Co-benefits for biodiversity and carbon in land planning decisions within oil palm landscapes

A science-for-policy paper for the Oil palm Research-Policy Partnership Network

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Cover photo: J. Lucey

Key messages

1. There is **high agreement** in the **responses of biodiversity** (number of species) and **Above Ground Carbon (AGC)** to different land-uses in **Malaysia and Indonesia**; meaning land use decisions to benefit one are highly likely to also have benefits for the other.

2. However, the **size of the benefit** for biodiversity and AGC **may differ**.

3. **Primary rainforest** is the land cover type with the **highest levels** of biodiversity and of AGC per hectare and protecting and conserving these forest will have the greatest co-benefits.

4. **Logging** can **reduce AGC levels** in forest by almost **half** compared with primary forest and are reduced most when logged intensively, whereas **overall biodiversity changes little,** although primary forest specialists may be lost.

5. Large tracts of **logged forest** have the potential to **recover** carbon stocks if left to regenerate, therefore **conserving logged forest also has large co-benefits.**

6. **Larger forest fragments** (a few hundred ha or more) can support around **70 % of continuous forest biodiversity levels**, and probably contain a substantial percentage of primary forest AGC levels.

7. **Oil palm plantations** contain around **20% of primary forest AGC** and **less than half** of primary forest **biodiversity levels**. Many of the species which occur in oil palm are open habitat or generalist species, and not forest species.

8. **Rubber and *Acacia*** contain slightly more carbon and biodiversity than oil palm but less than logged forest.

9. **Open habitats and grasslands** support around **5% of primary forest AGC,** and probably support **very little biodiversity.**

10. **More research is necessary** to develop methods for maintaining and enhancing carbon and biodiversity in oil palm landscapes.

Scope of the report

The aim of this report is to synthesize current scientific information to help oil palm policy makers make land-use decisions which jointly meet biodiversity and carbon conservation agendas. This report compares **Above Ground Carbon (AGC)** and **Biodiversity** across a gradient of land-uses in Malaysia and Indonesia. Biodiversity and AGC are referred to together as "conservation values". To aid comparison across land-uses, primary forests on mineral soils were chosen as a reference point for potential maximum levels of both AGC and biodiversity, and levels for other land-uses are expressed as a percentage of levels found in primary forest on mineral soils.

Carbon: Carbon is stored in living vegetation, dead organic matter and in the soil. This report focuses on **Above Ground Carbon** because there is good data available for this metric and in general it is a good proxy for the total carbon stock of a land-use. The exception to this is for peat land, where vast amounts of carbon are stored in the soil.

Biodiversity: In this report, **"biodiversity"** refers to the **number of species per unit area** and this is the unit of comparison across land-uses. This is a useful metric for comparing broad trends across land-uses, but may mask important changes for particular types of species, especially species of conservation concern (e.g. forest specialists, endemics, endangered species) which could be disproportionately negatively affected. This report does not quantitatively compare changes in species of conservation concern across land uses, but does discuss these changes qualitatively.

It should be noted that **Carbon** and **Biodiversity are not the only conservation values provided by natural habitats:** other vital ecosystem services will be considered in other science-for-policy outputs.

Geographical scope: The report focuses specifically on **Malaysia and Indonesia**, since these two countries produce most of the world's palm oil and there is an extensive research base available from these countries. The report only draws on research from further afield where there is a lack of research from within the focus area: it is always highlighted where information is drawn from other areas. The **findings of this report may therefore *not* be directly applicable to other regions** such as Africa and Central/South America. Additional evidence should be obtained to inform policy decisions in these regions.

Note: **The levels of biodiversity recorded in primary forest are likely to be underestimated, due to difficulties in sampling canopy and soil biodiversity. This may lead to an over estimation of the proportion of primary forest biodiversity levels that occur in land uses where the canopy and soil have been reduced or modified.**

Rationale

The oil palm industry is currently striving to find ways to balance a growing industry with the necessity to conserve biodiversity and reduce the greenhouse gas (GHG) emissions that cause climate change. Within the Roundtable on Sustainable Palm Oil (RSPO) the High Conservation Value (HCV) approach has been adopted to address biodiversity losses, but a process for tackling loss of carbon from the landscape has not been fully developed within the standard. The sustainable palm oil community is attempting to deal with this issue by developing High Carbon Stock (HCS) standards, under which the clearance of land storing large amounts of carbon should be avoided. There may be ways of streamlining sustainability standards if areas that are important for biodiversity are also important for carbon.

Global studies that investigate the correlation between areas of high biodiversity and high carbon storage reveal that, on a worldwide scale, areas of higher carbon stocks tend to also have higher biodiversity (Strassburg et al. 2010). Tropical rainforests are identified as habitats which contain extremely high levels of both AGC and biodiversity and SE Asia is a centre for both high biodiversity and carbon storage (Strassburg et al. 2010). However, within this region, the overlap between areas of high AGC and biodiversity may vary among land uses. This report investigates whether the global correlation between carbon and biodiversity is also apparent at a finer scale across land-uses within a high carbon- high biodiversity region.

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Confidence levels

Confidence levels are assigned separately to biodiversity and carbon levels for each land-use. This level indicates the confidence in the scientific evidence, based on the amount of evidence (i.e. the number of published research studies), the variation in the evidence (i.e. how similar estimates are for a particular land-use), and the size of the difference in the conservation value compared with primary forest.

High confidence: the evidence is robust and provides a clear consensus: there is very little doubt about the proportion of primary forest biodiversity or carbon that a land-use supports.

Reasonable confidence: The evidence is generally in agreement as to the biodiversity or carbon value of a land-use, but there is a small amount of uncertainty, either because there is some variation among estimates, or because there are fewer data available.

Low confidence: The evidence is lacking and/or variation among estimates is very large and more research is needed.

Levels of Biodiversity and Above Ground Carbon in different land uses

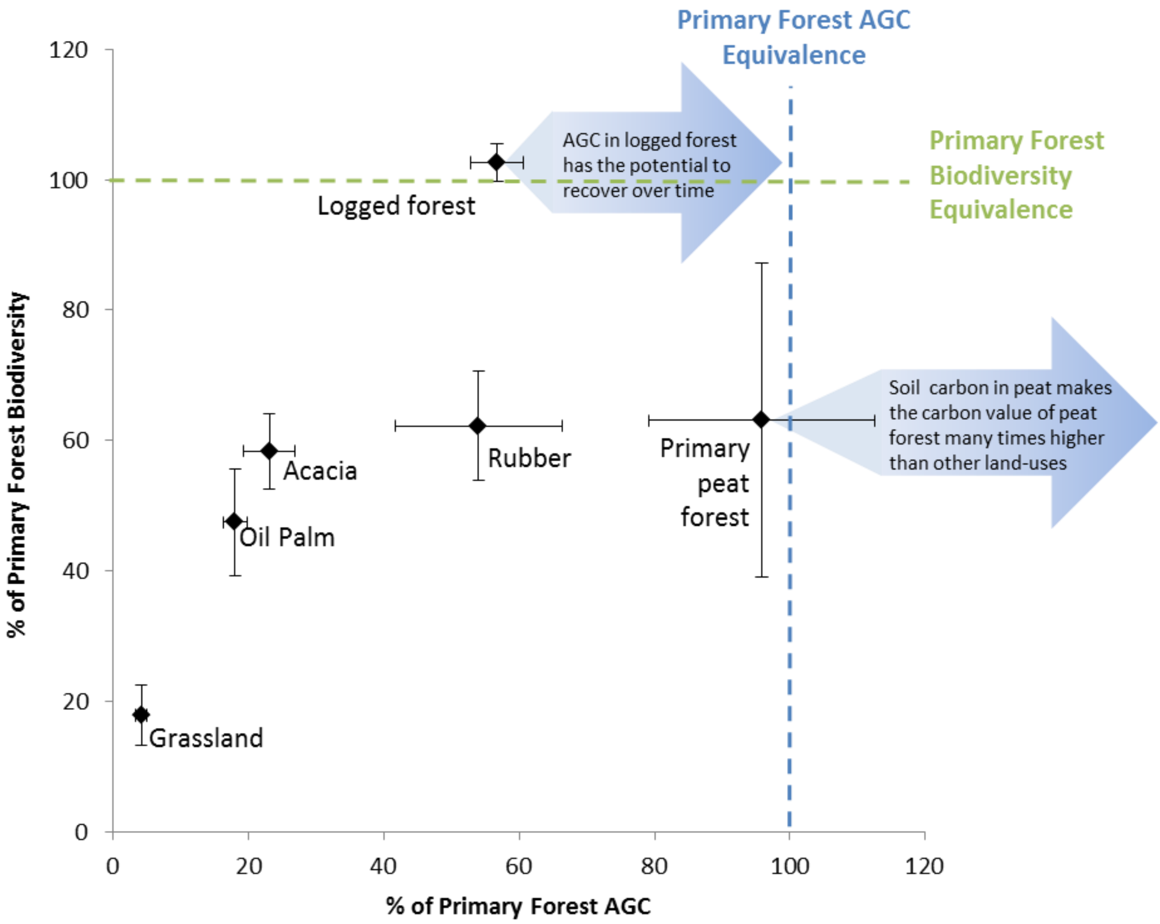

Figure 1. **Levels of Biodiversity (total number of species per unit area) and Above Ground Carbon (AGC, Mg C/ha) represented as a percentage of the levels found in primary forest on mineral soil in Malaysia and Indonesia for different land-uses.** Biodiversity levels of primary forest on mineral soils are set at 100% and indicated by the green dashed line for comparison. AGC levels for primary forest on mineral soils are also set at 100% and indicated by the blue dashed line for comparison. Biodiversity levels were collated from over 40 published studies covering 15 vertebrate, invertebrate and plant species groups. AGC data were collated from Ziegler et al. (2012) supplementary information for Malaysia and Indonesia. Error bars indicate the standard error around the mean. Note that information for fragmented forest is not included in the figure because there is no data for carbon in this land-use. For detailed methods see Appendix 1, for sample sizes for each land-use see Appendix 2.

Primary forest

Undisturbed forests are becoming increasingly rare in SE Asia, and most are within Protected Areas or remote, high elevation areas. Unfortunately, "Protected Area" status does not necessarily guarantee that these forests are not at risk (Curran et al. 2004; Laurance et al. 2012).

Biodiversity- Lowland rainforests contain the highest levels of terrestrial biodiversity globally and SE Asian rainforests are renowned for high numbers of species and high levels of endemism (species found nowhere else in the world). Upland forests and those with unusual soil types contain the highest levels of endemic species, although overall biodiversity may be slightly lower. Therefore, conserving the full range of forest types is essential to avoid species losses. **HIGH CONFIDENCE**

Carbon- Primary forests also contain the highest levels of AGC, stored primarily in large trees. Primary rainforest on mineral soil in Malaysia and Indonesia stores an average of 197 Mg AGC/ha but can store up to 400 Mg AGC/ha (derived from Ziegler et al. 2012; Lucey et al. 2014b). **HIGH CONFIDENCE**

Biodiversity and carbon in peat forest AGC in peat forest is slightly less than for forest in mineral soils (Ziegler et al. 2012), but peat forest is an especially important carbon store because of the very high levels stored in soil organic matter, which can range from a minimum of 300 Mg C/ha (based on the definition of peat soil as >50cm depth of partially decomposed organic matter, Lucey et al. 2014b) up to 1000s of Mg C/ha in deep peat (Lucey et al. 2014b). These stores are released to the atmosphere over time when disturbed, drained or converted to agriculture. **HIGH CONFIDENCE**

Biodiversity in these forests is poorly understood with very little research conducted in this habitat type (Posa et al. 2011). Tree diversity is known to be much lower in peat forest than in forest on mineral soils (Posa et al. 2011). Only one other study has compared biodiversity in peat forest and forest on mineral soil and this showed a small decline in bird diversity (Gaither 1994). Although overall levels of biodiversity are likely to be lower in peat forests, this habitat is probably important for rare and endemic peat soil specialists, which are uniquely adapted to the waterlogged soil conditions (Posa et al. 2011), but data are lacking. **LOW CONFIDENCE (lack of data)**

Preventing conversion and degradation of remaining primary forest will have co-benefits for carbon and biodiversity, and is especially important to avoid extinctions of specialist, endemic, rare and endangered species.

Large tracts of logged forest

In SE Asia commercial logging practices remove large, valuable timber trees, leaving small, low value or non-timber trees behind (Reynolds et al. 2011). Skid trails and logging camps cause additional damage to the forest (Reynolds et al .2011), and logging intensity can vary greatly, but the basic forest structure usually remains, and the forest is usually able to regenerate (Berry et al. 2010). Many of the remaining large tracts of lowland forest outside of protected areas have been selectively logged in SE Asia (Gaveau et al. 2014).

Biodiversity- Biodiversity losses from logging in continuous forest, even when logged repeatedly, can be relatively small. In once logged forest changes are often limited or undetectable, especially where logging is low intensity (e.g. Pinard & Putz 1996; Edwards et al. 2012). Overall, biodiversity levels appear to vary little between large tracts of logged forest and primary forest regardless of logging intensity, and can even increase a small amount due to mixing of forest and open habitat species. However, when only species which are also found in primary forest are compared, decreases of around 25-30% in heavily or repeatedly logged forests are evident (Edwards et al. 2011; 2014). **REASONABLE CONFIDENCE (Limited canopy data)**

Logged forest showing skid trail damage

Carbon- Across a variety of levels of logging intensity and time since disturbance, synthesis by Ziegler et al. (2012) indicates that logging in Malaysia and Indonesia reduces AGC to an average of 112 Mg C/ ha, or about 57% of primary forest levels, and this is similar in mineral and peat forests (Verwer & van der Meer 2010). Rates of carbon accumulation are often higher in disturbed forest due to high rates of plant and tree regeneration (Berry et al. 2010), meaning that logged forest can usually recover. It is estimated that logged forest AGC levels may recover to primary forest levels in around 120 years (Pinard & Cropper 2000), depending on the original level of logging intensity and continued disturbance, with more rapid Carbon accumulation occurring in the first few decades, and slowing as the forest matures. **REASONABLE CONFIDENCE (some variation depending on logging intensity)**

Protecting large tracts of logged forest will have co-benefits for biodiversity and carbon storage, especially if logged forests are allowed to recover. Sustainable management of natural production forests will ensure biodiversity and carbon are maintained while maintaining the economic value of the area.

Fragmented forest

Fragmented forests are often seen as vital sources of biodiversity and carbon storage in the oil palm landscape. However characteristics of fragmented forests mean they usually support fewer species and less AGC than the same area of continuous forest (Laurance et al. 2011). The hotter, drier and more exposed environments near the patch edge (referred to as "edge effects") cause the forest to degrade (Laurance et al. 2000a,b; Benitez-Malvido & Martinez-Ramos 2003; Ewers & Banks-Leite 2013) and eventually recede (Gascon et al. 2000). Most edge effects dissipate at around 100m into forest, but can reach over 500m (Laurance et al. 2011)

Biodiversity- Forest patches support fewer species than the same area of continuous forest and biodiversity will continue to decline over time (Ferraz et al. 2014; Gilroy et al. 2014). Fragments over a few hundred ha with higher forest quality can support 70% or more of continuous forest biodiversity levels (Lucey et al. 2014a; Tawatao et al. 2014; Benedick et al. 2008; Lucey et al. in prep), but small fragments (less than a few tens of ha) support only a small proportion of continuous forest biodiversity levels, and communities tend to be made up of many more open habitat, generalist or invasive species, with less representation of forest specialists, endemics, or species of conservation concern (Davies et al 2000; Terborgh et al. 2001; Edwards et al. 2010; Lucey et al. 2014a; Tawatao et al. 2014; Bernard et al. 2014; Lucey et al. in prep). **REASONABLE CONFIDENCE (due to research from restricted geographical range and co-effects of forest quality, size and shape)**

Biodiversity and carbon in riparian buffers- Riparian buffers are a particular kind of fragmented forest retained along rivers to protect water ways. Because of their long thin shape, often the whole buffer experiences degrading edge-effects, and often the vegetation remaining in riparian buffers has been heavily logged. However, they can provide some habitat and create connectivity for biodiversity between larger forest patches. Singh and Malhi et al. (2015) showed that riparian buffers in oil palm plantations contained about 30% of the AGC per ha found in the riparian zones of primary forest: more than the surrounding oil palm but much less than riparian zones in continuous logged forest. Gray et al. (2015) found that riparian buffers contained similar ant species richness and composition to riparian zones in nearby continuous logged forest. Dung beetle richness in riparian buffers was less than half of logged forest richness, but double that found in oil palm (Gray et al. 2014). Research from S America showed that bird and mammal diversity depended greatly on the width (hundreds of m needed rather than tens of m) and quality of riparian buffers, with connectivity with and proximity to large forest patches also being important (Lees and Peres 2008).

Carbon- Fragmentation causes declines in AGC, and like biodiversity, AGC unit area also decreases with decreasing fragment size (Laurance et al. 1997; Gilroy et al. 2014; Magnago et al. 2014; 2015). AGC also decreases substantially with proximity to the fragment edge due to adverse

environmental conditions (edge-effects) which cause increased tree mortality (Laurance et al. 1997; Magnago et al. 2014). So far there is no quantitative information on carbon stocks for forest fragments in SE Asia which can be compared with primary forest levels, however research from S. America shows a dramatic increase in carbon at around 105ha and strong correlations between carbon stocks and biodiversity (Magnago et al. 2014), indicating that retaining large forest fragments has co-benefits for both conservation values. More research is needed to determine whether fragments of this size would have the same carbon values in SE Asia. **LOW CONFIDENCE (Lack of data for SE Asia)**

Fragments over a few hundred ha in size will have substantial co-benefits for biodiversity and carbon. Very small fragments (less than a few 10s of hectares) may have very little benefit for either value, although there could be a role for small patches in dispersal of some species.

Newly prepared terraced oil palm plantations with intervening forest fragments

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Oil palm

Oil palm plantations are important to the economies of Malaysia and Indonesia, and the rapid expansion of the industry has put pressure on natural forests. To improve the sustainability of the industry it is necessary to understand how conversion of different land cover types to oil palm impacts biodiversity and carbon storage.

Biodiversity and carbon in smallholdings- It is often assumed that smallholdings support more biodiversity than large estates, due to more mixed cropping and native species creating a more complex habitat. However, recent research on oil palm smallholding suggests this may not be the case, finding no difference in mammal richness in smallholdings and large estates (Azhar et al. 2014a), and that multi-cropping does not improve bird species richness (Azhar et al 2014b). There is currently no quantitative information on carbon stocks in oil palm smallholdings that is directly comparable with forest.

Biodiversity- Comparison of biodiversity in oil palm across numerous studies and taxa indicates that oil palm plantations support less than half (47%) of primary forest biodiversity levels (Foster et al. 2011; Savilaakso et al. 2014). Many species occurring in oil palm plantations are generalist, open habitat or invasive species and very few forest species or species of conservation concern remain. Published syntheses estimate that for forest species in oil palm, the figure is between 15-30% (Fitzherbert et al. 2008; Savilaakso et al. 2014). **HIGH CONFIDENCE**

Mature oil palm plantation

Carbon- Oil palm in Malaysia and Indonesia contains an average of 36 Mg AGC/ha (derived from Ziegler et al. 2012; Lucey et al. 2014b;) which is less than 20% of AGC found in primary forest and around 32% of AGC in logged forest. This value is time averaged across the oil palm lifecycle, therefore, unlike logged forest, oil palm does not have the potential to increase this carbon stock over time and will maintain this level until the land use changes. **HIGH CONFIDENCE**

Despite being a tree crop with a relatively long life-cycle, oil palm does not support a very high percentage of either biodiversity or AGC, even compared with other tree crops such as rubber and Acacia. *To avoid biodiversity and carbon losses, future development of oil palm plantations should be targeted in scrub or grassland, which have much lower biodiversity and AGC.*

Rubber and *Acacia*

A number of tree crops are grown in SE Asia. Here, we focus on rubber and *Acacia* because they are commonly grown in the same regions as oil palm, and because more data are available for these crops. However, there may be marked variation in biodiversity and carbon across other tree crops depending on the life cycle of the crop, whether it is native or exotic, whether plantations are monocultures or polycultures, and the wood density of the crop species.

Young rubber plantation

Biodiversity- Biodiversity data for non-oil palm tree crops in SE Asia are sparse and most studies focus on birds. Rubber plantations support more species if the rubber trees are grown amongst native vegetation ("jungle rubber"). Beukema et al. (2007) found that jungle rubber supported 96% of primary forest bird diversity levels, whereas monoculture rubber plantations supported only 50% of primary forest bird diversity levels. They also found that plant diversity in jungle rubber plantations was 80% of primary forest on average, whereas standard rubber plantations supported 66% on average, and a much smaller proportion of these were forest species. *Acacia* plantations support low bird species richness when the plantations are young, but mature *Acacia* plantations have been found to support at least 66% of primary forest diversity levels (Sheldon et al. 2010; Styring et al. 2011; Fujita et al. 2014). A study on mammals found that numbers of mammal species occurring in *Acacia* were about 80% of natural forest, but were much less abundant in the plantations and were assumed to be dependent on the surrounding forest patches (McShea et al. 2009). **REASONABLE CONFIDENCE (data for a limited range of species groups.)**

Carbon- A synthesis of studies measuring AGC in rubber for Malaysia and Indonesia indicates an average level of around 106 Mg C/ha (derived from Ziegler et al. 2012), which is approximately 54% of primary forest carbon and similar to the average carbon stocks of selectively logged forest. Very few data are available for AGC in jungle rubber (Ziegler et al. 2012), but average AGC did not appear to differ from standard rubber plantations. *Acacia* contained much less AGC than rubber, about 45 Mg C/ha or approximately 23% of primary forest carbon. **REASONABLE CONFIDENCE (limited data, especially for jungle rubber).**

There appears to be little difference in AGC of rubber plantations compared to logged forest, but biodiversity decreases dramatically in monocultures. Acacia *plantations contain similar biodiversity levels to rubber but AGC is much less. Data is lacking for most species groups in* Acacia *and rubber, and even less is known about biodiversity in other tree crops.*

Grasslands and scrub

Grasslands and scrub have both low carbon, because of the lack of woody plant species, and low biodiversity, because the simple habitat structure provides a lack of niche availability.

Imperata grassland

Biodiversity- Biodiversity in grasslands and open habitats in Malaysia and Indonesia is assumed to be very low compared with primary rainforest, although data are lacking. If grasslands are present as a result of severe forest disturbance and fire, plant diversity is generally very low, and dominated by invasive species, especially *Imperata species*. Data on *Imperata* grasslands in SE Asia are lacking, however, one study showed these grasslands only supported 13% of mammal species present in natural forest, and all of these were introduced rat species (Harrison 1965). Open scrub was found to support around 22% of bird diversity levels (Peh 2006). A study from S America found *Imperata* grasslands, which replaced degraded forest, were species-poor compared to natural savannahs (Veldman & Putz 2011). REASONABLE CONFIDENCE (and low confidence for natural grasslands, due to lack of data)

Carbon- Synthesis of studies measuring AGC in grasslands, pastures and shrublands collected in Ziegler et al. 2012, indicates an average level of 12 Mg AGC / ha, around 5 % of primary forest AGC. HIGH CONFIDENCE

Grasslands contain very low AGC, and non-natural grasslands are highly likely to contain very little biodiversity, so should be a priority for targeting agricultural development. However, natural grasslands may contain important non-forest or endemic species, even if total species numbers are lower than for forest. Data are lacking for biodiversity levels in grasslands in SE Asia.

Conclusion

There is strong agreement between the responses of carbon and biodiversity to different land use types. As a proportion of conditions found in primary forest on mineral soils, carbon tends to be reduced more by land-use change than biodiversity. However, although the magnitude of change in biodiversity and carbon may be different from one land cover type to another, the direction of change is always the same. Therefore, land-use decisions which benefit one value are highly likely to benefit the other, but some land-use decisions could provide a greater benefit to one value than the other.

Large tracts of logged forest support very high biodiversity levels, and although AGC can be reduced by half, this is still higher than any other human-modified land-uses. Additionally, logged and degraded forest has the potential to recover AGC stock over time, although very degraded habitat may require active management intervention to encourage regeneration.

It is clear that conserving large tracts of forest and preventing their conversion and fragmentation will have the largest co-benefits for biodiversity and carbon, and that targeting low biodiversity-low carbon degraded grassland and scrub for future oil palm development will minimise biodiversity and carbon losses.

Protecting primary forest from degradation and conversion, and preventing logged forest that is part of large forest tracts from being converted and fragmented, will result in the highest biodiversity-carbon co-benefit.

Key knowledge gaps

There are a number of other land-use and management options available for boosting carbon and biodiversity, for which there is currently limited research available to quantify co-benefits:

1. *Designing HCV forest patches.* Research is emerging to show the high value of large forest patches (hundreds of ha) and the lower value of very small forest patches (less than a few tens of ha) for biodiversity, however there is currently a research gap in terms of the carbon value of these areas in the SE Asian region, as well as the role of small fragments in the dispersal of species.

2. *Controlling human activities in forests.* Activities such as hunting, illegal logging and harvesting of other forest products are likely to impact on biodiversity and/or carbon, and are exacerbated by fragmentation, but there is little scientific information available to quantify this impact, or whether methods to prevent or manage these activities are sustainable.

3. *Forest restoration.* It may be possible to improve the biodiversity and carbon value of degraded, fragmented and non- forest areas by actively restoring forest through replanting and/ or vine cutting activities, however, there is little information available about the co-benefits of these approaches.

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Appendix 1: Methods for data collation and analysis

Biodiversity: Data were collated from published research and PhD theses where studies reported biodiversity (measured as raw or rarefied species richness) in forest and in other land-use types, allowing us to compute change in biodiversity following land-use change. We included studies if they were from Malaysia or Indonesia. A data point comprised the published species richness value for a species group in a particular land-use type; thus a single published paper or thesis could contribute more than one data point to our synthesis if it included several land-use types, or several species groups (e.g. birds, ants etc.). We expressed each data point as the percentage of species richness of a species group in a land-use type relative to primary forest. For some studies species richness had to be extracted from a graph. In some cases, primary forest biodiversity was not reported and so our comparison was with selectively logged forest because it has been established that biodiversity does not vary much between primary and selectively logged forest. Most studies report biodiversity measures for each species group in each land-use type from replicated samples, and so data points are based on the mean richness in a particular land-use type relative to mean species richness in forest. Where studies had measured biodiversity within varying states of a particular land-use type (for example once-logged and twice-logged forest, or jungle rubber and rubber monoculture), we included the different land-use states as separate data points to capture the variation within the broad categories of land-use types examined in this report. Thus a **data point is the species richness of a species group for a given land use-state, relative to primary forest** (see Appendix 2 for table of numbers of data points and contributing studies for each land-use). We plot the mean of these data points for each land-use type, and error bars represent the standard error around the mean. Primary forest does not have an error bar because all values are set at 100%. Our method reflects the approach used by Ziegler and colleagues (2012) to collate AGC data (see below).

Carbon: Data were collated from the Supplementary Information from Ziegler et al. (2012). **A data point is the published value of AGC in Mg C/ha for a given land-use type in a given study** (see Appendix 2). Only values from research carried out in Malaysia and Indonesia were extracted from the published study. Primary and selectively-logged forest AGC values were extracted for lowland mineral evergreen dipterocarp forests (i.e. heath, mangrove, deciduous and mountain forests were excluded from the analysis because these areas are largely unsuitable for growing oil palm). Each data point was converted to a percentage of the overall mean AGC of primary forest on mineral soil. We plot mean values for each land-use type, and error bars represent the standard error around the mean. The number of data points varied for different land-use types depending on the number of studies available (See Appendix 2).

Appendix 2: Table showing the number of data points for each land-use and the number of studies the data points were extracted from.

Land-use	Biodiversity		Carbon	
	No. data points	No. of studies	No. data points	No. of studies
Primary forest	31	14	92	63
Peat forest	2	2	12	10
Logged forest	38	18	48	20
Acacia	7	3	19	14
Rubber	12	5	13	7
Oil palm	28	19	20	12
Grassland	2	2	7	6