Risks and Co-benefits of Biodiversity Conservation in REDD:

Suggestions based on a Case Study in Bornean Rain Forests

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Summary

1. Production forests targeted to permanently produce commercial timber exceed 50% of the land area in Borneo. Whether sustainable forestry is practiced in Bornean production forests will considerably influence the world LUCF carbon emission as well as the fate of biodiversity, especially endangered wildlife of world concern.

2. Current practices of logging in the majority of production forests are of high impacts, leaving behind highly degraded residual forests where carbon stock and biodiversity are much impoverished. These degraded residual forests are still qualified a bona fide "forest" by its definition. A baseline scenario in much of the production forests is thus a high-impact logging practice and by its definition the practice will not directly cause deforestation.

3. Sustainable forestry which employs reduced-impact logging with strict compliance to international principles can maintain carbon stock at a much higher level than the baseline (i.e. unsustainable forestry) does. Sustainable forestry can also restore the integrity of communities for various taxonomic groups, and thus has favorable co-benefits for biodiversity conservation.

4. Whereas the magnitude of degradation determines both carbon stock and biological assemblages (biodiversity), remote sensing with a coarser resolution targeted to such a wide area as a nation will most likely fail to distinguish the magnitude of forest degradation. Employing remote sensing with a coarser resolution to estimate the carbon stock of highly degraded forests without a proper consideration to account for spatially variable carbon density will inadvertently or advertently lead to a perverse overestimation of carbon stock and biodiversity.

5. It is highly desirable to develop a project-based, site-specific biomass estimate by using remote sensing with a finer resolution in each management unit (generally ranging from one hundred thousands ha) to encourage sustainable forestry to participate REDD and to drive out perverse accounting. This will also allow the project entity to build a capacity to monitor biodiversity in its project area.

6. Monitoring of biodiversity in a few representative monitoring sites is essential to secure the co-benefits of REDD. The magnitude of a change in community composition can best indicate the complex effects of deforestation and forest degradation on biodiversity.

7. Practicing sustainable forestry with strict compliance to international principles and standards is the best mitigation option to alleviate the current rate of carbon emission and biodiversity deterioration where production forests that are legally designated to produce timber dominate the landscape. If the concept of additionality (i.e. an increment of carbon over a baseline in a project period) is incorporated to REDD, it will provide a project entity (foresters) with the maximum incentive to adopt sustainable forestry and will in effect result in a higher permanent stock of carbon and better biodiversity conservation. Negotiations of REDD technical issues should consider incorporating additionality, and must not discount such sustainable efforts.

8. The incorporation of additionality concept will provide the project entity with a lowest cost option for generating emission reductions, which will in turn reduce the financial burden of buying countries.

Introduction

REDD (Reducing Emissions from Deforestation and Degradation) has been receiving a considerable attention as a post-2012 Kyoto mechanism to compensate developing countries to reduce CO_2 emissions from deforestation and forest degradation (Ebeling and Yasué 2008). During the year 2000-2006, the global carbon emission was 9.1 Pg C yr^{-1}, consisting of the top major source of fossil fuel burning (7.6 Pg C yr^{-1}) and the 2nd source from LUCF (land-use change and forestry) (1.5 Pg C yr^{-1}, i.e. 16%); the latter originated substantially from the tropical deforestation and degradation after 2000 (Canadell *et al*. 2007). Despite that the tropical deforestation and degradation is the 2nd major emission source in the global carbon budget, the Kyoto Protocol under the current UNFCCC (the United Nations Framework Convention on Climate Change) does not include any mechanisms to avoid the emission from deforestation and degradation from natural forests (Ebeling and Yasue 2008). REDD can resolve this problem and is expected to reduce emissions from natural forests if a sufficient economic incentive (carbon credit) is provided.

Although the primary purpose of REDD is climate change mitigation, it can have important co-benefits for biodiversity conservation. Tropical rain forests where the majority of deforestation occurs, coincide biodiversity hotspots. Deforestation is the major cause of the loss of biodiversity in the tropics. Avoiding deforestation therefore may alleviate the decreasing trend of biodiversity. In this report, I will address risks and co-benefits of REDD for biodiversity conservation and discuss what technical considerations need to be considered to develop a synergistic REDD to meet biodiversity conservation. My model case is Borneo as a whole to discuss historic deforestation trend and the single forest management area called "Deramakot Forest Reserve" as a specific example to demonstrate the effects of forest management on biodiversity.

Deforestation and land status in Borneo

Borneo is the third largest island, with an area of 757,100 km^2, and it is divided administratively between Indonesia (states of East, South, Central and West Kalimantans), Malaysia (states of Sabah and Sarawak), and Brunei. In recent years, Borneo has lost a large area of tropical rain forests due to forest fire, land conversion, and commercial logging (Langner *et al.* 2007). There are no reliable statistical data on the extent of intact forests left in Borneo. The latest estimate, using satellite data, of forested area including modestly degraded forests ranges from 40% of the total land area (Darmawan 2004; Saito and Kitayama 2005) to 57% (Langner *et al.* 2007) (Figure 1). The majority of the remaining forests comprise production forests that were commercially selectively logged for more than twice, i.e. degraded forests. Borneo has lost a total of 5.34 G tons of carbon to date (as of 2002) assuming that the mean carbon density in above-ground vegetation is 200 ton/ha in the high-stock forests, 150 ton/ha in the degraded forests and 0 ton/ha in the non-forest categories of Saito and Kitayama (2005). This is equivalent to 8.1% of the total carbon emitted from LUCF in the whole world between 1959-2003, the period when reliable statistical data are available (Kitayama unpublished). Indonesia and Malaysia together (including the regions other than Borneo) emitted 42.8% of CO_2 from LUCF activities in 2000 (Table 1, WRI 2007). Because Borneo is the center of current LUCF activities, the role of Borneo in the world carbon budget cannot be overstated from these figures.

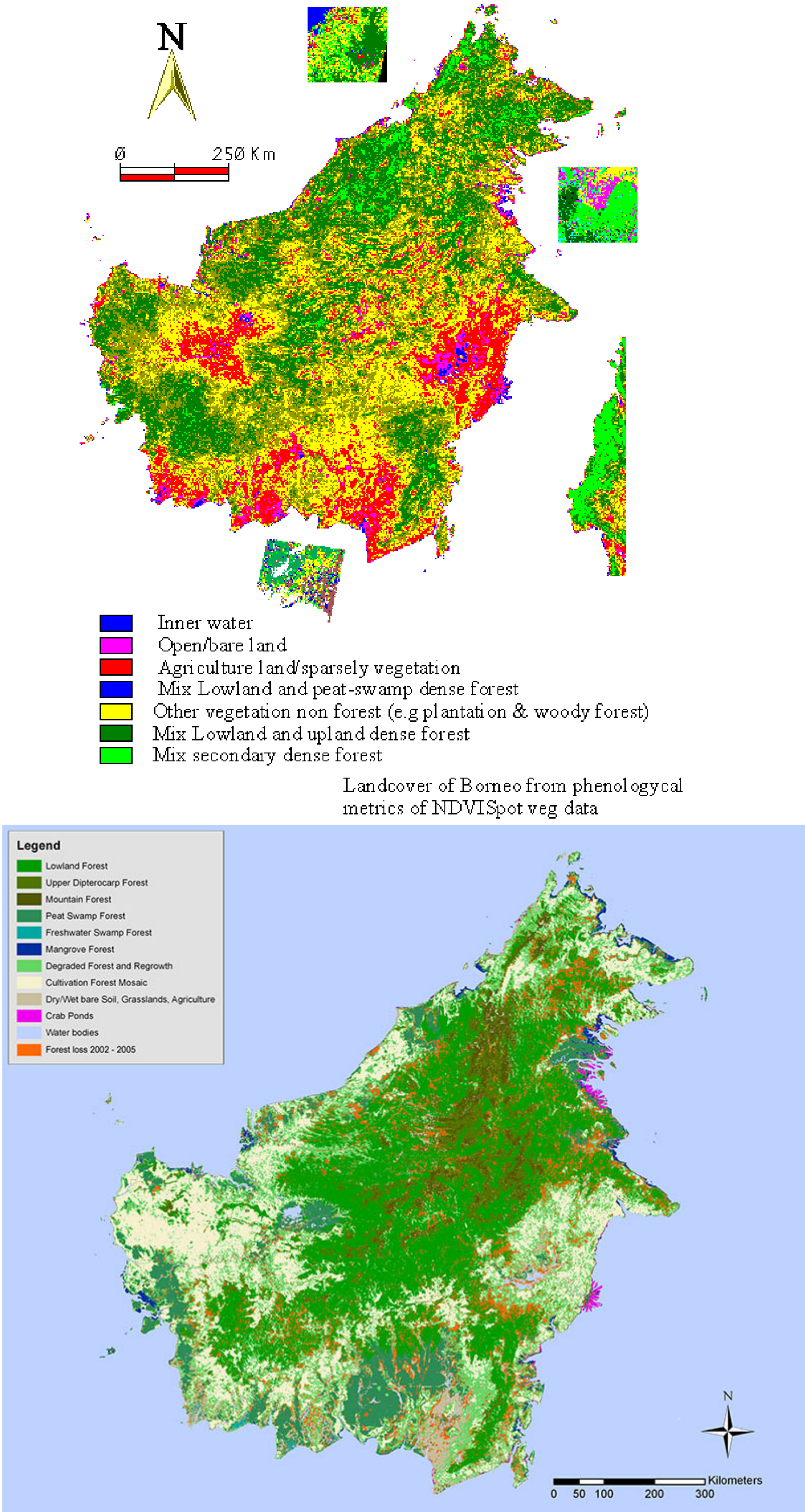

Figure 1. Recent land-cover condition of Borneo. Land cover types were classified based on SPOT VEGETATION (2002) with 1km resolution (upper diagram, Saito and Kitayama 2005) and on MODIS (2002) with 250m resolution (lower diagram, Langner et al. 2007).

Table 1. Amount of CO_2 emissions from top ten LUCF (Land-use change and forestry) CO_2 emitting countries in 2000 (data after CAIT data base, WRI 2007). Top ten are all tropical countries. # denotes a country which includes Borneo as a territory.

Country	CO_2 emission (million tons CO_2)	Percent of total LUCF (%)
A#	2,563.10	33.64
B	1,372.10	18.01
C#	698.9	9.17
D	425.4	5.58
E	317.3	4.16
F	235.5	3.09
G	194.8	2.56
H	187.2	2.46
I	146	1.92
J	144.1	1.89
World total	7,618.60	

Permanent forest estate (often called “production forests”) in Borneo set aside for the commercial production of forest resources is 37,500,000 ha or 50.2% of the land (excluding Brunei). The majority of current permanent forest estates are believed to consist of modestly or highly degraded forest stands or completely deforested stands due to the past logging of various intensities and forest fire. These forests are still legally protected for the future permanent timber production.

Existing strictly protected area is 1,174,398ha (may include marine parks) for Sabah, 1,308,993ha (may include marine parks and proposed areas) for Sarawak, and 3,700,000ha for Kalimantan (ca.7% of the land of Kalimantan, 7 national parks). Data are not available for Brunei. Strictly protected area will not exceed 10% of the land even if Brunei is included.

Many species, particularly large wildlife of wide home ranges, rely on degraded production forests in the current landscape of Borneo. In the case of orangutan, 70% of the wild population in the northeastern state of Sabah is found in production forests (Ancrenaz *et al*. 2005), and probably, a similar scenario exists for most endangered mammals for most areas. Production forests are *de facto* functioning in retaining biodiversity of the degraded landscape of Borneo. Sustainability of Bornean production forests can influence the future carbon budget as well as the fate of wildlife.

Historical and projected trend of land use in Borneo

Sodhi and Brook (2006) extrapolated the deforestation rate of 1990–2000 (1.5% per year in Indonesia and 1.4% per year in Malaysia) to the future and projected that forests would decrease by 90% of the original forested area in this region by the year 2100. This study includes highly populated areas of Malay Peninsula and Java and may under- or overestimate the deforestation rate for Borneo depending on the rate of socio-economic developments. Another estimate for deforestation rate based on the comparison of satellite data between 2002 and 2005 is 1.7% yr^{-1} for entire Borneo and closely agrees with the former estimate (Langner *et al*. 2007). It can be conservatively assumed that a multi-year average of historical deforestation rate for entire Borneo is 1.7% yr^{-1}.

Apart from the deforestation rate in terms of area, the biomass and productivity of a remaining stand may also deteriorate. Unsustainable logging (Bertault and Sist 1997; Huth and Ditzer 2001; Sist and Nguyen-The 2002), fire (Woods 1989; Toma *et al*. 2000), and global climate change (Kitayama and Aiba 2002) may affect the biomass and productivity.

Imai and Kitayama (*unpublished*) projected the dynamics of the amount of carbon in the vegetation and soils of a Bornean lowland tropical rain forest by using the Century Model with four scenarios (global warming, heavy selective logging, El Nino droughts, and the combination of droughts and logging). The combination of a heavy selective logging and droughts will considerably reduce the rate of vegetation recovery. Selective logging is a legal operation if it is sustainably operated in compliance to the law, while droughts are one of the natural disasters that are predicted to increase in magnitude under current global-change scenarios in the Southeast Asian tropics (IPCC 2001). Therefore, deterioration of the above-ground biomass by these combined effects is the most likely and alarming projection. Moreover, selectively logged lowland tropical rain forests are known to be susceptible to wild fire (Woods 1989; Cochrane 2003; Langner *et al.* 2007). Depending on the logging methodology fires are especially damaging in intensely logged forests due to the larger amount of potential fuel left behind after the logging process (Goldammer 2007). The permanence of carbon stock is therefore highly dependent on the magnitude of degradation.

Description of the model site, Deramakot

Deramakot is one of the forest management units in Sabah (North Borneo), Malaysia, and is designated as Class II Forest Reserve by the Sabah State government, which is meant to permanently, commercially produce timber by selecting logging. Its area is 55,149 ha. Lowland tropical rain forest of mixed dipterocarp trees is the major vegetation in this area (Huth and Ditzer 2001). Historically, Deramakot and the surrounding areas were licensed for logging from 1955 and 1989 and “conventional logging” with heavy impacts was applied to the area. The Sabah Forestry Department with technical support from the German Aid Agency for Technical Cooperation began developing a management system in Deramakot in 1989. All logging activities were suspended in 1989 in Deramakot, but continued in the surrounding area, providing us with a chance to experimentally investigate management effects on carbon stock and biodiversity.

A forest management plan was developed and started to be implemented in 1995. Reduced-impact logging (RIL) has been employed for harvesting with minimal impacts on the physical environment since then. The entire Deramakot area (55,149 ha) is set aside for log production with internal conservation areas under the new management plan (Kleine and Heuveldop 1993; Lagan *et al*. 2007). To date, this forest management plan serves as the blueprint for operational work in Deramakot. Deramakot is divided into 135 compartments of varying sizes, and the annual harvest is planned on the compartment basis. 17 compartments are set aside for conservation (not to produce logs) and 118 compartments for natural forest management (to produce logs). Two to three compartments are harvested annually with RIL, giving a rotation period of 40 years. The annual allowable cut is not more than 20,000 m^3. A strict protection area is set aside for biodiversity conservation within the internal conservation area.

Deramakot Forest Reserve was certified as “well managed” by the Forest Stewardship Council (FSC) in 1997 and is the first natural forest reserve in Southeast Asia to be managed in accordance with sustainable forestry principles. Certified logs are sold for a much higher price per volume compared with non-certified timber, bringing a substantial net profit for the Sabah Government. The Sabah Government directly manages Deramakot as a model site for RIL and forest certification, which mimics natural processes for sustainable production of low-volume, high-quality, high-priced timber products. The Sabah Government intends to ultimately manage all forest management units in Sabah in a similar manner by issuing licenses to the entities which have capacities to develop sustainable management plan and to implement.

In 2007, a collaborative research project was initiated between the Sabah Government and several Japanese universities to investigate the management effects on carbon and biodiversity, funded by the Ministry of the Environment, Japan. Additive effects of RIL are being evaluated by comparing Deramakot with the surrounding areas where conventional logging (CV) has been continued until recently. What follows is the reevaluation of the results of this project and primarily addresses the additive effects of sustainable forestry in form of RIL on top of the conventional logging. In the following report, I assume that a hypothetical REDD project were applied to Deramakot. Project period is 13 years from 1989 (when logging was suspended) until 2002 (when the Landsat data were collected for the analyses). Although the sustainable forestry was initiated in 1995, the re-growth after 1989 would need to be taken into account for the net carbon gain. In this case, the baseline scenario is the conventional logging which has been continued until the time of comparison. Deramakot (RIL) and the surrounding CV forests are collectively termed “case study area” hereafter.

Deforestation versus Degradation: a technical issue

The accounting of carbon must be ideally provided by the change of forested-area multiplied by carbon density (above-ground biomass) per area. Remote sensing is expected to carry out such carbon accounting on the ground. It can demarcate forested stands from non-forested stands based on a threshold value that is dependent on the reflectance and resolution of the sensor, but evaluating biomass on a country level is probably not realistic for a present remote sensing technology. Therefore, a formal agreement at the international level for REDD may be reached to adopt carbon accounting based on aerial changes only. There is a considerable concern that the loss of carbon from forest degradation will not be correctly evaluated. According to FAO definition, forests are defined as stands with a crown cover exceeding 10% and a stature greater than 5m (FAO 2001). Accordingly, the carbon loss due to deforestation will not be accounted for until crown cover decreases below 10%.

I can demonstrate how seriously carbon stock is overestimated if an inadequate remote sensing resolution is applied (Figure 2). Conversely, if the magnitude of biodiversity is dependent on forest biomass, the loss of biodiversity will not be legitimately assessed. Langner et al. (2007) successfully classified entire Borneo into 11 land cover classes using MODIS Moderate Resolution Imaging Spectroradiometer with 250m resolution. In their map, degraded forests are defined as stands with 40% crown cover or less while “closed forests” are those exceeding 40% crown cover. Deramakot and the surrounding conventionally logged area are both categorized as “closed forests” in their map (Figure 2). A closer visual inspection of the same area using Landsat ETM (2002) with 30m resolution indicates that the most area is in fact degraded (Figure 2).

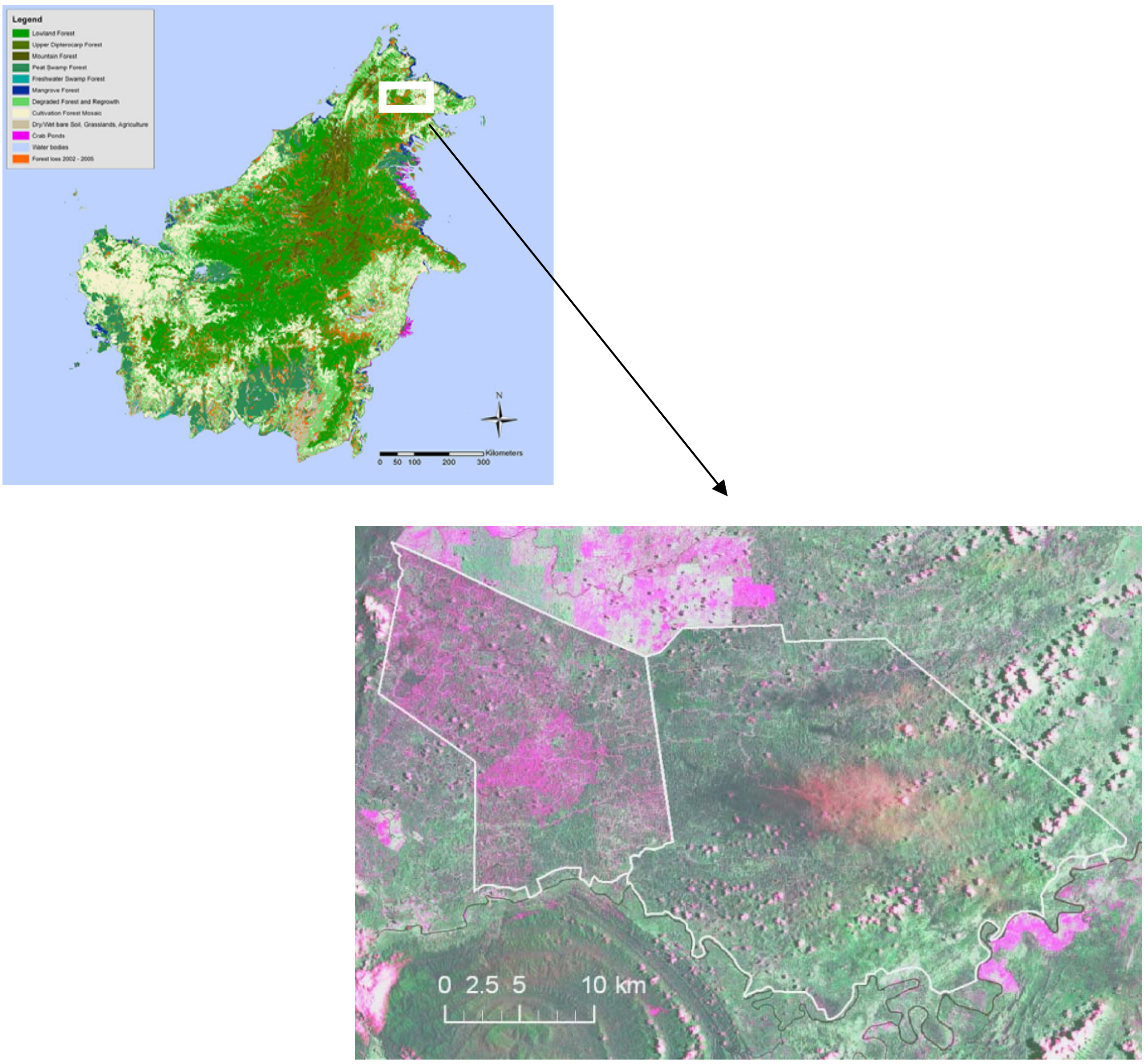

Figure 2. Closer inspection of the case study area as bounded by white lines in the lower diagram with Landsat ETM (2002) with 30m resolution. The case study area was identified as “non-degraded forest” both in Saito and Kitayama (2005) and Langner et al. (2007). However, the magnitude of forest degradation considerably varies within the bounded forest area. The left bounded area is highly degraded due to heavy-impact conventional logging which is still continued practicing in 2002, whereas the right bounded area has restored forest cover due to the sustainable forestry with reduced-impact logging introduced after 1995. Pink color indicates a denuded area. Note dense networks of logging roads in the left bounded area as indicated by nebulous pink patterns.

Kitayama et al. (2006) developed a model to estimate above-ground biomass of the tropical rain forests in the case study area and extrapolated the model to elucidate the spatial variation of biomass using Landsat ETM (taken in 2002) with 30m resolution (Figure 3). In this case, the magnitude of variation is indicated by the loss of biomass, which is the direct indication of carbon emission. Above-ground biomass of the case study area as illustrated in Figure 3 considerably varies and reflects the ground-truth data (not shown here). CV forests are highly degraded with much reduced above-ground biomass. The coefficient of variation in biomass density at multiple training points ranges from 18.1 to 18.7% in this area.

I conclude that the resolution of analysis and algorithm used (whether crown cover *versus* biomass is analyzed) considerably affect the final product of carbon accounting. Medium resolution will be useful for land cover classification at a larger-scale such as nation-level accounting; however, it gives a serious overestimation of "closed forest" and most likely cannot detect forest degradation (and hence the deterioration of biodiversity on the ground).

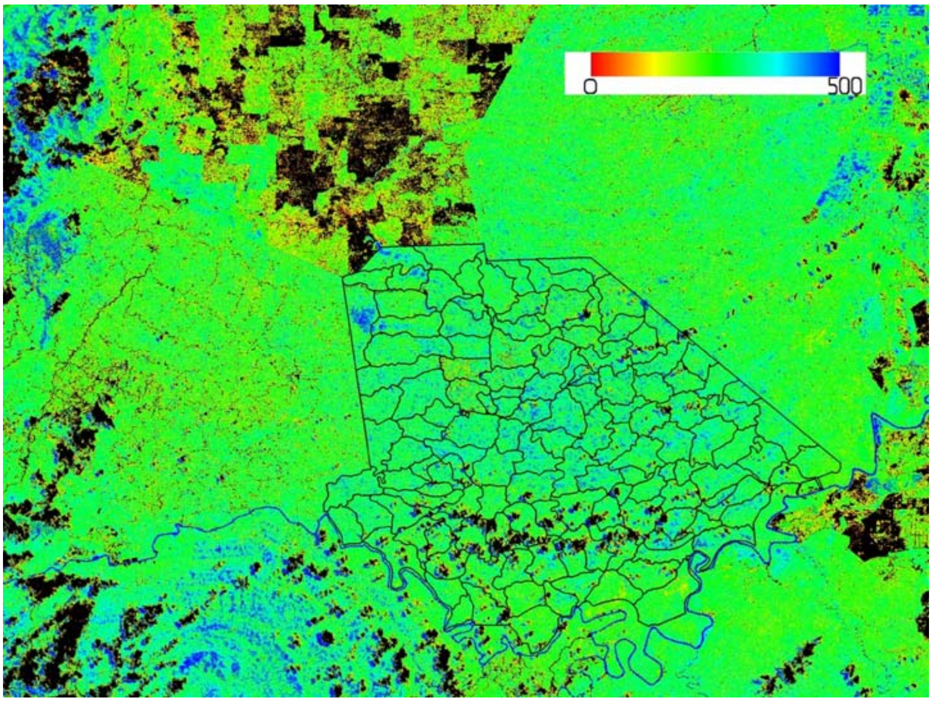

Figure 3. Variation of biomass density (ton per ha) in the case study area. Biomass density is highly and unexpectedly variable over the case study area. The mean biomass density± standard deviation (ton/ha) over multiple training points is 362.0±65.7 for the sustainable forestry area (right) and is 248.0±46.4 for the conventional logging area (left). The magnitude of variation as coefficient of variation is 18.1% for the sustainable forestry area (right) and is 18.7% for the conventional logging area, suggesting that the mean biomass density is dependant on forest management and that biomass is highly spatially variable.

Additive effects of carbon sequestration in sustainable forestry

The amount of carbon was further calculated by assuming that 45% of the above-ground biomass was carbon (Imai *unpublished*) in the case study area based on the data in Figure 3. The mean amount of carbon in the above-ground vegetation is estimated to be 156 ± 18 Mg ha^{-1} in Deramakot where RIL is practiced, while it is 123 ± 11 Mg ha^{-1} in the neighboring CV forest. The difference of 33 Mg carbon per hectare is considered as the mean positive effect that is added by sustainable management for 13 years from 1989 until 2002. By extrapolating for the entire area, sustainable forestry resulted in a net addition of 1.8×10^6 Mg carbon for the 55,149 ha area of Deramakot for 13 year against the baseline scenario (i.e. conventional logging).

Technical issues in monitoring biodiversity

A forest ecosystem consists of producers (tree species), decomposers and predators. Forest harvest can physically damage all biodiversity components in a forest ecosystem. Moreover, biodiversity can be influenced by a chain of reactions through a food web or of indirect reactions, leading to a highly unpredictable system for human interference. Decomposers include soil macrofauna (animals) and microbes, and play a role in nutrient cycling and sustain tree growth. They are relatively immobile compared with those species living above the ground, and their representative samples can be relatively easily obtained. Forest degradation can impact decomposers primarily through the change in microclimate and supply of food (i.e. litter) (Johns 1997). Predators include flying insects, birds and mammals. Large mammals in tropical rain forests are often placed in a higher position of a food web and recognized as a flagship species in conservation. Deforestation can impact predators through changing microclimate, changing habitat structure, bottom up effects of changing food supply or top down effects of changing higher predators (Johns 1997). Top down effects include human hunting pressure for large mammals.

Logging can most directly influence tree species diversity. Against expectation, logging can sometimes increase the number of tree species by favoring fast-growing pioneer species (Figure 4). If the species number of such new comers after logging surpasses the number of disappeared species in a logged over area, the total number of species can increase compared with the initial condition (Cannon et al. 1998). Therefore, the number of tree species (or genus or family) per unit area should be interpreted with precaution although species number is the most widely-used first approximation of species diversity or richness. A similar misleading can occur in any other taxonomic groups. I will therefore discuss the effects of management on biodiversity using a “community composition approach” in addition to the number of species (or genus or family) *per se*.

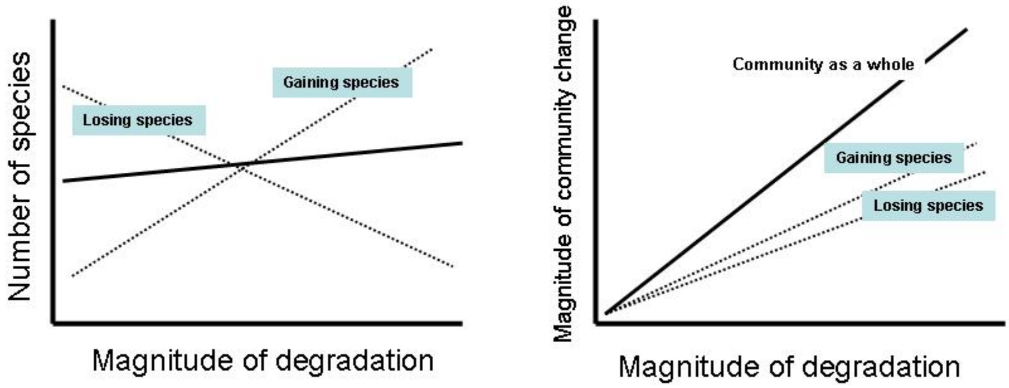

Figure 4. Technical considerations in biodiversity monitoring. When biodiversity is monitored as the number of species (taxa) against the magnitude of forest degradation (as in the left diagram), it may result in an erroneous evaluation of a net increment due to a greater number of “new comer species” than of “losing species.” Effects of forest degradation can be correctly evaluated with a community approach where both gaining and losing species are taken into account (as in the right diagram).

The community composition approach is explained in Figure 4. A community composition is the product of species assemblage (i.e. a list of species in a given area) and the abundance of each species (such as the number of individuals or biomass of each species in the area). The overall change brought by a management scheme is the sum of the magnitude of reduction in losing species and of the magnitude of increment in gaining species, which equals the change in species composition. The magnitude of reduction or increment is expressed by the change in species abundance. Technically, the change in community composition can be analyzed with one of multi-variate analyses. “Species” can be substituted with genus or family in any taxonomic groups.

Additive effects of biodiversity conservation in sustainable forestry

In the case study area, the community composition and taxonomic richness were both analyzed for trees, flying insects, medium to large mammals, and soil macrofauna, and compared among pristine forest with minimal influence of logging, reduced-impact logged forests (RIL), and conventionally logged forests to discuss the effects of management.

The richness of species, genus, and families of canopy trees per small plot (0.2 ha) and several indices of species diversity (such as Fisher and Shannon indices) were consistently and significantly greater in the RIL forests than in the conventionally logged forests but were not different between the RIL forests and the pristine forests (Figure 5, Seino et al. 2006). The maintenance of the richness of tree species in the RIL forests could have occurred due to the addition of “new comers” which invaded mildly disturbed patches by RIL, as I demonstrated in Figure 4. However, community composition of the RIL forests was similar to that of the nearby pristine forest (Figure 6). The conventionally logged forests were remotely placed from the RIL forests and the pristine forests. Therefore, it was safe to conclude that that RIL could maintain the integrity of community composition but conventional logging negatively influenced the integrity.

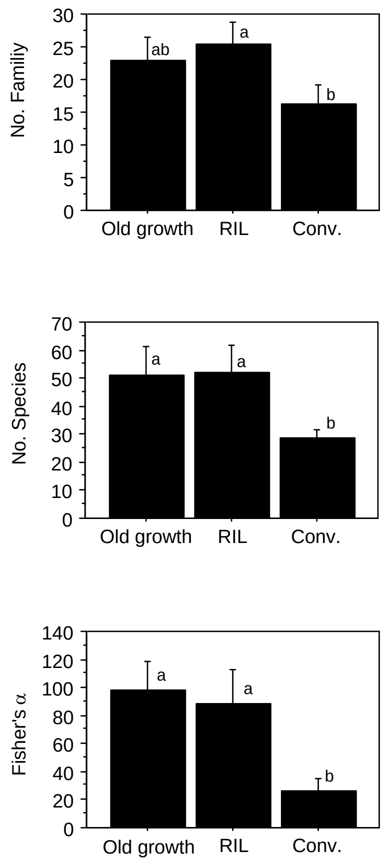

Figure 5. The mean number of species and families, and richness (Fisher’s index) of tree species larger than 10cm stem diameter in pristine forests (old growth forest), reduced-impact logged forests (RIL) and conventionally logged forests (Conv.) in the case study area. Adopted from the Figure 1 of Seino et al. (2006). The number of tree species and families does not drastically decrease in reduced-impact logged forest as indicated in the diagrams. This pattern indicates two contrasting effects: 1) an increase of new comer species after mild disturbances introduced by the reduced-impact logging compensates a deleterious effect of the logging, and 2) truly favorable effects of the reduced-impact logging which do not cause any losing species. The number *per se* cannot differentiate those mutually confounding effects.

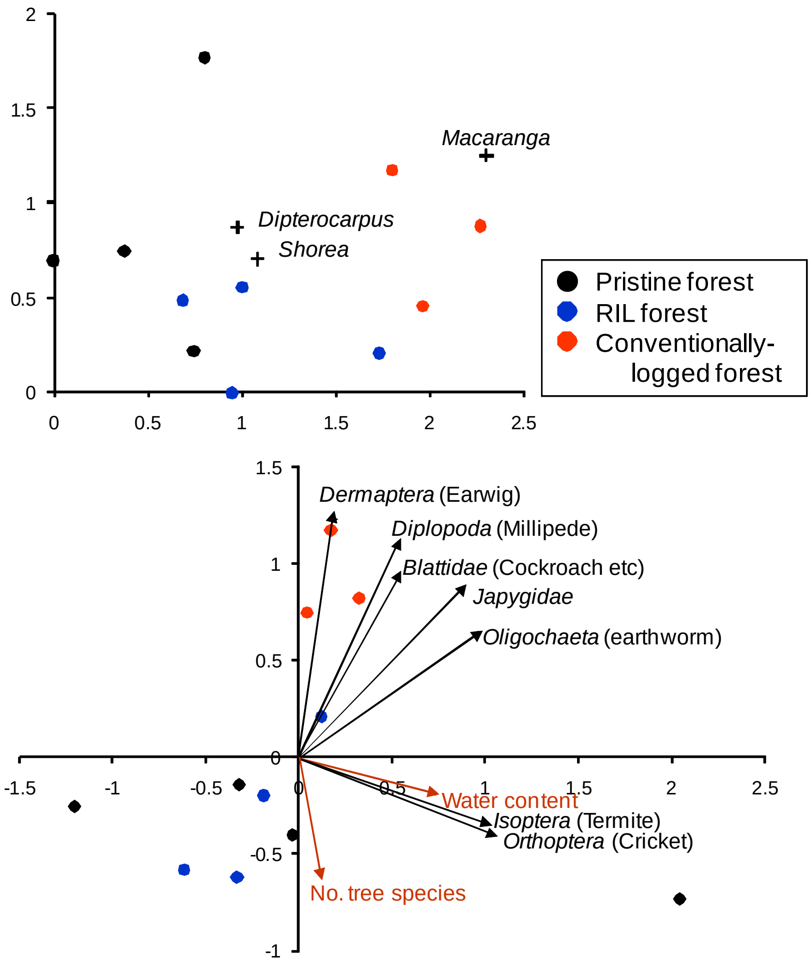

Figure 6. Effects of management on the community composition of tree species (upper diagram) and of soil macrofauna (lower). The figure was adopted from Kitayama et al. (submitted to Frontiers in Ecology and the Environment). In both cases, conventionally logged forests are remotely placed from pristine forests and reduced-impact logged forests. By contrast, reduced-impact logged forests are closely located with pristine forests suggesting that reduced-impact logging can protect tree species communities.

Another example is soil macrofauna which is the representative of the decomposers exceeding 2 mm in body size. The density and the number of taxa of soil macrofauna at order or an equivalent taxonomic level were not different among the RIL, conventionally logged, and pristine forests (Hasegawa et al. 2006). This is in contrast to tree species community. However, the composition of soil macrofauna community was modified greatly by conventional logging but less so by the RIL operation (Figure 6). Therefore, RIL could maintain the integrity of community composition in soil macrofauna in agreement with tree species community. Generally, soil macrofauna is believed to have a good indicator value (Hasegawa et al. 2006).

A survey using camera traps indicated that the number of photographed mammal species was greater in the RIL forests than in the conventionally logged forests. A few mammal species showed a statistically higher frequency of appearance in the RIL forests. Large mammals are often hunted for bush meats unless the access of hunters is physically limited. The greater species richness and population abundance in the RIL forests may reflect the improved physical condition of the forests as well as the protection of mammals from hunting because of restricted access to this forest. Another independent census of the orangutan population from a helicopter also indicated a significantly higher nest density in the RIL forest than in the surrounding conventionally logged forests (Ancrenaz *et al*. 2005). RIL could maintain the greater community integrity also for flying insects (Akutsu *et al*. 2007).

The above results indicate that the improved forest management in Deramakot has beneficial effects on biodiversity. Strict compliance to international principles maintains the abundance of keystone fruit species, standing dead snags, large stems, foliage, and litter on which animals depend for food and habitat (Johns 1997), and probably, these altogether help in maintaining the community of plants and animals relatively intact. Considering that the entire case study area was the target of logging licensees between 1955 and 1989, the plant and animal communities recovered their integrity in Deramakot during the time elapsed after the suspension of conventional logging. Therefore, biodiversity will respond to avoided forest degradation in a reasonably short time period.

Economic Consideration in Biodiversity Protection

Ebeling and Yasue (2008) express a concern of daunting motivation for biodiversity conservation as follows (rephrased after them): "Carbon markets value carbon not biodiversity and are designed to focus on the lowest cost options for generating emission reductions. They will thus favor areas with low land-use opportunity costs which may not coincide with areas of high conservation priorities. For example, global hot spots for biodiversity conservation have high land-use conversion rates and are consequently likely to have high opportunity costs for conservation."

This may be the case when hot spots are expressed on a nation basis and the mode of REDD is nation-based rather than project-based. Hot spots are the places which have rich biodiversity with high endemism but are threatened by human activities. As I have demonstrated, the major hot spots in the tropical countries with high deforestation rate exist in production forests. Employing sustainable forestry does not require a major cost of emission reduction because timber production is the primary land use purpose. If forest certification can provide a higher price for the timber produced, it becomes a further economic incentive.

Moreover, the international community should consider an innovative scheme to allow carbon markets to value carbon as well as biodiversity. Assuming a conservative unit carbon price of US$10 /Mg CO_2 (US$36.7/Mg C) (EcoSecurities 2007), irrespective of biodiversity, the net additive economic value of RIL in entire Deramakot (55,149 ha) is $66 million for 13 years (between 1989 and 2002). If the economic value of carbon can be proportionately weighed by the net increase of biodiversity (i.e. the integrity of biological communities), the total economic value would further increase.

Discussions and suggestions

I have demonstrated that there is a considerable variation in carbon density reflecting past management in the case study area despite that the area is uniformly identified as "forest." The case study area represents a chunk of fragmented and deteriorated landscape of Borneo. The entire region is legally defined as the state "Class II Forest Reserve" to permanently produce timber and it is unlikely that its forest area will change either based on remote-sensing change-detection (due to technical limitation) or on government statistics (due to its legal status). However, conventional logging would remove a substantial amount of carbon as timber and suppress carbon density as a significantly lowered level for a prolonged time. On the other hand, sustainable management based on RIL and forest certification would foster tree growth and maintain carbon density at a significantly higher level than conventional logging would.

Depending on the policy decisions on the mode of REDD, the case study area (Deramakot) will not benefit from carbon credit if the business as usual scenario does not reflect predominating management scheme and if degradation is not correctly evaluated. However, if a more flexible mechanism is added to REDD and conventional logging becomes as business as usual by reflecting its historical trend of decreasing carbon density, sustainable forestry can bring up a substantial amount of monetary benefit as well as important co-benefits in biodiversity conservation. A contrast between the dominating idea of REDD and my suggestion is indicated in Figure 7. The REDD as the post 2012-Kyoto mechanism should consider incorporating beneficial effects of sustainable forestry based on additionality concept that I demonstrate in Figure 7, which will bring up assured co-benefits in biodiversity.

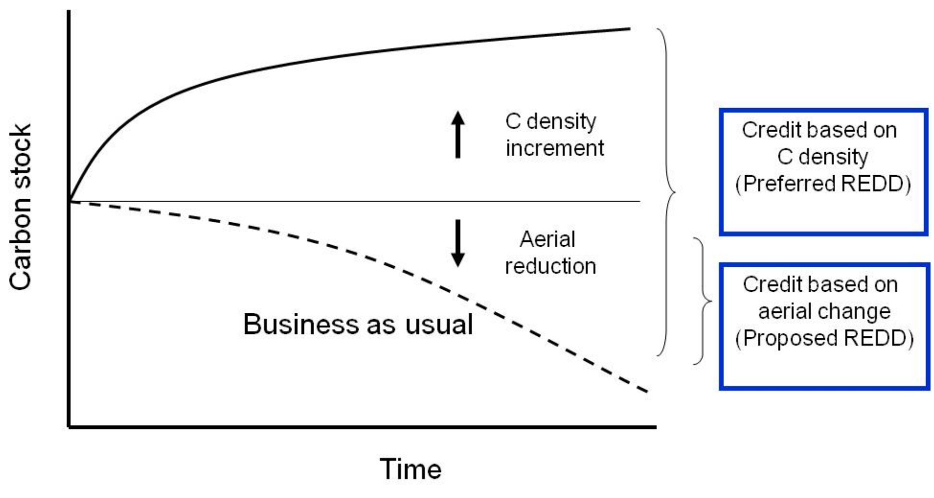

Figure 7. The difference of the proposed REDD with the Compensated Reaction which is based on aerial changes only *versus* the preferable REDD which incorporates sustainable forestry. The latter evaluates carbon based on aerial change and carbon density and also incorporates the additionality (i.e. increment effects) of carbon stock. Unless the latter is adopted, true joint benefits of emission reduction and biodiversity conservation will not be materialized. The figure was adopted from Kitayama et al. (submitted to Frontiers in Ecology and the Environment).

I conclude that:

1. Production forests targeted to permanently produce commercial timber exceed 50% of the land area in Borneo. Sustainable forestry of Bornean production forests will considerably influence the world LUCF carbon emission as well as the fate of biodiversity, especially endangered wildlife.
2. Current practices of logging in the majority of production forests are of high impacts, leaving behind highly degraded residual forests where carbon stock and biodiversity are much impoverished. These degraded residual forests are still qualified as a bona fide "forest" by its definition. A baseline scenario in much of the production forests is thus a high impact logging practice and by its definition the practice will not cause deforestation.
3. Sustainable forestry which employs reduced impact logging with strict compliance to international principles can maintain carbon stock at a much higher level than the baseline (i.e. unsustainable forestry) does. Sustainable forestry can also restore the integrity of communities for various taxonomic groups, and thus has favorable co-benefits for biodiversity conservation.
4. Whereas the magnitude of degradation determines both carbon stock and biological assemblage (biodiversity), remote sensing with a coarser resolution targeted to such a wide area as a nation will most likely fail to distinguish the magnitude of forest degradation. Employing remote sensing with a coarser resolution to estimate the carbon stock of highly degraded forests without proper consideration to account for spatially variable carbon density will inadvertently or advertently lead to a perverse overestimation of carbon stock and biodiversity.
5. It is highly desirable to develop a project-based, site-specific biomass estimate by using remote sensing with a finer resolution in each management unit (generally ranging from one hundred thousands ha) in order to avoid the perverse accounting report. This will allow the project entity to build capacity to monitor biodiversity in its project area.
6. Monitoring of biodiversity in a few representative monitoring sites is essential to secure the co-benefits of REDD. The magnitude of a change in community composition can best indicate the complex effects of deforestation and forest degradation on biodiversity.
7. Practicing sustainable forestry with compliance to international principles and standards is the best mitigation option to alleviate the current rate of carbon emission and biodiversity deterioration where production forests that are legally designated to produce timber dominate the landscape. If the concept of additionality (i.e. an increment of carbon over a baseline in a project period) is incorporated to REDD, it will provide a project entity (foresters) with the maximal incentive to adopt sustainable forestry and will in effect result in a higher permanent stock of carbon and better biodiversity conservation. Negotiations of REDD technical issues should consider incorporating additionality, and encourage sustainable forestry to participate.
8. The incorporation of additionality concept will discourage the perverse incentive for those countries (or projects) which have a high historic deforestation rate to gain carbon credits. It will on the other hand provide the project entity with a lowest cost option for generating emission reductions, which will in turn reduce the financial burden of buying countries.

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