Fire risks in forest carbon projects in Indonesia

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Abstract It is well known that forest carbon or sink projects have not been included in the Clean Development Mechanism (CDM), one of the flexible mechanisms created under the Kyoto Protocol. The main concern for postponing sink projects is related to issues of methodology and integrity. Project eligibility needs to be judged in a transparent manner if they are real, measurable, provide long-term benefits to mitigate climate change, and provide additional benefits to those that would occur in the absence of a certified project.

One of the biggest challenges in implementing sink projects is fire risks and the associated biophysical and socio-economic underlying causes. This study attempts to assess fire probability and use it as a tool to estimate fire risk in carbon sink projects. Fire risks may not only threaten ongoing projects but may also cause leakage of carbon stocks in other areas, especially in protected areas. This exercise was carried out in the Berbak National Park located in Jambi Province, Sumatra, Indonesia and the surrounding areas.

Fire probability is associated with (i) the means by which access to a given area is possible, and (ii) vegetation type or fuel load. Although most fires were intentionally ignited, fire escape is common and is enhanced by long spell of dry weather. When this occurs, secondary road was the most frequently used means, and it was certainly the case during 1997/1998 big fires when damage to natural vegetation (natural and secondary forests) was substantial. Burnt natural vegetation was 120000 ha or 95% of the total burnt areas, and released more than 7 Mt of carbon into the atmosphere.

Keywords: Kyoto Protocol, forest carbon benefits, probability, project eligibility, collateral benefits.

As stated in Article 12.2 of the Kyoto Protocol, the Clean Development Mechanism (CDM) has a dual purpose. On one hand, it is to assist parties not included in Annex 1 in achieving sustainable development and in contributing the ultimate objective of the Framework Convention on Climate Change. On the other hand, CDM is also to assist parties included in Annex 1 in achieving compliance with their quantified emission limitation and reduction commitments[1]. CDM projects will be eligible and able to generate certified emission reduction (CER) when they are real, measurable, long-term benefits related to mitigation of climate change and other benefits that would occur in the absence of the certified project activity. This implies that the inclusion of land-use, land-use change and forestry (LULUCF) activities in CDM will require a robust monitoring methodology. In addition, it also embraces ethical-related issues in connection with the efforts of conserving existing forests cover. Therefore, eligible forest carbon or sink projects should be accountable on the issues such as leakage and permanence[2].

It is worth noting that, globally, deliberate land management activities that enhance CO_2 uptake and reduce its emissions have the potential to remove a significant amount of CO_2 in the atmosphere over the next three decades[3]. As one of non-Annex 1 countries with large potential in LULUCF activities, Indonesia could participate in the CDM projects if the issues of leakage and permanence can be resolved. However, the “big fires” in 1997/1998 challenged the implementation of CDM projects in the forestry sector. Fire could be a potential risk that introduces substantial leakage and undermines the additionality that the projects would create, because it is not only a threat to the ongoing projects but also to the existing carbon stocks.

It was recognised that the emphasis of national strategies and action plans related to forest and land fires management had been on capacity building in fire-fighting[4]. No policy measures that could effectively discourage biomass burning were devised. Fire dynamics is not only biophysical processes but requires an understanding of the underlying socio-economic causes if sink projects were to succeed. In Jambi Province, and also in many other provinces, fire has been widely used by smallholder farmers and rubber tree planters as a tool to remove plant residues during land preparation and regeneration of the plantations. Biomass burning is a cheap way to gain space for new plantation, provides ashes, and reduces weeds, pests and diseases[5]. It may escape and become uncontrolled wildfire, especially when the weather is dry and fuel loads are high. Fire escape may occur in the neighbouring farm or even into the protected areas or nature reserves like Berbak National Park where this study was carried out. However, in a situation where land tenure is uncertain, fire may also be used as weapon to claim land ownership[6]. Economic incentive to the large-scale oil palm and forest planters has substantially enhanced the rate of forest and land conversions. Before zero burning policy and regulation were not fully implemented, there were a number of incentives that encouraged the use of fire. In contrast, market deregulation on smallholders’ timber harvested from agroforestry systems proposed by the Alternatives to Slash-and Burn (ASB) Consortium[7] did not materialise. If sinks were to be included in CDM it may be an attractive economic incentive for host countries to meet their sustainable development objectives. It would be real, measurable and additional when the land managers refrain from burning the biomass and eventually would offer environmental benefits for transboundary stakeholders[8]. Funding available from CDM projects should be a rewarding mechanism for the managers to maintain the existing carbon stocks and for avoiding the use of fire while enhancing carbon sequestration capacity.

Although it is understood that avoiding deforestation and forest conservation are not eligible for CDM projects, a case study was carried out in Berbak National Park in the Province of Jambi, Sumatra, Indonesia. Forestry activities in the buffer zones that are in the transition areas between the conserved and cultivated zones may be eligible if properly designed. This study assesses fire probability by analysing the pattern of hotspots using spatial and temporal data of 1997/1998 fire events. Analysis of weather data has also been carried out to demonstrate the dryness of the area, which is related to flammability of biomass fuels. In the study area, biomass is usually slashed and accumulated in March-April and deliberately ignited in September-October[9]. It is expected that fire probability would be a useful tool to estimate fire risk in forest carbon projects. Finally, this study also reports the associated carbon emissions from using fire as a tool to remove terrestrial carbon stocks.

1 Site description

The Berbak National Park is located in the eastern coast of Jambi Province on Sumatra Island, Indonesia. It covers an area of 162700 ha and is one of the largest protected wetland ecosystems in the region situated at 103°27′47.39″E—104°30′42.52″E and 0°58′30.43″S—1°54′8.58″S. This National Park, like the rest of the province and almost the whole island, was badly affected by the big fires in 1997/1998. The surrounding buffer areas of the National Park were also included in the study.

Wetland ecosystems are the most common vegetation type in the region with high diversity of flora and fauna including a number of endemic species. In this study, out of 19 land-cover types only 14 experienced fire in 1997/1998. These are: dry land crops, high forest regrowth, low forest regrowth, medium peat forest, medium forest regrowth, mosaic of other vegetation and forest, mosaic of plant and secondary forest, non-forest regrowth, oil palm plantation, open peat forest, other vegetation plantation, other forest plantation, wetland crops, and wetland grass.

Soils are mainly waterlogged with over 55% of organic matter (organosols). Gleisols and alluvial are found nearby the rivers and differentiated by their texture. The C/N ratio is usually high (more than 30%) with low pH of around 4.0. When the organosols are drained and exposed they become very acid and are of little use for agriculture. Drainage may also cause land subsidence and increased fire susceptibility. The mean annual rainfall of the study area ranges between 2000 and 2500 mm with one to four dry month (less than 100 mm) resulting in high humidity throughout the year (81%—86%). The mean monthly temperature ranges from 22.7℃ to 31.6℃ with an annual average of 26.5℃.

The park is surrounded by villages and small townships with various ethnical groups. The Javanese and Malay occupy the dryland, Banajarese and Buginese occupy the coastal area and the Chinese mostly live in towns. In 1990 the population density of four sub-districts in the wetland area was 35—45 people/km^2 with a growth rate of less than 2% per annum. The main occupations of the population are farmer, fisherman, wood and rattan gatherer, and merchant. Farmers are usually without land tittle and the increasing need of land may cause further encroachment of natural vegetation.

2 Methodology

Fire events were detected by using temperature threshold ranging between 315 and 320 K from the NOAA-AVHRR imageries from August 1997 to May 1998. The accumulated hotspots data were plotted using ArcView for the entire island of Sumatra and Jambi Province. In order to identify the locations and impacts of 1997 fires in the study area the fire-scars were interpreted from high-resolution LANDSAT-TM imageries for 1998 using RGB 542 and RGB 754 combinations. Due to the low spatial resolution of NOAA satellite from which the hotspot data were obtained, the fire-scars were used to filter the hotspot data. Only hotspots inside the fire-scars were considered as valid fire events and used for further frequency analysis. Therefore, hotspot frequency is defined as the occurrence of hotspots within the fire-scars relative to the occurrence of the entire hotspots or observable fire events in the study area.

Road and river networks provide access for people to lit fires, and types of land-cover would determine their attractiveness for people to convert. Together with the other information, such as settlement and transmigration areas, these biophysical attributes are available in vector format. In order to relate the hotspot frequency with these attributes all data were converted into raster format of 1.1×1.1 km^2 grid cells (following spatial resolution of NOAA data) using IDRISI32 software.

The atmospheric dryness of the region which leads to the flammability of biomass fuels was estimated using Keetch-Byram dryness index (KBDI)[10] by employing weather data including daily rainfall, annual rainfall and daily maximum air temperature. Ranges of dryness indices are grouped into four classes: low (0—999), medium (1000—1499), high (1500—1749) and extremely high (1750—2000).

Fire spatial information of vegetation types, fire-scars and carbon density are needed in order to estimate carbon stocks and losses. The 14 land-cover types included in the study were regrouped into four main vegetation types whose carbon densities were estimated: natural forests, secondary forests, early stage crops and plantations, and shrubs. Three to four replicates were taken along the transect to estimate their biomass. In the event of fire, the amount of biomass burnt ranged between 50 and 66 percent depending on the volume of woody biomass[11]. A correction factor of 0.55 was adopted to estimate biomass burnt by fires, and a factor of 0.45 was applied to convert biomass loss into carbon (C) loss as suggested by ref. [12].

Since there is no socio-economic data available in a compatible format the analysis was based on interviews during a household survey carried out in April 1999. The survey was conducted in three villages of Air Hitam Laut, Rantau Rasau and Sungai Rambut. Air Hitam Laut is situated on the east coast of Jambi Province from where people could get direct access to Berbak National Park through Air Hitam Laut River, while Rantau Rasau and Sungai Rambut are situated along the boundary of Berbak National Park. During the household survey 25 families were involved in detailed interviews excluding individuals met inside the Park who provided information about land ownership, main income and expenditures, land productivity, etc. A small scale experiment on fuel load was carried out by following the local practice of slash and burn, especially relevant to readily burned biomass fuels. Fine dead and live materials (leaves and branches less than 5 cm in diameter) were grouped and separated from those larger than 5 up to 10 cm. Samples were collected from three replicates of 10×10 m^2 plots both outside and inside the Park. Dry weight data is presented in this study.

3 Results

3.1 Fire distribution and biophysical attributes

The accumulated hotspot data for the entire island of Sumatra and Jambi Province were plotted using ArcView and shown in fig. 1. The fire distribution and severance were mainly associated with September and October 1997 hotspot data yielding more than 3000 hotspots in the Park. Plate I(a) shows the fire-scars analysed from LANDSAT-TM imageries of 1998 to demonstrate the impacts of previous year fires on the vegetation cover inside and outside the Park. The hotspots considered for the fire frequency or probability analysis are only those included within the fire-scars and shown in Plate I(b).

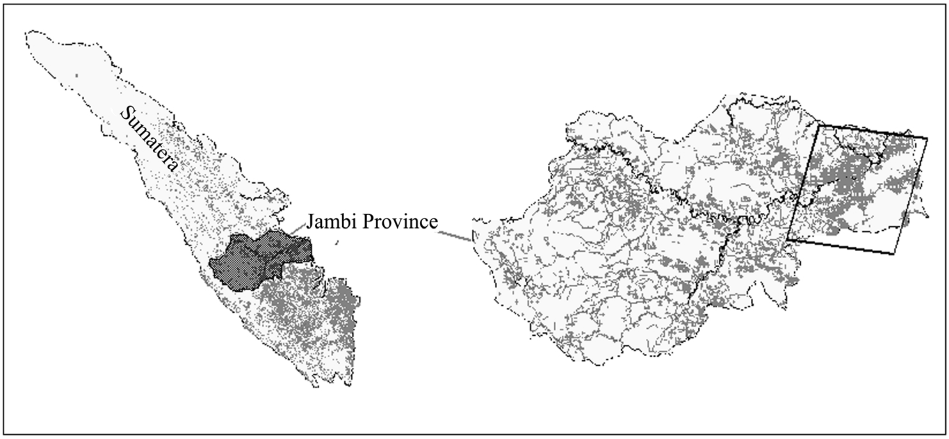

Fig. 1. Hotspots in Sumatra island and Jambi Province during 1997/1998 fire events. More than 3000 hotspots were found in Berbak National Park during September—October 1997 fires.

The relationship between hotspot frequency or fire probability to the distance to biophysical attributes are summarised in fig. 2. It shows that secondary roads are the most preferred means to access land, which is indicated by the sensitivity of the frequency of hotspots with distance to secondary roads. In reality secondary roads are old logging roads that provide access to the areas currently seen as burnt areas. Secondary rivers are the most unlikely means to reach sites to set fires. Main roads are also not commonly used to access the area. Thus, fires are used for land clearing in remote places where transportation is relatively easy and the sites are less than 10 km from the means of access. There is no indication that the community groups set fires nearby their homestead. It is very logical that they care about their own safety, regardless of the ethnic group.

3.2 Relationship of fire to dryness index

The daily KBDI of the study area during 1991—1999 is calculated using daily weather data obtained from two stations within the study area. The results are shown in fig. 3 which demon-

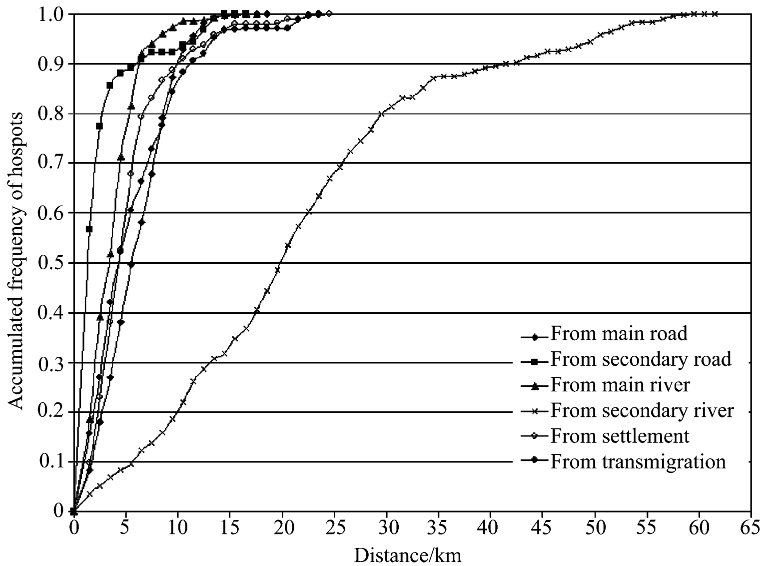

Fig. 2. Accumulated hotspot frequency against distances to various biophysical attributes. Secondary roads are the most closely linked attribute to the occurrence of fire.

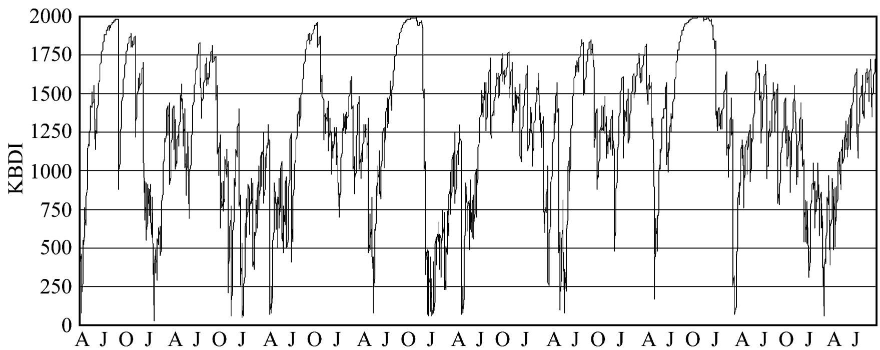

Fig. 3. Keetch-Byram Dryness Index (KBDI) of the study area during 1991—1999. Extremely high indices (larger than 1750) that lasted for five months (July—November) is shown in 1997.

strates that the timing of 1997 big fire was associated with extremely high KBDI (higher than 1750) which lasted for almost five months (1 July—22 November 1997) and reached the highest value of 1998. Fig. 3 also shows that during the dry season of 1991—1994 the KBDI were also high but not as high as found in 1997 but did not last as long, except in 1994 KBDI lasted for almost four months (19 July—30 October 1994). Similar outcome was found when the method was used in East Kalimantan[13]. It means that KBDI is a good proxy for fire risk and may be used as an early warning system. The problem lies on the capacity in forecasting or generating daily weather data.

3.3 Relationship of fire to land use and land cover

The rasterised land-cover types in the study area obtained from the TREES Project (Dennis, 2000——unpublished data) was plotted against hotspot frequency. Fig. 4 shows that high frequencies of hotspot occurred in natural vegetation like primary and secondary forests or regrowth of logged forests. The accumulated frequency of hotspots in these land cover types is almost 70%. Man-made croplands were almost not affected during 1997/1998 fire episode with hotspot frequency of only around 1%. These are in agreement with the calculated burnt areas by vegetation types as summarised in table 1. The largest area burnt was natural forest (67%) and the least burnt was crop and plantation (1%). In addition, secondary forests were affected the most among all types of vegetation burnt. Three quarters of the existing secondary forests were burnt compared to one quarter of natural forests. It indicates that fire probability is higher in forested lands than in croplands and shrubs, and secondary forests in particular were affected most seriously.

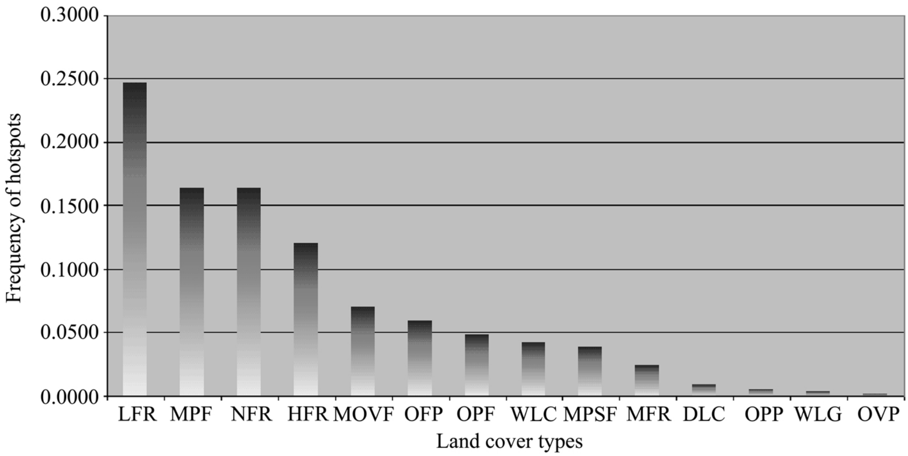

Fig. 4. Hotspot frequency in each land-cover type. Accumulated frequency in natural vegetation (almost 70%) is much higher than man-made vegetation.

Table 1 Area of vegetation types before and after fire in the study area/ha

Vegetation type	Before fire	After fire	Area burnt		
				each type (%)	total burnt(%)
Natural forests	356,145.70	272,401.71	83743.99	24	67
Secondary forests	48,143.91	13,477.15	34666.76	73	28
Early stage crops and plantations	247,447.99	246,023.33	1424.67	0.5	1
Shrubs	26,896.81	22,483.84	4412.97	15	4
Total	678,634.42	554,386.03	124248.39		

These trends are supported by the relative importance of readily combustible biomass fuel load in both natural and secondary forests as shown in table 2. Secondary forests have more fuel load than natural forest inside the park. In addition, the condition of biomass in the Park is wetter than those found in the secondary forests outside the Park. No measurements on fuel load were made in croplands and shrubland but it is expected to be lower than in forested lands. A study in *Imperata* grassland in West Java, which has similar features as shrubs, shows that the fuel loading was 18.6 Mg ha^{-1}[14].

Table 2 Readily combustible biomass fuel loads in areas with natural vegetation inside and outside the Park (dry weight, Mg ha^{-1})

Diameter /cm	Natural forest (NF)			Secondary forest (SF)			Mean	
	I	II	III	I	II	III	NF	SF
< 5	27.0	14.8	16.8	54.8	34.7	38.2	19.5 ± 6.5	42.6 ± 10.7
5—10	8.4	8.2	8.2	164.5	97.7	119.9	8.3 ± 0.1	72.5 ± 63.8

3.4 Estimates of carbon loss

The amount of carbon stored in each vegetation type was estimated using available information on biomass of each vegetation type. Based on the study carried out by the consortium of the Alternatives to Slash-and-Burn (ASB) project the carbon density of those vegetation types listed in table 1 are estimated to be 306 Mg ha^{-1} for natural forests, 93 Mg ha^{-1} for secondary forests, 22 Mg ha^{-1} for crops, and 2 Mg ha^{-1} for early stage of plantation[15]. These figures are within the range of 10%—15% standard deviation, which were derived from several replicates from different sites in the upland having similar vegetation structure. The amount of carbon loss due to fires from each vegetation type was estimated (table 3). The amount of carbon released to the atmosphere was around 7 M t during the 1997/1998 fire event alone.

Table 3 Biomass and carbon loss from each vegetation type due to fire events in 1997/1998

Vegetation type	Biomass loss/Mg	Carbon loss/Mg
Natural forests (undisturbed)	14094113.52	6342351.08
Secondary forests (logged-over)	1773204.77	797942.15
Crops and plantations (early stage)	17238.51	7757.33
Shrubs (including grassland)	4854.27	2184.42
Total	14889411.07	7150234.98

4 Discussions

4.1 Fire risks and forest carbon project eligibility under CDM

Using fire-scars it is demonstrated that most fires occurred outside the park where access is easier and fuel loads are higher. It means that developing forest carbon projects following land-use change in these areas would face higher risks. Long dry spell may worsen the situation when fires could accidentally escape or intentionally set in protected areas. Project eligibility would then be under question. In order to secure the sequestered carbon in the project areas, incentives obtained from CDM should cover possible risks of leakage into protected areas. The incentives may be used to encourage smallholder farmers not to burn the ‘waste’ or timber produced from their farm. The incentives could also be used to promote no-burning policy (e.g. by chipping or shredding woody biomass) with appropriate and cost-effective technology and transportation systems[16].

With these activities the fuel loads may be kept as low as possible. Securing the sequestered carbon in the living biomass is a permanence issue that merit further quantification regarding biomass harvest and decay.

4.2 Collateral benefits

Although funds for CDM projects cannot be used for conservation purposes, forest carbon project activities outside the Berbak National Park could ease the pressure on the Park from further encroachment. During the socio-economic and household survey a number of local people were met inside the Park to collect logs and catch fishes. Since the water level of the rivers and their tributaries were low the access to the site was difficult and people tend to stay for several days in the Park. Fish catches were smoked to preserve them, a process by which wildfires were accidentally initiated. The assumption that local people participation in the projects would give better security to the effort to protect the Park was demonstrable[17].

The most vulnerable system in the Park is peat swamp when the land is cleared, burnt and converted[18]. With incentives for activities outside the Park the threat to the fragile ecosystems may be reduced or avoided. The Park is also known to host several endemic species that require special care of the entire ecosystem. No monetary accounting has been done for these species but forest carbon projects outside the Park could generate positive collateral benefits.

5 Concluding remarks

Overlying hotspots and fire-scars has been a useful approach to delineating fire events in spatial terms from which statistical analysis may be conducted with high degree of confidence. Furthermore, the method could demonstrate the relative importance of biophysical attributes to the occurrence of fires.

Fire risk is higher where access is easier and fuel load is higher. Dry weather enhances fire probability and facilitates fire escapes to become uncontrollable wildfires. Nonetheless, fire risk is demonstrable and may be taken into account to evaluate the feasibility of forest carbon projects. Fire risk does not only threat the sequestered carbon in the project but may also cause leakage in the other sites, especially in protected areas. Capability in internalising fire risks in the project such as local people participation, accounting of collateral benefits could enhance project eligibility under the CDM.

It is a challenge to project proponents that in a long dry spell in 1997 a single fire event could release 7 Mt of carbon to the atmosphere from the so-called protected areas and its buffer zones. This magnitude is equivalent to the amount of carbon that would have been sequestered by a plantation of 0.5 Mha fast growing tree species with mean annual increment of 3 m^3 when it reaches harvesting time in 10 years. However, forest carbon should not be viewed solely as carbon sink. The sustainability of the ecosystems and the livelihood have to be consciously taken into account as that is what CDM for.

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