area of swamp forest declined 82 kha, where 24 kha of this deforestation occurred inside oil palm concessions. However, no oil palm has been planted in 2006–2011, and the total oil palm cultivation in the regency was quite low (around 7 kha in estates and 1 kha under smallholdings) (Fig. 4). The oil palm concessions are unlikely to be cultivated in the near future due to unfavourable agro-ecological conditions – oil palm did not thrive and turned yellow when attempted to be grown on the ex-MRP peatland.

The total land occupied by small farmers did not increase much since 2003 compared to Gunung Mas, despite both regencies share a similar land size. Paddy and rubber are the two major crops cultivated. The farmers are troubled with difficulties in farming due to lower soil quality and frequent peat fire. Pulang Pisau in general performs worse than the other three regencies in terms of agricultural income. The average income generated from own farms is only 316 USD/ha (Fig. 6).

5.5.2. Possible land-use strategies

For this regency, the debates lie within the utilisation of degraded peatland – these areas are under-utilised, but not low carbon. While these areas are certainly not of low carbon, it is considered 'under-utilised' by both farmers and policymakers to be considered for further intensification. In fact, many farmers (especially transmigrants) in the regency rely on degraded peatland which is the only property they have for their living (they were relocated and given these peatland during the MRP). The problem is quite different from the other three regencies.

6. Conclusions and recommendations

This study has attempted to quantitatively explore the ULC land resources in Kalimantan at regency level by utilising the available information from multiple perspectives. Firstly, the review unravelled that the indication of ULC land resources based on six monitoring domains, i.e. land cover, land suitability, land occupancy, land-use intensity, legal classification and concessions, and land degradation, carry different meanings and have their own limitations. These aspects have been well-studied, but the findings were hardly used complementarily when assessing ULC land resources. While the scope of ULC land has a strong focus on carbon

[11] Presentation by Pak Arie Romp as head of WALHI Kalteng in March 2015 'Penglolalan Gambut dan Konflik Agraria di Kalimantan Tengah'.

stocks, other environmental factors, such as biodiversity and water, are also crucial to ensure sustainable land use (as is shown in HVC assessments for individual oil palm plantations[12]). These aspects, however, have not been covered in this study because there is to our knowledge no quantitative data available for these aspects for all the regencies in Kalimantan.

To improve the assessment of ULC land resources, a range of quantitative physical land indicators was derived by analysing the available information from the six domains. The results show that the values vary substantially for individual regencies. For example, regency Pulang Pisau has a substantial area of 'temporarily unused agricultural land' but a very limited area of 'low carbon land' – this implies that not all temporarily unused agricultural land is ready for future exploitation. Using a single indicator to quantify ULC land is risky as it is likely to be either an over-estimation (potentially inducing more unsustainable large-scale expansions) or under-estimation (potentially leaving a large area of land unused for decades).

In order to reduce such risks, all indicators from different monitoring domains were compared together. This was demonstrated for the four selected case studies. By comparing information from different sources, ULC land potential was assessed for possible land-use strategies (e.g. intensification of small farmers or large-scale expansion), resulted in preliminary estimates of ULC land that may be available for mobilisation. This study shows that by combining available data from different aspects, the assessment of ULC land resource can be significantly improved from over- or under-estimation. This is, however, depending on data availability and reliability for a particular region. The case of Kalimantan shown in this study has revealed that there are significant uncertainties due to lack of reliable data, which has to be carefully cross-checked with ground evidence and literature.

In addition to the issues of data availability and reliability, there are still questions left unanswered by physical land area indicators. For example, labour availability was mentioned in the interviews with local communities to be a major barrier for the case of Gunung Mas that affects the 'real' potential of ULC land (i.e. land will remain under-utilised due to lack of labourers to carry out the intensification, thus it is not 'readily available'), but the physical land area indicators used in this study cannot tell much about this. Meanwhile, the addition of other information into the case study analysis, i.e. population, household income and other qualitative information, was found to be crucial in examining the suitability of different land-use strategies. This shows that a more in-depth analysis of ULC land potential must be performed in the context of socio-economic progress in individual regencies.

Therefore, it is important to further investigate ULC land resources beyond physical land indicators. Especially the socio-economic factors underlying land under-utilisation at regency level are crucial to be analysed in more details in order to understand and address the key factors in mobilising ULC land, e.g. labour scarcity, soil quality or potential land-use conflicts. Particularly important is the analysis of these factors through the lenses of different actors, i.e. indigenous communities, (trans)migrants, industry, government officials and civil society. These deserve greater scrutiny in the exploration of ULC land resources, not only in quantitative manner, but also using a narrative approach for collecting opinions from the different actors in order to understand the opportunities and barriers which cannot be directly 'measured' in numbers.

[12] See https://www.hcvnetwork.org.

Acknowledgements

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Appendix A. Study area

Study area

See for the study area and for the list of villages visited.

Indicators for ULC land at provincial level

Table A2 shows the key indicators at aggregated island and provincial level from all monitoring domains. Of the four provinces, South Kalimantan is the smallest province, but more than half of its land is of low carbon, and largely considered suitable for oil palm by WRI (2012). Nevertheless, about 13% of the province is occupied by small farmers, which is the highest among the four provinces. Meanwhile, East Kalimantan has the lowest percentages of low carbon land and land suitable for oil palm. About half of West Kalimantan is considered non-forested and under critical status, while East Kalimantan has only about 10% of such land but more than half of its forests are considered degraded.

13. Indicators for ULC land at regency level

Fig. A2 shows the land cover indicators by regencies. For about half of the regencies, >30% of their total land is low carbon land. Several smaller regencies and municipalities also appear to have large percentages of low carbon land, e.g. Hulu Sungai Selatan (S06), the heartland of the Banjarese people with little forest and extensive wet rice fields, but the actual areas are small. In contrast, most of the large regencies have smaller ratios of low carbon land. For example, the largest regency, Malinau (E06), has only 4% of low carbon land, because it is mainly still forested with a low indigenous Dayak population. A few regencies, however, do not follow this general trend. This is especially prominent for regencies in West Kalimantan, e.g. the top three regencies with the highest percentages of low carbon land are located in that province.

In Fig. A3, land suitability for oil palm in each regency is shown. The top five regencies with the largest area of such land, which are large regencies located in East and West Kalimantan, accounted for >5 Mha alone. Compared to the other regencies, they have a larger potential for future development. In contrast, the regencies where oil palm is currently rapidly expanding, e.g. Kotawaringin Timur (C02), have far less suitable land left – this signals that any further large-scale expansion will likely come at the expense of land with high carbon stocks. In terms of percentage of land that is suitable for oil palm, the values vary from very low (2%) to very high (83%), illustrating that local situations may very strongly deviate from the provincial averages.

Fig. A4 depicts the total and average area claimed by small farmers by crops. The pattern greatly varies from regency to regency. In terms of land occupied per household, farmers from Gunung Mas (C11) have occupied relatively much larger areas. Meanwhile in the crowded and old major cities like Pontianak (F13) and Banjarmasin (S12), the area of land per household is relatively much smaller. Combining information from BPS (2013b) and DG Estate Crops (2014a, 2014b), we found that in large regencies in West Kalimantan like Sintang (F07), Sanggau (F05), Ketapang (F06) and

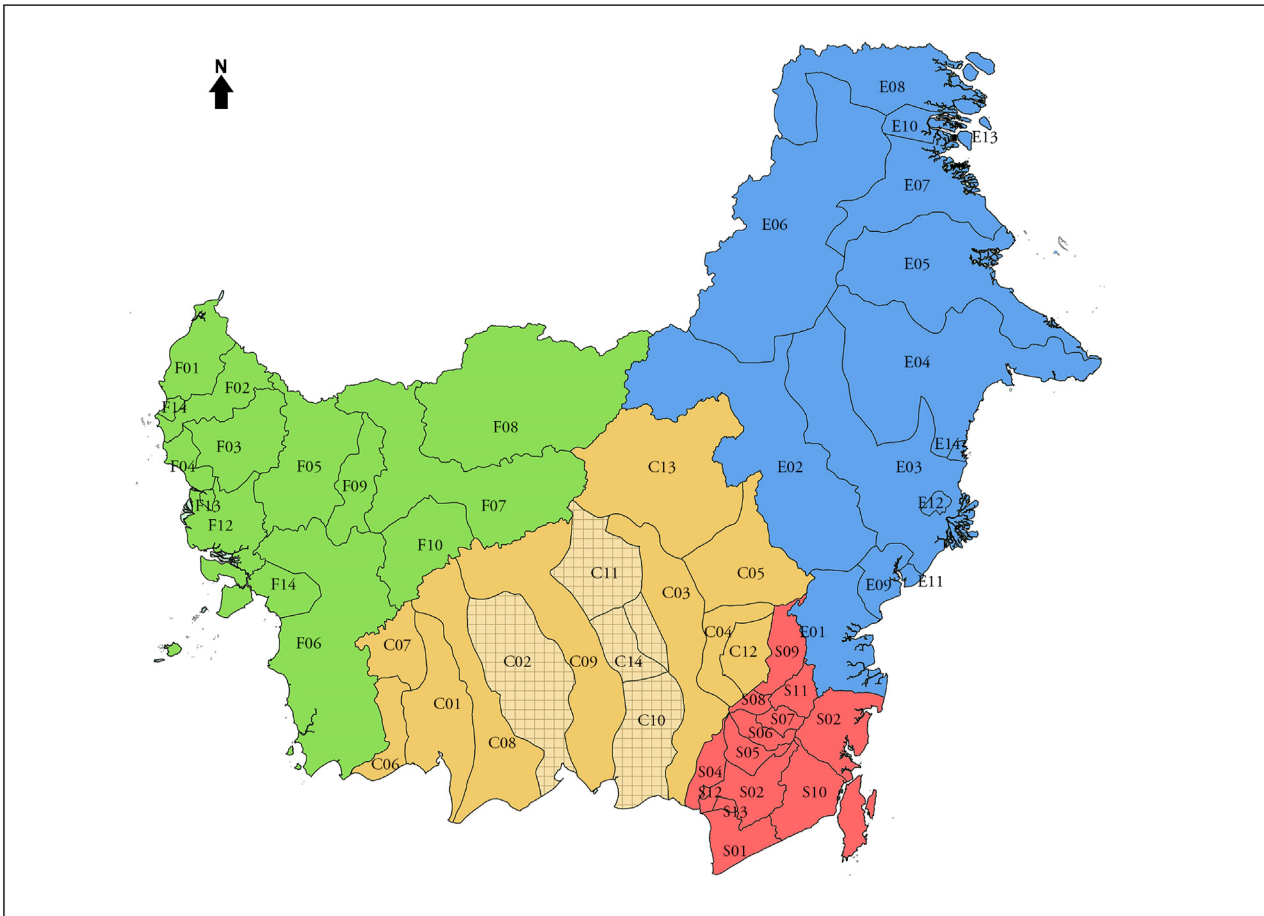
Table A1
List of villages visited.

	Village/*Desa* or *Kelurahan*	Sub-regency/*Kecamatan*	Regency/*Kabupaten*	Date of visit	No. of interviewees
1	Bereng Bengkel	Sebangau	Palangka Raya	30–11-2014	3
2	Sei Gohong	Bukit Batu	Palangka Raya	8–12-2014	2
3	Petuk Bukit	Rakumpit	Palangka Raya	8–12-2014	2
4	Pager	Rakumpit	Palangka Raya	8–12-2014	3
5	Tuwung	Kahayan Tengah	Pulang Pisau	30–11-2014	2
6	Bukit Liti	Kahayan Tengah	Pulang Pisau	3–12-2014	2
7	Ramang	Banamatingang	Pulang Pisau	5–12-2014	2
8	Tewah	Tewah	Gunung Mas	4–12-2014	3
9	Kasintu	Tewah	Gunung Mas	4–12-2014	3
10	Sandung Tambun	Tewah	Gunung Mas	4–12-2014	4
11	Kuala Kurun	Kurun	Gunung Mas	4–12-2014	2
12	Tarakas	Manuhing	Gunung Mas	8–12-2014	2
13	Bapinang Hilir	Pulau Hanaut	Kotawaringin Timur	15–12-2014	10
14	Babirah	Pulau Hanaut	Kotawaringin Timur	15–12-2014	2
15	Babaung	Pulau Hanaut	Kotawaringin Timur	15–12-2014	2
16	Bapinang Hulu	Pulau Hanaut	Kotawaringin Timur	15–12-2014	2
17	–	Cempaga Hulu	Kotawaringin Timur	16–12-2014	2
18	Karang Sari	Parenggean	Kotawaringin Timur	16–12-2014	2
19	Sumber Makmur	Parenggean	Kotawaringin Timur	16–12-2014	4
20	Sampit	Sampit	Kotawaringin Timur	17–12-2014	2
21	Pasir Putih	Sampit	Kotawaringin Timur	17–12-2014	4
22	Lampuyang	Teluk Sampit	Kotawaringin Timur	18–12-2014	6
23	Kampung Bugis	Teluk Sampit	Kotawaringin Timur	18–12-2014	2

Table A2
Comparison of key indicators at provincial level (million ha).

Monitoring domains	Indicators[a]	Provinces				Total
		Central	East	West	South	
General land cover	Total area (MoF, 2015)	15.4	19.5	14.7	3.8	53.3
	Forested land (MoF, 2015)	8.0	13.5	6.4	0.9	28.8
	Non-forested land (MoF, 2015)	7.4	6.0	8.3	2.9	24.6
Land	Low carbon land in 2011 (MoF, 2015)	3.1	3.9	6.2	2.0	15.2
cover	Low carbon land in 2010 (Gunarso et al., 2013)	–	–	–	–	15.5
Land suitability	Land suitable for oil palm excluding existing plantation (WRI, 2012)	2.2	3.6	4.4	1.5	11.8
	Land suitable for oil palm including existing plantation (WRI, 2012)	3.4	4.3	5.3	1.8	14.7
	Land excluding EU-RED zone[b] (Hadian et al., 2014)	3.2	4.1	4.8	1.9	14.0
	Dry-field suitable for crops and livestock (BBSDLP, 2014)	4.2	6.1	4.0	0.0	14.3
Land occupancy	Total land occupied by small farmers for agriculture (BPS, 2013b)	0.8	0.5	1.6	0.5	3.4
	Total area of oil palm and rubber smallholdings in 2013 (DG Estate Crops 2014a, 2014b)	0.4	0.3	0.6	0.2	1.5
Land-use intensity	Temporarily unused agricultural land (BPS, 2013a)	1.4	1.2	1.2	0.2	3.9
Land legal classification	Low carbon land within the 'forest zone', oil palm and timber concessions (WRI, 2012; MoF, 2015)	3.0	3.8	5.3	1.0	13.0
	Low carbon land within oil palm concessions	1.0	1.0	1.9	0.1	3.9
	Dry-field suitable for crops and livestock within the 'forest zone' (BBSDLP, 2014)	3.4	3.1	1.2	0.0	7.7
Land degradation	Critical non-forested land (MoF, 2015)	4.9	2.1	7.2	1.5	15.6
	Critical forested land (MoF, 2015)	1.5	7.6	2.9	0.6	12.6

[a] Some indicators were further processed in this study and not directly reported by the source shown in the brackets, see Table 2 for details. These numbers are presented on a detailed regency level in Figs. 2–7.
[b] EU-RED zone is defined as the land area that has fulfilled the requirements of sustainability criteria set by EU-RED (European Union Renewable Energy Directive) for biofuel production.



Central Kalimantan		East Kalimantan		West Kalimantan		South Kalimantan	
C01	Kotawaringin Barat	E01	Pasir	F01	Sambas	S01	Tanah Laut
C02	Kotawaringin Timur	E02	Kutai Barat	F02	Bengkayang	S02	Kota Baru
C03	Kapuas	E03	Kutai Kartanegara	F03	Landak	S03	Banjar
C04	Barito Selatan	E04	Kutai Timur	F04	Mempawah	S04	Barito Kuala
C05	Barito Utara	E05	Berau	F05	Sanggau	S05	Tapin
C06	Sukamara	E06	Malinau	F06	Ketapang	S06	Hulu Sungai Selatan
C07	Lamandau	E07	Bulungan	F07	Sintang	S07	Hulu Sungai Tengah
C08	Seruyan	E08	Nunukan	F08	Kapuas Hulu	S08	Hulu Sungai Utara
C09	Katingan	E09	P. Paser Utara	F09	Sekadau	S09	Tabalong
C10	Pulang Pisau	E10	Tana Tidung	F10	Melawi	S10	Tanah Bumbu
C11	Gunung Mas	E11	Balikpapan	F11	Kayong Utara	S11	Balangan
C12	Barito Timur	E12	Samarinda	F12	Kubu Raya	S12	Banjarmasin
C13	Murung Raya	E13	Tarakan	F13	Pontianak	S13	Banjar Baru
C14	Palangka Raya	E14	Bontang	F14	Singkawang		

Fig. A1. Map of the regencies and municipalities in Kalimantan in 2012. *Shaded regencies are regencies selected for case studies (see also Section 4).

Landak (F03), substantial areas of land were occupied not for paddy, oil palm or rubber, but other form of agriculture. However, in several cases, the reported area of oil palm smallholding is much larger than the area claimed by small farmers (see 'extra oil palm' in the figure). One explanation is that these extra areas are not directly managed by the small farmers but probably controlled by larger private enterprises through plasma scheme.

The indicators that reflect intensity are shown in Fig. A5. A prominent trend is that regencies with a relatively small share of 'temporarily unused agricultural land' often have sizable areas of 'non-irrigated paddy fields' and vice versa. In several regencies, substantial areas of agricultural land are also used for 'shifting agriculture'. These three land classes are difficult to be clearly distinguished because criteria used in BPS (2013a) are not clearly defined. They may share similar land cover types, i.e. fallows of various lengths.[13]

In terms of legal classification and concessions, the distribution of low carbon land within concessions and the 'forest zone' is shown

[13] In Seruyan and Katingan (Central Kalimantan), there is still considerable shifting cultivation in the middle and upper reaches of the rivers beyond the oil palm zone. Kutai Barat in East Kalimantan also has considerable areas of swidden. Also for the case in Kapuas Hulu and Sanggau, there is considerable development of '*padi paya*', i.e. wet swiddens in Dayak agriculture, with shorter fallows but less water control than the normal wet rice technology, either irrigated or rain fed (to the personal knowledge of the co-author, Lesley Potter).

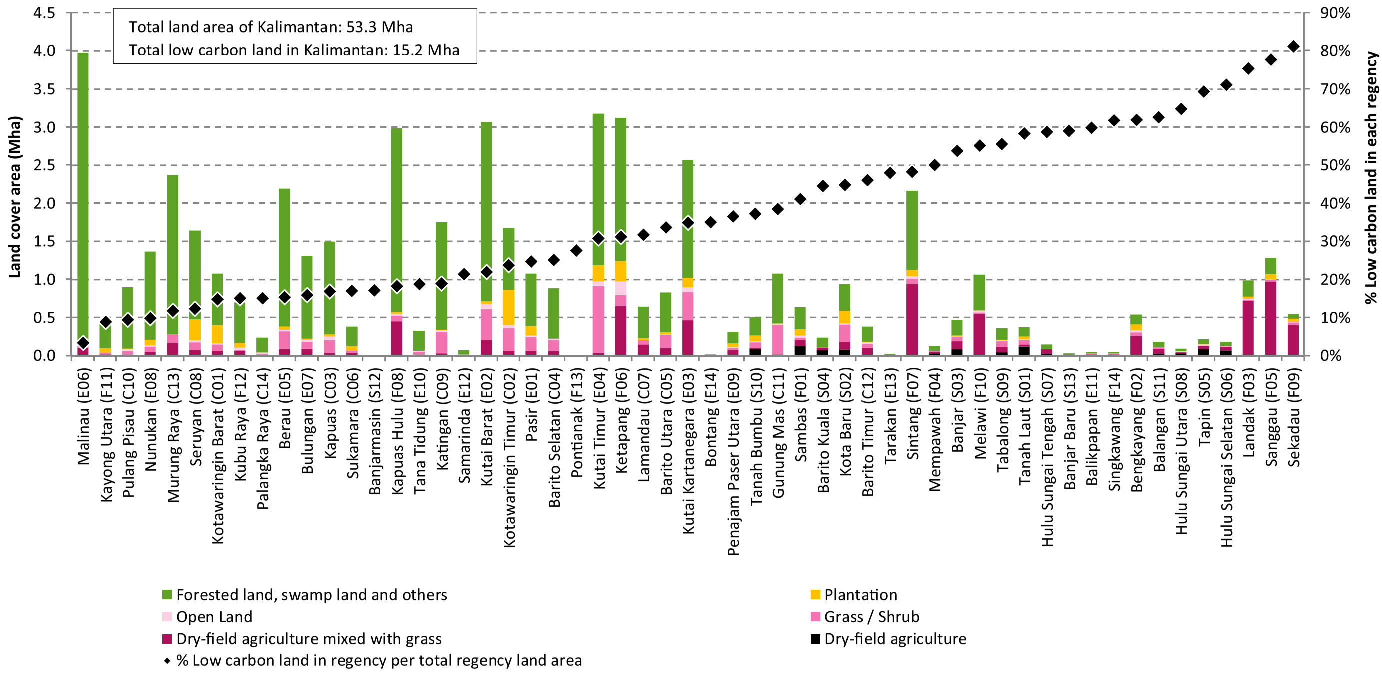


Fig. A2. Land cover: Distribution of low carbon land and land cover types by regencies in Kalimantan in 2011.
Suitability criteria are: low carbon land with elevation <1000 m, soil depth >75 cm, soil acidity <pH 7.3, slope <30%, water resource buffers >100 m, and conservation buffer >1000 m.

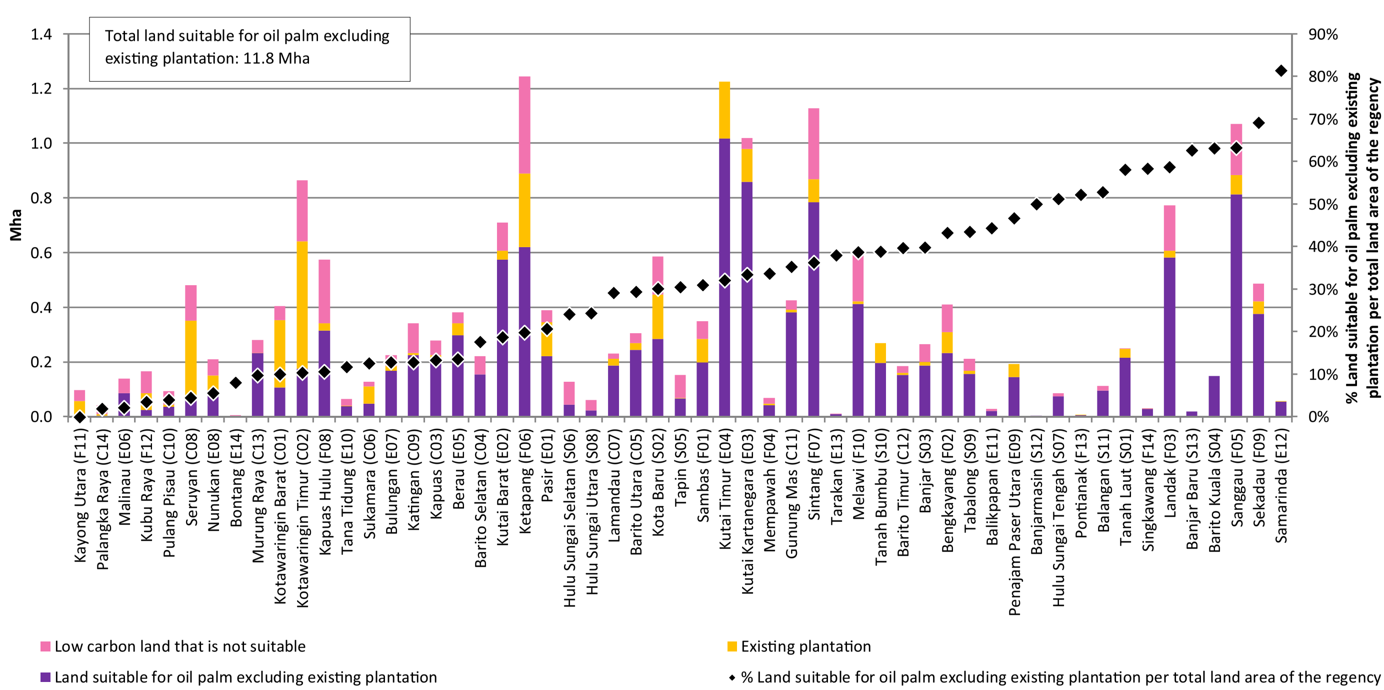


Fig. A3. Land suitability: Land suitable for oil palm in Kalimantan as identified by WRI (2012).
*There are discrepancies between the smallholding area reported by DG Estate Crops (2014a, 2014b) and area occupied by small farmers reported by BPS (2014). Extra rubber and extra oil palm areas are the differences between the two sources.

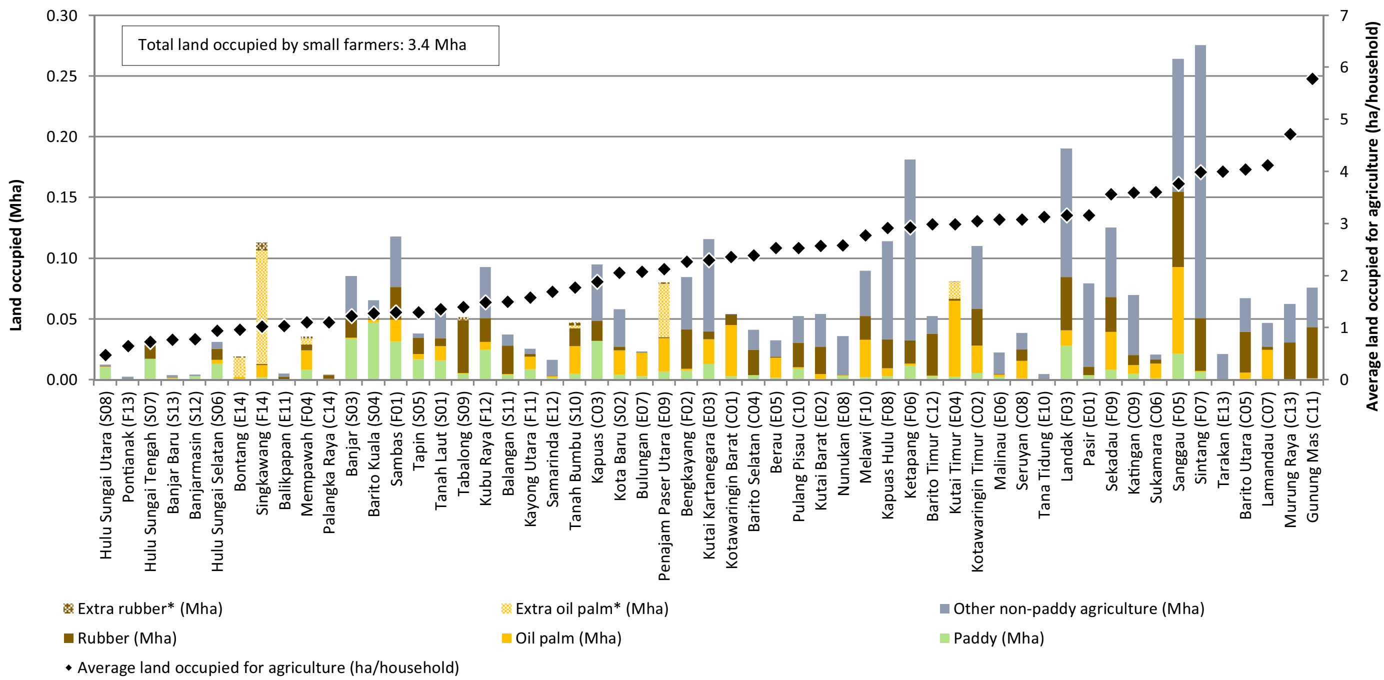


Fig. A4. Land occupancy: Land occupied by small farmers for agriculture by regencies in Kalimantan in 2013.

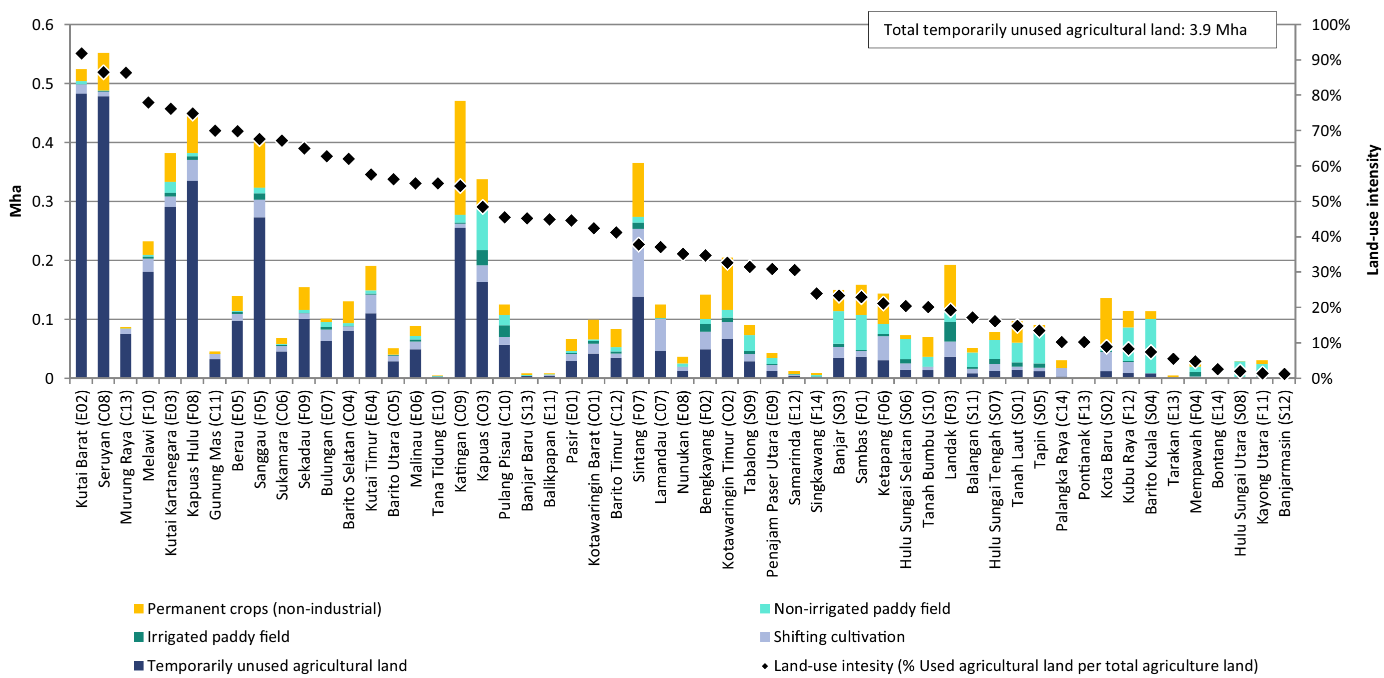


Fig. A5. Land-use intensity: Agricultural land-use status by regencies in Kalimantan in 2011.
Note that some overlaps between concessions and 'forest zone' exist. All overlaps with oil palm concessions was included in oil palm concessions; all overlaps between timber concessions and 'forest zone' was included in timber concessions.

in Fig. A6. In two-thirds of the regencies, more than 80% of low carbon land has the status of either 'forest zone', timber concession and/or oil palm concession. Some regencies even have >50% of low carbon land located within oil palm concessions. These areas are probably the undeveloped land banks of the companies in major oil palm regencies, e.g. Landak (F03), Ketapang (F06) and Sanggau (F05) in West Kalimantan, as well as Kutai Timur (E04) in East Kalimantan, the biggest oil palm producing regency in that province. It was reported in 2005 that 1.5 Mha of planted oil palm land had been abandoned in West Kalimantan. In East Kalimantan, millions hectares of land were originally given for oil palm under the 'oil palm safety belt' policy, but many were not planted after the timber was taken (Potter, 2011).

Fig. A7 depicts the indicators for land degradation for the regencies. Overall, the share of critical land ranges widely across the regencies, but two marked trends are that seven out of ten regencies with the highest share of non-forested land categorised as 'critical' are situated in West Kalimantan, while the regencies for which forested land is in a 'critical' state are those in East Kalimantan, e.g. Kutai Timur (E04) and Kutai Barat (E02).

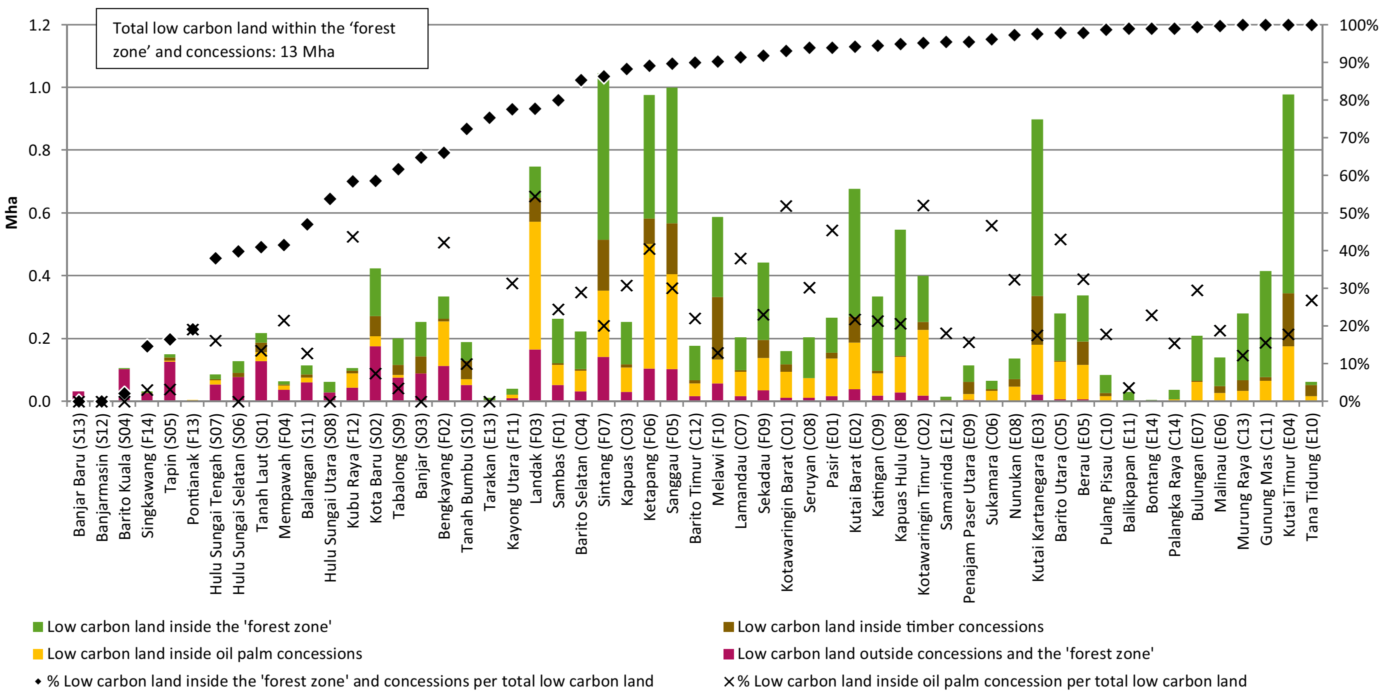


Fig. A6. Legal classification and concessions (overlapping with land cover): Low carbon land falling within concessions and the 'forest zone' in Kalimantan in 2011.

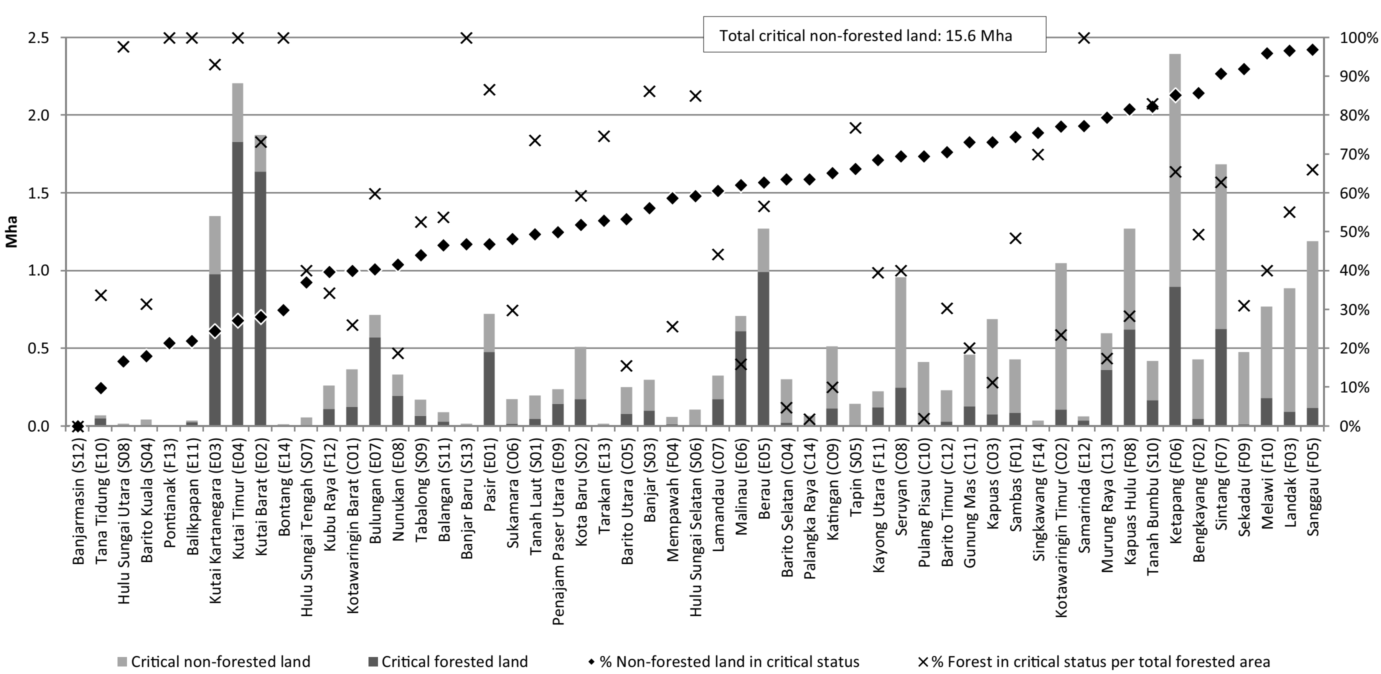


Fig. A7. Land degradation: Critical land in Kalimantan in 2011.

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