Recent peat fire trend in the Mega Rice Project (MRP) area in Central Kalimantan, Indonesia

Erianto Indra Putra
Candidate for the Degree of Doctor of Philosophy
Supervisor : Associate Prof. Hiroshi Hayasaka
Division of Human Environmental System

I. INTRODUCTION

In 1996, the Indonesian Government initiated the Mega Rice Project (MRP) in Central Kalimantan to convert one million hectares of peatland between Sebangau and Barito rivers to fields for cultivating rice and promoting transmigration (migration inside of Indonesia). The MRP closed at 1999 but it left vast drained peatland mainly due to the built of the channels to open up this area and make it suitable for cultivation. Frequently large fire occurrences in MRP area are believed released huge amounts of carbon dioxide to the atmosphere. Around 4,740 km² area in MRP has been damaged from severe fire episodes in 1997 and released 0.19 – 0.23 Gt of carbon to the atmosphere [1]. This huge amount of carbon released to the atmosphere is suggesting that severe peat fires in MRP area may lead to the large amount of carbon emission.

More than 90% of peat fires in Central Kalimantan from 1997 to 2007 occurred in dry season. Ground Water Level (GWL) in peatland area is getting lowered under dry weather condition, dry up peat and organic fuel in its upper layer and creates suitable condition for fires to be ignited. Main goal of this study is to gain better understanding on the peat fire trend in the MRP area and underlying it causes and impacts. To achieve this, objectives of this study were as follows: (1) to understand how drought and peat fires were related in the MRP area through daily hotspot and weather data analysis, (2) to investigate the relationship among precipitation pattern in the dry season, SST Anomalies, ground water level and peat fire trends in the MRP, (3) to identify the most affected areas from peat fires and to assess the burnt area in MRP, (4) to estimate carbon emission due to peat fire in MRP area, and (5) to clarify the effect of peat fire occurrences to air quality.

II. METHODOLOGY

Analysis is done for daily hotspots data captured in MRP area by SiPongi-NOAA and NASA-MODIS satellite, daily precipitation and SST anomalies data to clarify the relationship among SST anomalies, precipitation and peat fire occurrences. Precipitation and hotspots data are processed by using five-days moving average to obtain their smoothed daily and seasonal pattern. Ground water level (GWL) is modeled from data measurement done by Takahashi et al. [2].

Mapping of hotspots using 3,117 grids of 1 km² by using ArcView is done to determine where the worst fire occurred in the MRP. To assess the burnt area, this study built an algorithm to obtain the of 1.21 km² buffer of each of hotspots captured by SiPongi-NOAA and 1 km² of NASA-MODIS.

To observe impact of peat fire occurrences on air pollution condition in Palangkaraya, daily hotspots and daily air pollution data were analyzed. Number of fire was derived from daily hotspots detected on about 400 km² area of MRP surrounding Palangkaraya.

Carbon-loss due to peat fire in MRP area is estimated by using formula of:

\[ C_t = \rho \ A \ d \ c, \text{ where } C_t = \text{carbon-loss (ton)}, \rho = \text{peat bulk density (g/cm}^3\text{ or ton/m}^3\text{)}, A = \text{burnt area (m}^2\text{)}, d = \text{peat burnt depth (m)} \text{ and } c = \text{peat carbon content (%)}\]

Peat bulk density assumed here was 0.1 g/cm³ and peat carbon content is 57% [1]. CO₂ emission is derived by converting carbon-loss using conversion factor of 3.67 (ratio of molecular weights of CO₂ and carbon).

III. RESULTS AND DISCUSSIONS

3.1 Recent hotspot (fire) trend in Kalimantan and Sumatra

Fires in tropical forest and peat area in Indonesia are not new phenomenon. Recently forest and land fires in Indonesia have become commonplace and occurred every year. Unfortunately, the old fires history data in Indonesia is not documented well. Official reports on burned forest areas provided by the Ministry of Forestry of Indonesia became available only from 1984. In other hand, the daily satellite data detection was available only from July 1997 when the Ministry of Forestry (MOF) and Japan International Cooperation Agency (JICA) started hotspot detection using NOAA-AVHRR satellite for the western part of Indonesia. From the end of 2000, MODIS satellite from NASA/FIRMS started to detect hotspots in Indonesia. However, the complete fire datasets from NASA/FIRMS were available from 2001.

Fig. 1 showed recent Indonesian forests burns and the number of hotspots detected in western Indonesia by NOAA-AVHRR satellite from the Japan International Cooperation Agency Forest Fire Prevention Management Project (JICA-FFPMP) – SiPongi. The hotspots data in Fig. 1 covers Sumatra, Kalimantan, Java, Bali, and Sulawesi Islands.

Over 1,000 km² of forest area burned in 1991, 1994, and 1997, with the highest in 1998. Over 60,000 hotspots or Indonesian fires were recorded in 1997 and 2002 or in El-Nino years, brought the evidence of the close relationship between fire and El-Nino event. However, recently large number of fires also found in
Non El-Nino year such as in 2001, 2003, 2004, 2005, and 2006. The highest number of hotspots is found in 2006 (147,731), made 2006 as the worst fire year since 1997. These findings strongly suggest that recently fire in Indonesia has become yearly occurrences and not only El-Nino event any more.

Fig 1. Forest burnt area and number of hotspots detected by SiPongi-NOAA, 1984 – 2007

3.2. Recent hotspot (fire) trend in MRP area

3.2.1. Trend of dry season in Palangkaraya

The smoothed mean daily precipitation curve shows a U-shaped precipitation pattern in Palangkaraya (Fig. 2). A daily mean precipitation (7.84 mm) is used to differentiate the dry and wet seasons in Palangkaraya.

The wet season lasts about seven months and it is two months longer than the dry season. The length of the dry season is about five months from the start of June (DN 152) to the end of October (DN 301). Thus, this study defines June to October as the dry season in Palangkaraya.

The precipitation pattern in Fig. 2 clearly shows the large difference in precipitation between the wet and dry seasons in Palangkaraya. There is a more than two times difference between the mean daily precipitation values in the dry season (4.69 mm) and wet season (10.0 mm), and the total precipitation in the dry season (698.9 mm) is only 1/3 of that in the wet season. This pattern clearly describes the overall dry climate conditions in Palangkaraya during the dry season.

Low daily precipitation, less than the mean dry precipitation (4.69 mm), occurred between July and September and the lowest daily precipitation of less than 3 mm is in the middle of August. Low precipitation brings a drier climate and increases the dryness of the peat in the MRP area. Thus, based on the data here we suggest the middle of August as both the peak of the dry season as well as the start of the peak of the fire season.

There was a negative correlation between SST Anomalies and precipitation in Palangkaraya in July – October, 1978 - 2006 (Fig. 3), indicating that the drought in Palangkaraya is proportional to positive SST anomalies. The of more than +0.5°C SST Anomalies bring less than 400 mm precipitation in July – October such as in 1997, 1991, 2004, 2006, 1982, 1987, and 2002. However, below mean value precipitation also occurred in several neutral or non El-Nino years such as in 2003, 2004 and 2005, when there were low positive SST Anomalies between +0.1°C and +0.5°C. This may indicate that recently even low positive SST Anomaly occurrences may bring on severe dry conditions in Palangkaraya.

Fig. 3. Correlation between SST Anomalies and total precipitation in July - October, 1978 – 2007

Dry climate during dry season may dry up above ground fuel and peat and increasing its flaming risk. Over 90% of hotspots in the MRP area from 1997 to 2007 (Fig. 4) occurred between July and October or during the dry season.

High numbers of hotspots were detected primarily in the dry seasons with high positive SST Anomalies. The SiPongi-NOAA captured 8,401 hotspots in 1997, 4,961 in 2002, 3,591 in 2004, and 5,734 in 2006, when high positive SST Anomalies enhanced longer dry periods. In these years fire events peaked in August, September, and October, when the area had precipitation below 100 mm.

Fig. 4. Precipitation and hotspot occurrences in the MRP area, 1997 – 2007.

High numbers of fires, however, also occurred in the dry seasons of 2001, 2003 and 2005; when positive SST anomalies were low, suggesting that fire occurrence is associated with droughts as indicated by positive SST anomalies. Therefore peat fires in the
MRP area are no longer limited to El Niño years.

Strong relationship ($R^2$=86.42%) is found between the number of hotspots and positive SST anomalies in July to October in 1997 to 2007 (Fig. 5). Positive SST anomalies thus clearly induced high numbers of fires. The highest number of hotspots occurred during the 1997 following the highest SST anomalies in this year. A relatively high number of fires were observed also, however, in non-El Niño years with positive SST anomalies, i.e., in 2001, 2003, and 2005. Over 1,500 fires occurred in these years when SST anomalies exceeded +0.3°C, indicating that recently even low positive SST Anomalies yield high numbers of fires.

![Fig. 5. Relationship between number of hotspots and maximum SST anomalies, July – October 1997-2006](image)

Number of hotspot detected per km² area is used in this study to express fire density. Hotspots density from 1997 - 2007 in MRP and non-MRP area is shown in Fig. 6. In average, hotspots density in MRP area (21 hotspots/100 km²) is 5.54 times higher than that in non-MRP area (6 hotspots/100 km²), suggesting that MRP is the most dense peat fires area in Central Kalimantan in recent years. More than 63% (9,191 km²) areas of MRP consist of peatland which is equal to 30% of total existing peatlands in Central Kalimantan (30,951 km²).

![Fig. 6. Hotspots density in and non-MRP, 1997 - 2007](image)

Analysis on daily hotspot occurrences captured by NASA-MODIS satellite (Fig. 7) showed fire is more pronounced in the dry season. More than 88% fires occurred during the dry season, strongly suggesting the close relation between dry season and fire occurrences in MRP area.

The number of fires increased progressively in the dry season as the dry season progressed. Fires in the starting month of the dry season (June) contributed only 1.24% of the total number of fires, but fires at the end of the dry season (October) contributes more than 39% of the total number. The peak of the fire period tends to start from the middle of August and ends at the start of November. Fires in the peak fire periods numbered 2938 or around 87.1% of the annual number of fires in the MRP area.

![Fig. 7. Daily hotspot occurrences trend, 2001-2007](image)

Fig. 3-26 shows that the peat fire occurrence in the MRP area coincides with the precipitation curve. Daily precipitation decreased gradually from June and reached the lowest point in the middle of August, creating the necessary dry conditions for fires to ignite. Then, fires start to occur on a daily basis from the middle of June and become numerous from the end of July, making the end of July the start of the fire season in the MRP area. The peak fire period starts from the middle of August when daily precipitation drops below the lowest mean value, less than 3 mm. The fire season ended at the middle of November or about twenty days after the end of the dry season at the end of October. This may indicate that peat in the MRP area is still in the dry condition at the beginning of the wet season, after suffering from the severe dry conditions of the long dry season, thus maintaining the condition where ignition is easy.

![Fig. 7. Daily precipitation and hotspot occurrences trend in MRP area](image)

3.3. Ground water level, precipitation and peat fire occurrence in MRP area

Fig. 8 showed the changes in GWL in the MRP area. The GWL stays steady at around 5 cm higher than the soil surface between January and the middle of May, in the wet season; suggests that the area could be categorized as a peat swamp forest area. The GWL decreased progressively below soil surface during the dry season from the end of May until it reached the lowest value in early October; clearly indicating that the GWL followed the precipitation changes. However, there is a time-lag between GWL and precipitation.

There is about a one and a half month time-lag between the lowest precipitation in mid August and the lowest GWL in early October. The decrease of
precipitation takes 3 months to reach the lowest in mid August (from mid May), but the lowering of GWL below the soil surface takes around 4.5 months from the middle of May until it reaches its lowest value in early October. The GWL then reaches the soil surface again at the end of December after the precipitation has reached its highest value in mid December. This may suggest that the recovery of the ground water level in the MRP area occurs after having been replenished by the water supplied by the continuous precipitation.

Fig. 8. Ground water level and precipitation changes

Fire occurrences in the MRP area coincide with the GWL (Fig. 9). More than 99% of fires occurred when the GWL was below the soil surface. The peak fire period in the MRP area started when the GWL reached -40 cm in the middle of August and fires become more severe when GWL is below -40 cm from the middle of August till early November. Therefore this study suggests -40 cm as a critical level of GWL for large peat fire occurrences in the MRP area, and this GWL should be used as an indicator for a high likelihood of severe fire occurrences there.

Fig. 9. Ground water level and hotspot occurrence in MRP Area

The decreases of GWL clearly indicated that in recent years GWL in the Mega Rice Project (MRP) area became very deep mainly in the dry season. Therefore peatlands were in severely dry conditions in the dry season and this creates a situation where ignition and combustion is promoted, and the large number of fires that occur while the ground water level is low in the dry season substantiates this.

3.4 Peat fire distribution and density

In order to find the most dense areas from peat fire, local MRP area fire density of 1 x 1 km grids is calculated based on NASA-MODIS daily hotspot data from 2001 to 2009 (Fig. 10). Number of hotspots/km² is used as a unit for fire density. Almost all areas were affected by fires, with the highest fire density in the southern part of Block C and upper part of Block A. High fire density was also observed along channels in Blocks C and B, central part of Block A and near main drainage channels in Block A and B. Recurring fires in these areas resulted to the high fire density.

Fig. 10. Hotspot (fire) density in MRP area during 2001 – 2009

High hotspots density of more than 32 hotspots/km² during 2001 – 2009 was found along the canals in southern part of Block C, paddy fields in Block A and along primary channel in Block A and B. Southern part of Block C is dominated by high hotspot density of more than 53 hotspots/km² as well as along Trans-Kalimantan highway road and along canals in northern and eastern part of study area. Less hotspots density was found in forest area of Block E.

There were many agricultural field and abandoned farmland found along the canals as well as along Trans-Kalimantan highway road. The fact that these high-fire-density areas mainly involve paddy fields and abandoned farmland, mostly located near channels, suggests that using fire in land preparation and slash-and-burn activities in the dry season still continuing. Thus, as the peat fires here are human-caused fires, peat fire in MRP must be prevented by reducing both intentional and careless fire use. This requires that people in MRP area communities must be trained and their awareness of fire prevention and fire extinguishing must be raised.

3.5 Assessment of fire-affected area

Series of fire-affected areas in MRP from 1997 to 2009 is shown in Fig. 11. The estimation of these fire affected areas is done by using daily hotspots dataset provided by SiPongi-NOAA (from 1997 to 2001) and NASA – MODIS (from 2001 to 2009).

Large fire-affected areas in MRP are found in 1997, 2002, 2006 and 2009. Highest number of hotspots (fires) was detected in 1997 (8,481) and largest burnt area (4,344 km²) was found in the same year.
in MRP in 1997 is estimated at 0.087 Gt, following largest burnt area in this year. Carbon emission is estimated at 0.056 Gt in 2002, 0.059 Gt in 2006, and 0.042 Gt in 2009.

Even the MRP land area (14,571 km²) occupies only 0.77% of whole land area of Indonesia (1,890,754 km²), but CO2 emission from fires here are estimated to be responsible for 12.4% (0.32 Gt) and 11.6% (0.22 Gt) of Indonesian CO2 emission in 1997 and 2006, respectively. The estimation for CO2 emissions from fires in Indonesia is derived from Hoijeer et al. [4]. Numbers provided above strongly suggest the importance of fire prevention in MRP for carbon emission reduction.

3.7. Peat fire impacts on air quality

Figs 14 and 15 showed that PM10 and CO concentration increased significantly every year in the dry season, and peaked in October after large number of peat fires occurred. Highest PM10 and CO concentration was observed in 2002 following largest number of fires in this year; decreased air quality in Palangkaraya to seriously hazardous level for PM10 and to very unhealthy level for the CO.

Number of fires from July – October 2002 was 775 and maximum PM10 and CO concentration was observed in October 2002 (1904 µg/m³ for PM10 and 38 ppm for CO). Peat fire occurrences in 2006 increased PM10 concentration to around 1700 µg/m³.
and 21.9 ppm for CO (Fig. 14). CO concentration in 2006 was almost similar with that in 2004. These evidences clearly indicate that large number of fire occurrences will decrease air quality in Palangkaraya greatly to dangerous levels for human health.

IV. CONCLUSIONS

Hotspot (fire) data, daily weather data, SST Anomalies, and ground water level data were analyzed in this study to clarify recent peat fire trend in the Mega Rice Project (MRP) area. The results of this study are summarized as follows:

1. This study clearly showed that large areas of bare peat in the MRP area are now highly susceptible to fires. Recent trend of hotspot (fire) showed that many hotspots (fires) found in bare peatland in MRP area after MRP development. Most of hotspots (fires) were occurred in dry months of August to October from 2001; indicating the couples of dry season and peat fire trend in MRP area.

2. The daily precipitation analysis using 30 years weather data from 1978 to 2007 clearly showed that Palangkaraya has seven month wet season and five months dry season that starts from early of June and ends at the end of October. About two times difference between mean precipitation values in the dry and wet season was also found. Mean daily precipitation less than 3 mm were found in August or in the middle of dry season, suggesting the middle of August as the peak of the dry season as well as the start of the peak fire period. Under this precipitation pattern, dryness of peat is increased and stimulated the large number of fire occurrences.

3. Peat fire in MRP area is found more pronounced in El-Niño years, but number of fires exceeded 2,500 in non-El-Niño year with positive SST anomalies in 2003 and 2005; indicates that recently even low positive SST Anomalies more than +0.3°C may result to high number of fires. Thus, SST Anomalies may more precisely relate to fire trend in MRP area instead of El-Niño event.

4. In the MRP area, peat fire occurrences are closely related to the severity of drought and SST anomalies. SST anomalies have a negative correlation with precipitation and positive high correlation with number of hotspots (fires). From the above relation, we may say that peat fire trends in the MRP area is related to local peat dryness there.

5. GWL (ground water level) starts to decrease from around the middle of May. This GWL tendency is mainly due to precipitation pattern change from the wet to dry season. Then, the fire season starts when GWL becomes negative, showing that fire occurrence is closely related with ground water level change and precipitation pattern in the dry season.

6. The peak fire period coincided with low GWL less than -40 cm, suggesting around -40 cm as a critical level for peat fire occurrence. Thus, -40 cm of GWL could be used as an alarm for the severe peat fire occurrence in the MRP area.

7. A detailed hotspot distribution map showed that large area of Blocks C and A in MRP seriously damaged by peat fires. Their percentage of fire-affected area to total block area during 1997 – 2009 reached 73.9% in Block C and 74.6% in Block A. High peat fire density are found in agricultural fields, abandoned lands and along canals and roads, suggesting that intensive ongoing human activity accelerates fire occurrences in MRP. Thus, this situation allows us to classify peat fires here as one of man-made disasters.

8. Carbon emission from peat fires in MRP is estimated at 0.087 Gt in 1997, 0.057 Gt in 2002 and 0.059 Gt in 2006, by assuming constant burnt depth of 51 cm from 1997 to 2001 and 39 cm from 2002 to 2009. Although the MRP land area (14,571 km²) occupies only 0.77% of all land area of Indonesia (1,890,754 km²), CO₂ emission from fires in the MRP area are estimated to be responsible for 12.4% (0.32 Gt) and 11.6% (0.22 Gt) of Indonesian CO₂ emission in 1997 and 2006, respectively, strongly indicating the importance of peat fire prevention in the MRP from the viewpoint of world carbon emission.

9. Severe peat fire occurrences in 2002 and 2006 decreased air quality in Palangkaraya when PM₁₀ and CO concentration exceeded 1700 µg/m³ and 20 ppm, respectively; strongly indicates that large peat fire occurrences will decrease air quality significantly to very dangerous level for human health.

REFERENCES