2017 Asia Forest Fire Management Training

Seoul, Republic of Korea, 15-22 October 2017

Peat land fire behavior and environmental impacts

•by

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National Institute of Forest Science

APAFRI

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국립산림과학원
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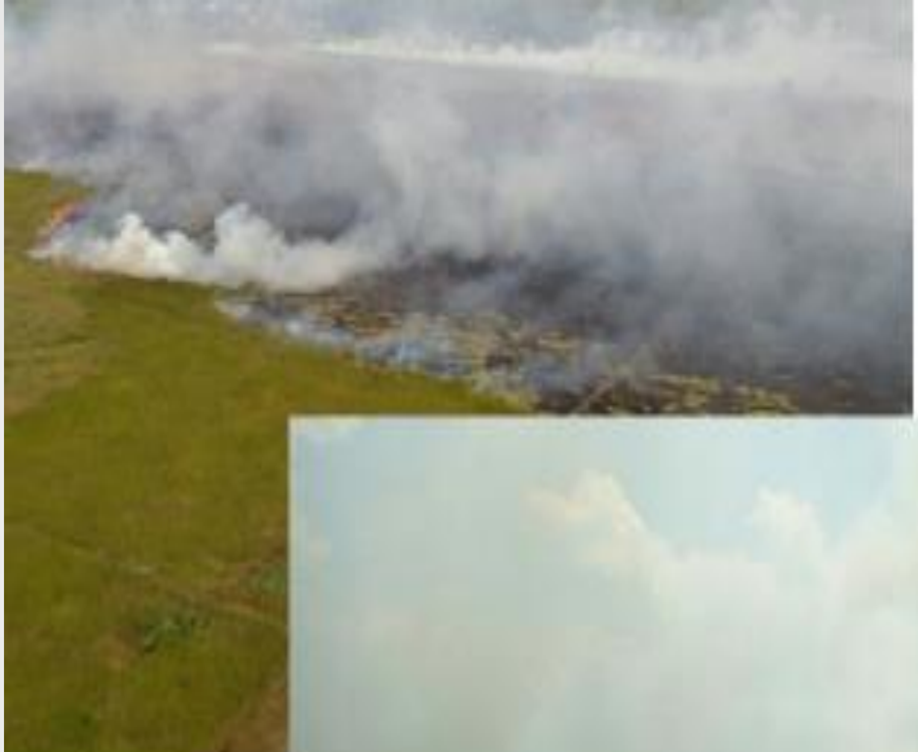
INTRODUCTION

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CITY OF PALEMBANG, SOUTH SUMATERA (OCT. 2014)

What is peat?

- Peat is formed by the accumulation of organic matter derived mainly from dead vegetation (e.g. mosses, shrubs and trees) in situations where decomposition (i.e., the breaking down of plant and animal material) is limited.
- Tropical peat is formed mainly from the undecomposed remains of rain forest trees.

TROPICAL PEAT

- Tropical peat is defined as all organic soils in the wetlands of the tropics and subtropics lying within latitudes 35 degrees North and South including those at high altitudes (Andriesse, 1988).
- Formed under anaerobic conditions (Carlson, 1985) through the action of bacteria, fungi and chemical compounds on plant remains, peat is an organic material which develops as a result of the incomplete breakdown of wetland vegetation (Shier, 1985).
- Tropical peatland covers about 10 - 12% of the world total peatland area, though, it store about 191 Gt C (Page &Rieley, 1998) or about one third from the total carbon storage in peatland.
- Assuming that average peat depth of 5 m, tropical peatland ecosystem store 2,500 ton C/hectare, compared to the average of 1,200 ton C/ha in peatland in general (Diemont *et al.*,1997).

PEAT DECOMPOSITION

- The decomposition of the peat is called the degree of humification (Carlson, 1985) of which peat are grouped into (Stanturf and Schoenholtz, 1998);
- Fibrists (peat), more than 2/3 of the plant fibres they contain are identifiable and less than 1/3 decomposed,
- Saprists (mucks), less than 1/3 of the plant fibres they contain are identifiable and more than 2/3 decomposed,
- Hemists (mucky peats), intermediate decomposition between peats and mucks.

PEAT CHARACTERISTICS

- Peat can contain 500 to 1000 % (van Veen, 1997) or 300 to 800 % (Sugandhy, 1997) of its own weight in water on a dry weight basis.
- Tropical lowland peat soil has a particularly high water holding capacity (Radjagukguk, 1997).
- Moisture content of peat increased with depth from less than 400 % in 0 – 30 cm depth to more than 550 % in 30 – 60 cm depth (Franky *et al.*, 1999).
- It seems that the difference of moisture content was determined by that of decomposition level and also botanical origin (Andriesse, 1988).
- The large variation in water retention between peat materials is a function of porosity, pore size distribution (Sanches and Logan, 1992) and hydraulic conductivity (Andriesse, 1988).
- Coarse fibric materials have large pores, whereas the most-decomposed sapric material has relatively small pores.
- Water is increasingly held as the degree of decomposition increases.

How important is tropical peat as a global carbon store?

- In tropical peatlands, both the vegetation and underlying peat constitute a large and highly concentrated carbon pool, which, upon degradation, releases greenhouse gases (GHGs) that can have a significant effect on global environmental change processes.
- Tropical peatlands, although they cover only about 0.25% of the Earth's land surface, contain 50,000-70,000 million tonnes of carbon (about 3% of the amount of carbon stored in soil worldwide).
- Tropical peatland accounts for about 12% of the global peatland area but it may contain 25% of the total global peatland carbon.

Carbon stocks in peatland area of Southeast Asia (Page *et al.*, 2010)

Country	Area (Km^2)	Thickness (m)	Volume $(m^3)*10^6$	G-content (Gt C)	C-content (t C/ha)
Brunei	909	1	6,363	0.321	3,528
Indonesia	206,950	5.5	1,138,225	57.367	2,772
Malaysia	25,889	7	181,223	9.134	3,528
Myanmar (Burma)	1,228	1.5	1,842	0.093	756
Papua New Guinea	10,986	2.5	27,465	1.384	1,260
Philippines	645	5.3	3,418.5	0.172	2,671
Thailand	638	1	638	0.032	504
Vietnam	533	0.5	266.5	0.013	252
Total Southeast Asia	247,778	-	1,359,441	69	-
Avg C-content/ha				1.909	

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FIRE BEHAVIOR

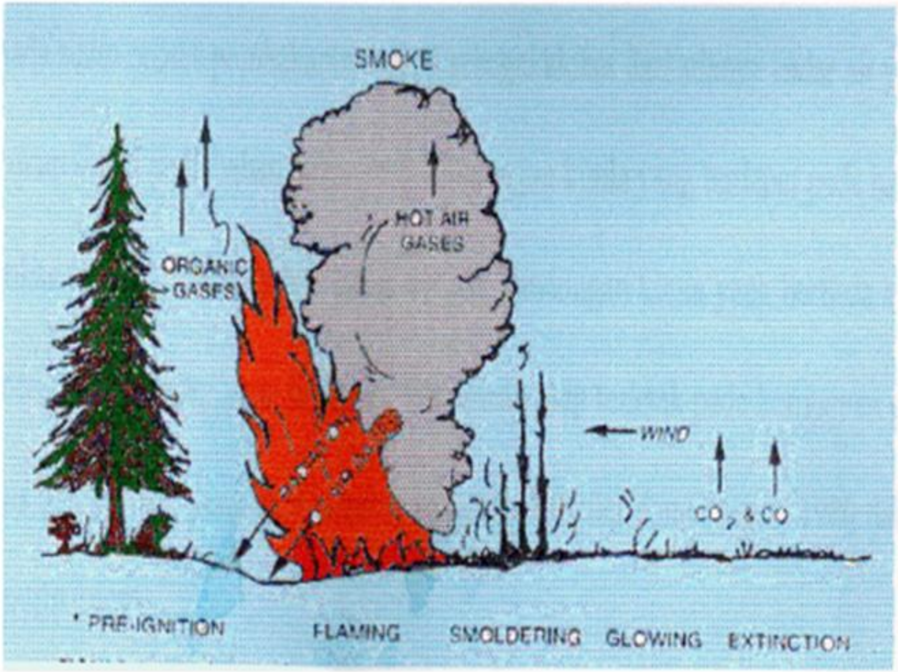
FIRE TRIANGLE

- Combustion occurs when there are three elements that unite i.e. fuel material, oxygen and heat.
- This principle is known as the fire triangle.
- Payne *et al.* (1996) reported that cellulose has a thermal stability up to a particle temperature of 250°C.
- At a temperature of 325°C, cellulose decomposes quickly and produces large amounts of flammable gases.

COMBUSTION PROCESS

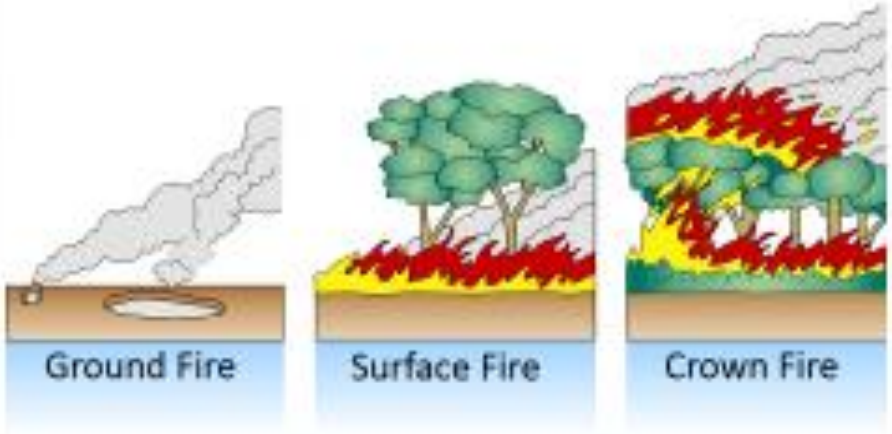
- De Bano *et al.* (1998) classified combustion process into five phases, namely:

- ➢ pre-ignition,
- ➢ flaming,
- ➢ smoldering,
- ➢ glowing and,
- ➢ extinction.

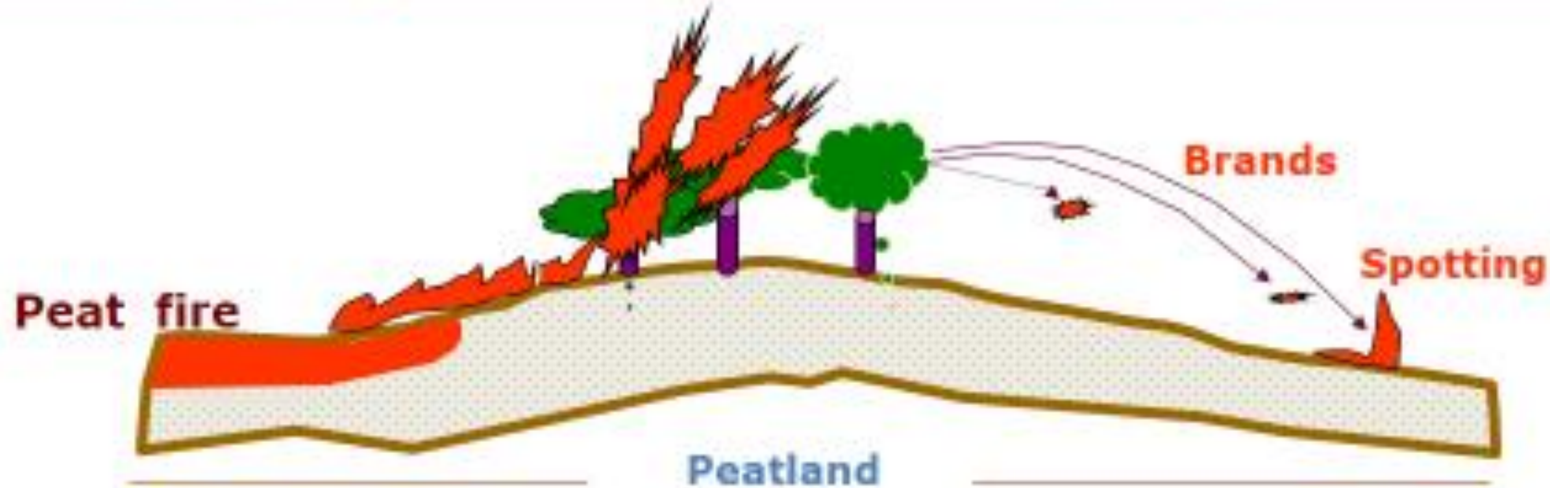


Terms:

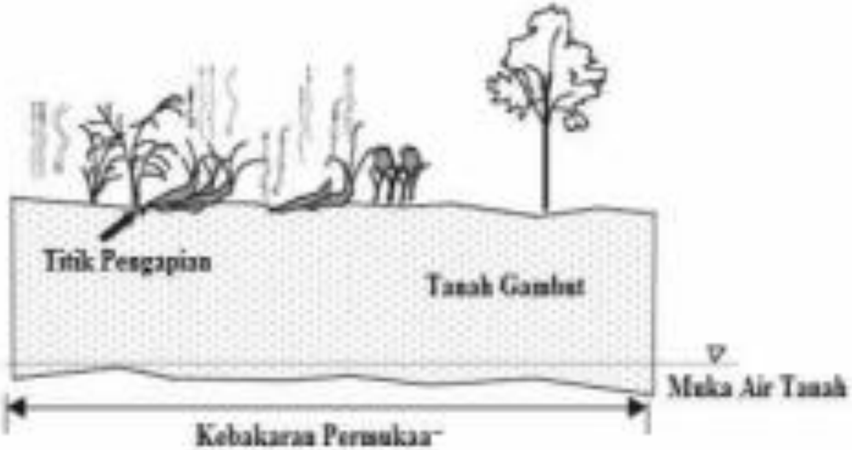
Types of Fire:



Fire propagation regimes in tropical peatland



(Usuf, 2011)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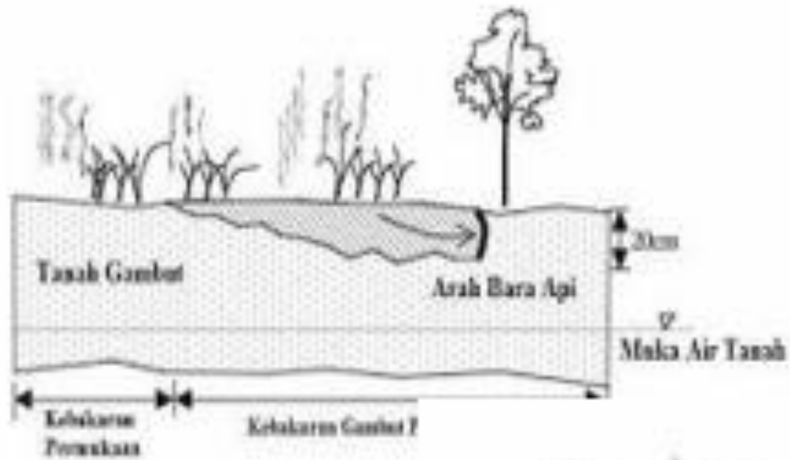
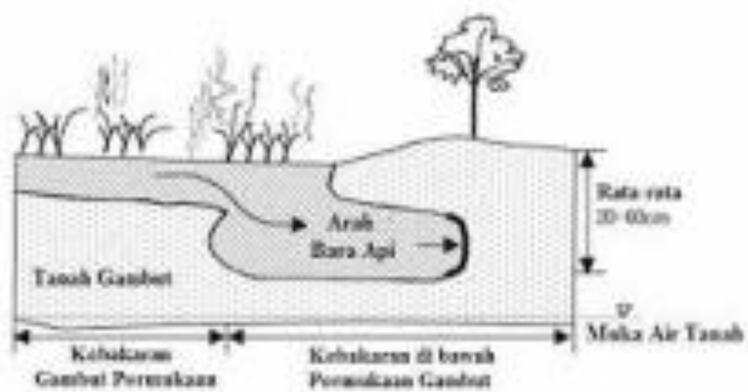
Tanah Gambut
Muka Air Tanah
Kebakaran Permukaa


20cm
Tanah Gambut
Arah Bara Api
Muka Air Tanah
Kebakaran Permukaan
Kebakaran Gambut


Rata-rata
20-60cm
Arah
Bara Api
Tanah Gambut
Muka Air Tanah
Kebakaran Gambut Permukaan
Kebakaran di bawah Permukaan Gambut

Usup, 2015

Case study in peatland area in Pelalawan

Sapric site

Table 3. Fuel bed depth in the subplot.

Plot	Depth (cm)
1	96.0 (±45.9)a
2	82.8 (±21.3)bc
3	98.4 (±47.3)c
4	93.4 (±55.15)b

Means are significantly different when standard errors are followed by different letters ($p \leq 0.05$).

Table 4. Fuel load before burning (ton ha^{-1}).

Plot	Litter	Branches	Total
1	20.83 (±1.44)a	40.83 (±23.22)a	61.67 (±22.41)a
2	23.30 (±7.63)a	32.33 (±8.74)a	55.67 (±14.01)a
3	22.50 (±2.50)a	36.37 (±13.77)a	59.17 (±11.25)a
4	20.0 (±2.5)a	35.60 (±6.61)a	55.0 (±9.0)a

Means are significantly different when standard errors are followed by different letters ($p \leq 0.05$).

Table 5. Fuel moisture content before burning (%).

Plot	Litter	Branches
1	10.64 (±1.15)a	14.09 (±3.40)a
2	8.67 (±1.56)a	14.49 (± 4.44)a
3	7.50 (±2.21)a	13.87 (±4.37)a
4	8.84 (±1.72)a	13.36 (±2.8

Means are significantly different when standard errors are follo by different letters ($p \leq 0.05$).

Wetlands Ecology and Management 13: 105–110, 2005.

Mitig Adapt Strat Glob Change (2007) 12:135–146

Global Environmental Research 15/2011: 39-44

Table 6. Weather condition and fire behavior parameters during burning.

Parameter	Plot 1	Plot 2	Plot 3	Plot 4
Weather condition				
Temperature (°C)	38	38	39	35
Relative humidity (%)	55	50	49	52
Wind speed (m/sec.)	0.41	1.09	1.07	0.63
Fire behavior				
Fuel load (ton ha^{-1})	61.67 (±22.41)a	55.67 (±14.01)a	59.17 (±11.25)a	55.0 (±9.0)a
Fuel moisture (%)				
Leaves	10.64 (±1.15)a	8.67 (±1.56)a	7.53 (±2.21)a	8.84 (±1.72)a
Branches	14.09 (±3.40)a	14.49 (±4.44)a	13.87 (±4.37)a	13.36 (±2.89)a
Flame length (m)	1.56 (±0.52)a	2.11 (±0.26)ab	3.09 (±1.07)b	1.94 (±0.85)a
Fire int. (kW m^{-1})	792.95 (±572.39)a	1401.6 (±355.2)ab	1830.55 (±634.73)b	1379.0 (±1103.6)ab
R.of the spr.(m min^{-1})	0.47 (±0.15)a	0.99 (±0.26)ab	1.11 (±0.32)b	0.98 (±0.29)ab
Flame temp. (°C)				
1 cm below ground	70	90	95	80
Ground	800	985	1000	900
Slope (%)	0	0	0	0
Plot size (ha)	0.04	0.04	0.04	0.04
Duration (min)	22.13	21.30	28.10	19.00
Burning time	11.22 a.m	13.43 p.m	14.54 p.m	15.55 p.m

Means are significantly different when standard errors are followed by different letters ($p \leq 0.05$).

Table 7. Burnt fuel percentage (%).

Plot	Litter	Branches
1	50	45
2	80	60
3	90	75
4	78	50

Table 8. Burnt peat depth and size of burned area.

Plot	Depth (cm)	Burnt size (m^2)	Percentage
1	18	12	3
2	31.87	7	1.75
3	15.44	17	4.25
4	12.72	22	5.5

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PEAT LAND FIRE CHARACTERISTICS

Peatland Fire vs. Peat Fire

- Peatland Fire = Fire on a peat dominated site
- Peat Fire = Ground Fire burning in Peat Soil

surface fires on peatlands
lead to peat fires
<u>when peat soil is dry</u>.

(Ryan, 2014)

(Usuf, 2011)

Fuels

Available Fuel (actually burned in this fire)
Total Fuel (burns in worst case fire)
Total Biomass

Problem:

- **Not all biomass is burnable in the first fire – may burn in later fire**

- **How to determine available fuel (predict, measure, monitor)**

(Ryan, 2014)

Fuel & GHG Emissions

- Living and dead biomass that burns is termed

  Fuel

- Fuel chemistry, size, and composition affect combustion, and **GHG Emissions**

(Ryan, 2014)

Surface Fire Fuels

- Fine Herbaceous-Litter (FH-L) =
  live & dead non-woody vegetation – grasses, forbs, ferns, small shrubs (e.g., leaves, foliage, small non woody stems)
- Fine Woody Debris (FWD) =
  wood < 3cm diameter (e.g., dead twigs and small branches)
- Medium Woody Debris (MWD) =
  wood 3-8 cm diameter (e.g., medium branches & roots)
- Course Woody Debris (CWD) =
  wood> 8 cm diameter (e.g., large branches & logs) ~ Heavy Fuel Load

Surface Fuels Flaming (Ryan, 2014)

Herbaceous Fuels (ferns), EMRP

(Ryan, 2014)

Ground Fuels (Peat) Smoldering

Ground fire burning beneath a "shelf" of unburned peat

Ground Fire – burns organic soil:

- **Fire Environment**

  - ✓ Peat Properties (fibric, sapric, hemic)
  - ✓ Moisture Content (within Peat *Soil*)
  - ✓ Water Table Depth (moisture profile above water table)
  - ✓ Heavy Fuel Loading (mass/area)

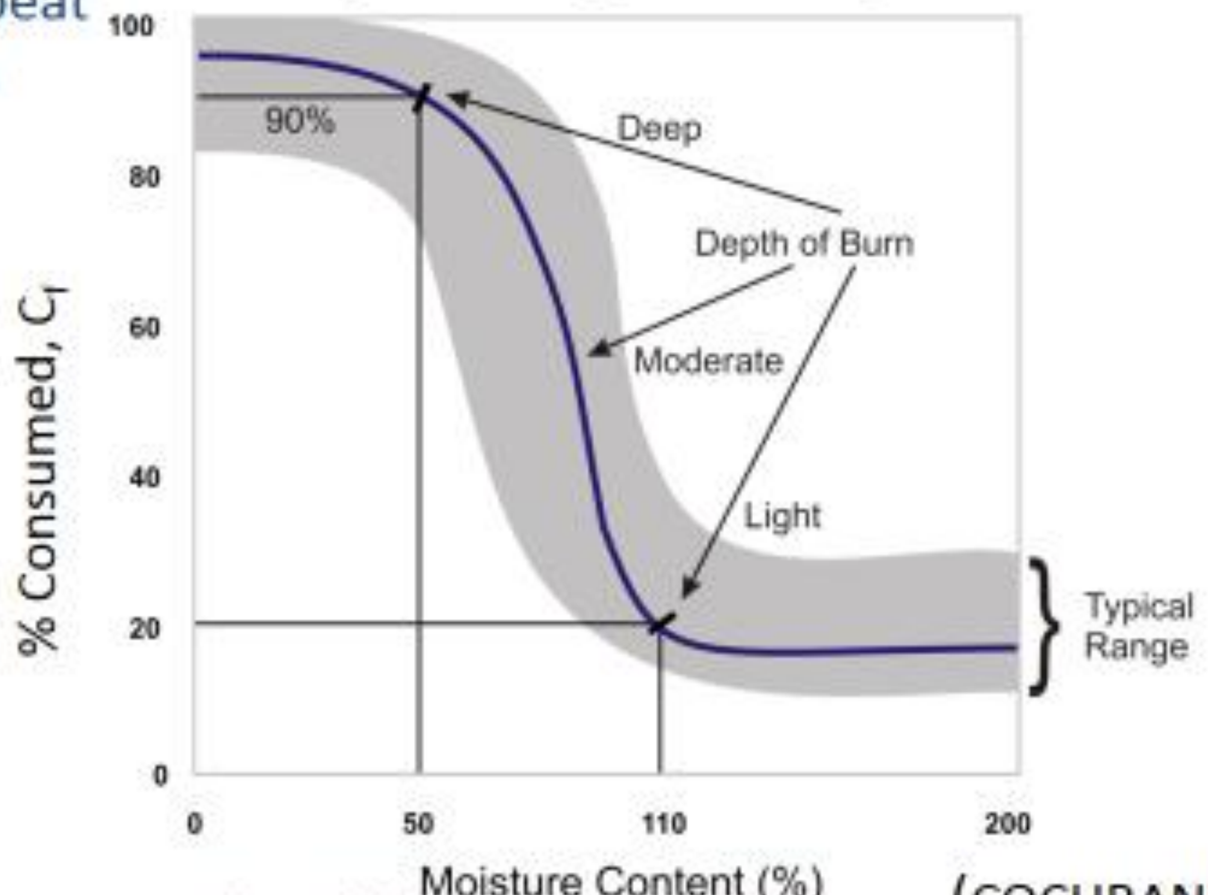
(Ryan, 2014)

Depth of burn (DOB)

Direct field moisture measurements

Organic Soil > 4 cm Deep

Air dry peat
35-55%



(COCHRANE, 2014)

DOB is predictable & measurable

What kind of biomass and how it burns

(Ryan, 2014)

September 22, 2012 near SP1, EMRP

(COCHRANE, 2014)

(COCHRANE, 2014)

Light surface fuels: burn quick and "clean"

September 22, 2012 , Near SP1, EMRP

Heavy surface fuels: burn long and "dirty"

May initiate shallow peat fires

(COCHRANE, 2014)

Ground Fuels (peat): burn slow and "dirty"

(COCHRANE, 2014) September 22, 2012 Near SP1, EMRP

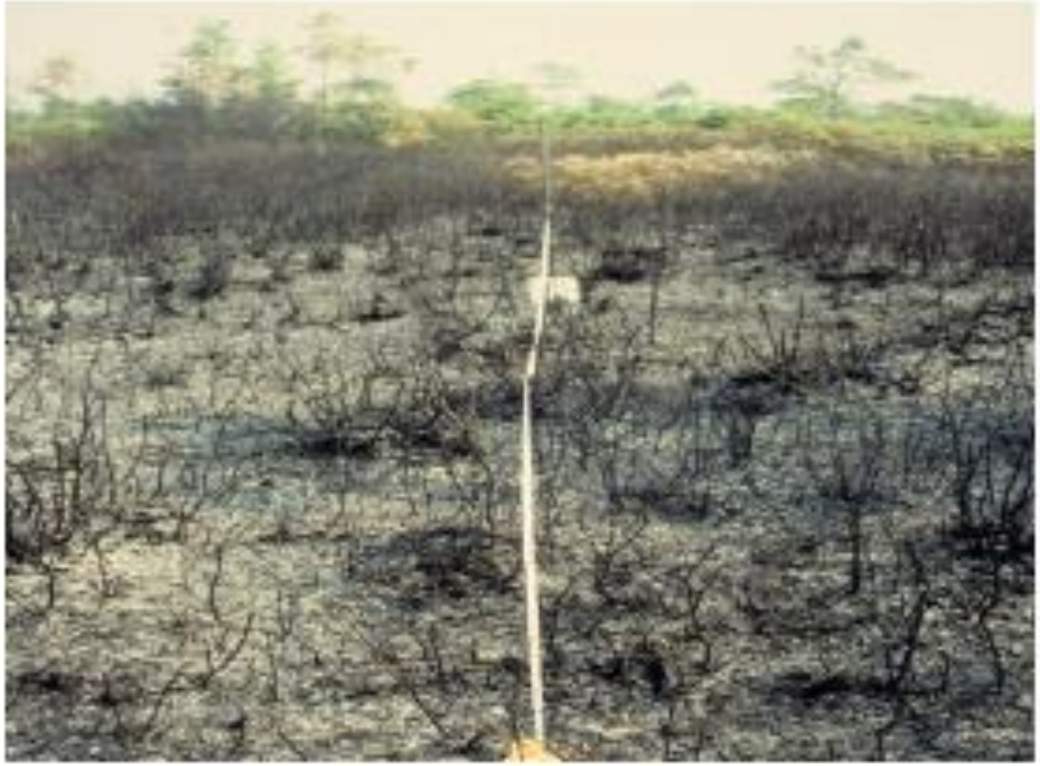
Surface Fire burns fine & course fuels < 2 meters tall:

- Flaming Combustion + Smoldering
- Area Burned - Dominant Factor
- Rate of Spread, Intensity & Consumption Vary with Fire Environment –
  - ✓ **Fine Fuels – mass & type**
  - ✓ **% Relative Humidity (*Air*)**
  - ✓ **Wind Speed**

Fire Assessment Goal: Develop better data on Fire Environment and depth of burning (Ryan, 2014)

Biomass vs. Fuels

Surface Fires
burn quickly
spread rapidly
consume little
less smoke



e.g., Light Surface Fire in Shrub-Dominated Peatland
- peat soil was too wet to burn, shrub stems standing

(COCHRANE, 2014)

Burning peat = less flame but more smoke

(COCHRANE, 2014)

Light depth of Burn

(COCHRANE, 2014)

Biomass vs. Fuels

- **Peat Fires:**
  - Burn slowly
  - Spread slowly
  - consume soils
  - alter terrain
  - yield heavy smoke

e.g., Ground Fire in Shrub-Dominated Peatland, pockets of peat were dry enough to burn

(COCHRANE, 2014)

Deep Depth of Burn

(COCHRANE, 2014)

Ground Fire – burns organic soil:

- Smoldering Combustion
- Major Contributor GHG Emissions
- Peat fires spread slowly (~ 3-5 cm/hr)
- Peat Consumption – varies with **Fire Environment** –

✓ **Peat Properties (fibric, sapric, hemic)**
✓ **Moisture Content (within Peat *Soil*)**
✓ **Water Table Depth** (moisture profile above water table)
✓ **Heavy Fuel Loading (mass/area)**

Fire Assessment Goal: Develop better data on Fire Environment

Depth to the water table is a prime determinant of the peat that can burn

(COCHRANE, 2014)

Fuels & Fire Environment Assessments

- Fine Herbaceous-Litter (FH-L)
- Fine Woody Debris (FWD)
- Medium Woody Debris (MWD)
- Course Woody Debris (CWD) & logs) ~ Heavy Fuel Load
- Peat

- Vegetation Plots
  - Seedlings
  - Saplings
  - Poles
  - Trees
  - Forest Litter
- Peat Characteristics
  - Bulk Density
  - Moisture Content%
  - Mineral Content %
- Heavy Fuel Load Assessments
- Peat Depth maps
- Vegetation maps

Fuels density in secondary peatland forest

Fuels in Secondary peatland forest (This study)

Fuel Components	ton/ha	%
1. Crown fuels (Leafs and trunk)	29.7	8.0
2. Surface fuels (Grass, litter, wood debris, fallen wood)	43.1	11.6
3. Ground fuels *)	300.0	80.4

*) Calculated for 1 m in depth

Fuels in another region (In tropical forest of Para Brazil) Araujo, et al, (1999)

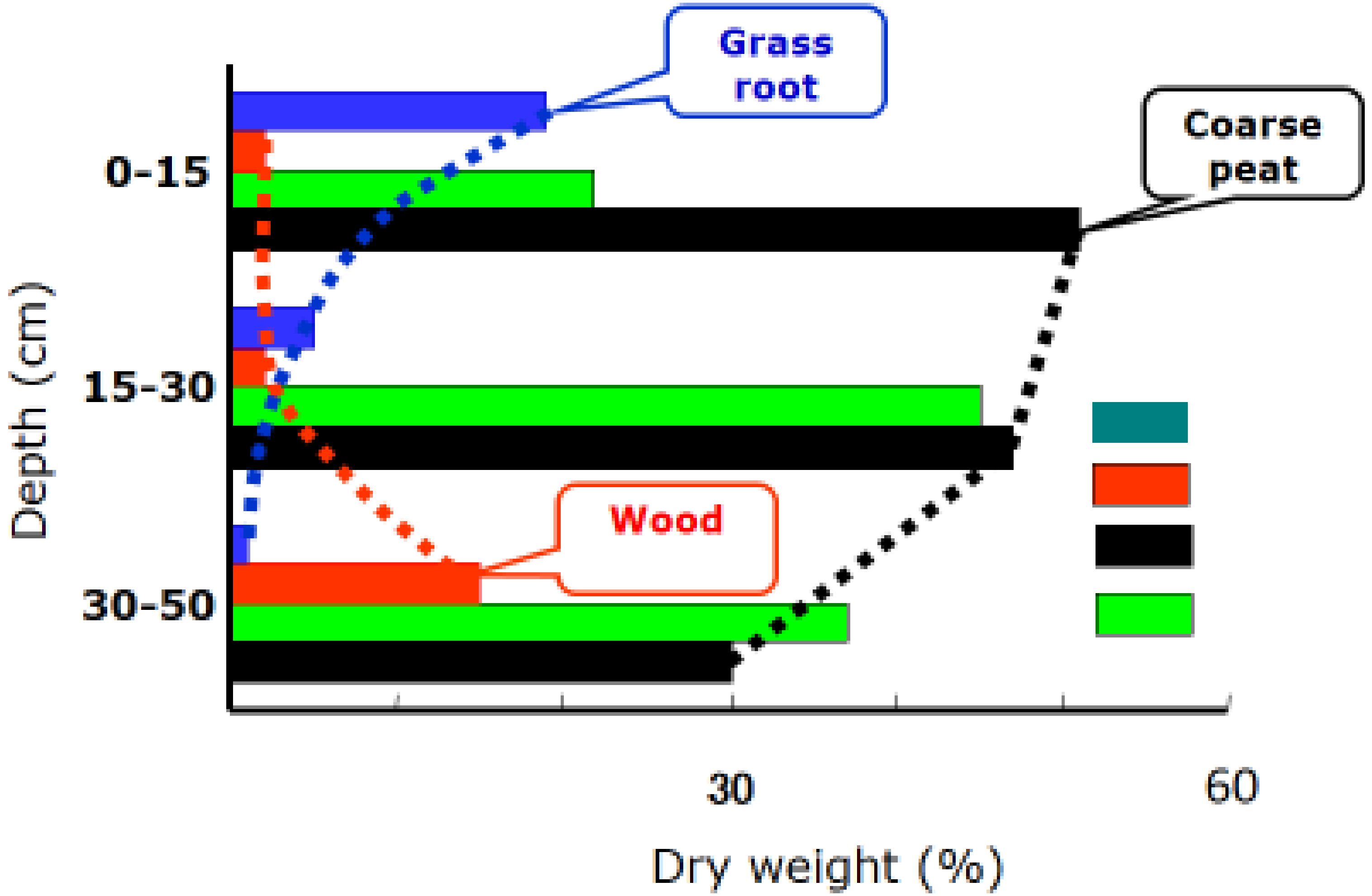
1. Crown fuels (Leafs and trunk)	188.7 ton/ha
2. Surface fuel (Litter and Fallen trunk)	45.0 ton/ha
Total	233.7 ton/ha

The fuel composition about 80% in the ground

(Usuf, 2011)

Kevin Ryan

Fuels composition in the ground

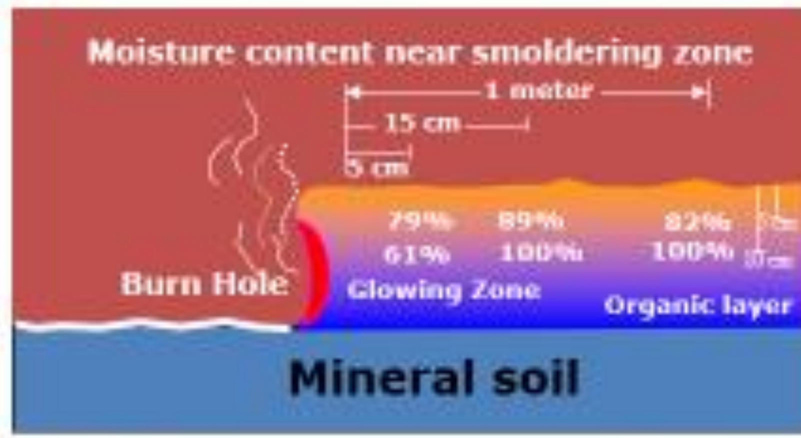


(Usuf, 2011)

Peat moisture near smoldering zone

Plot 3

Plot 5

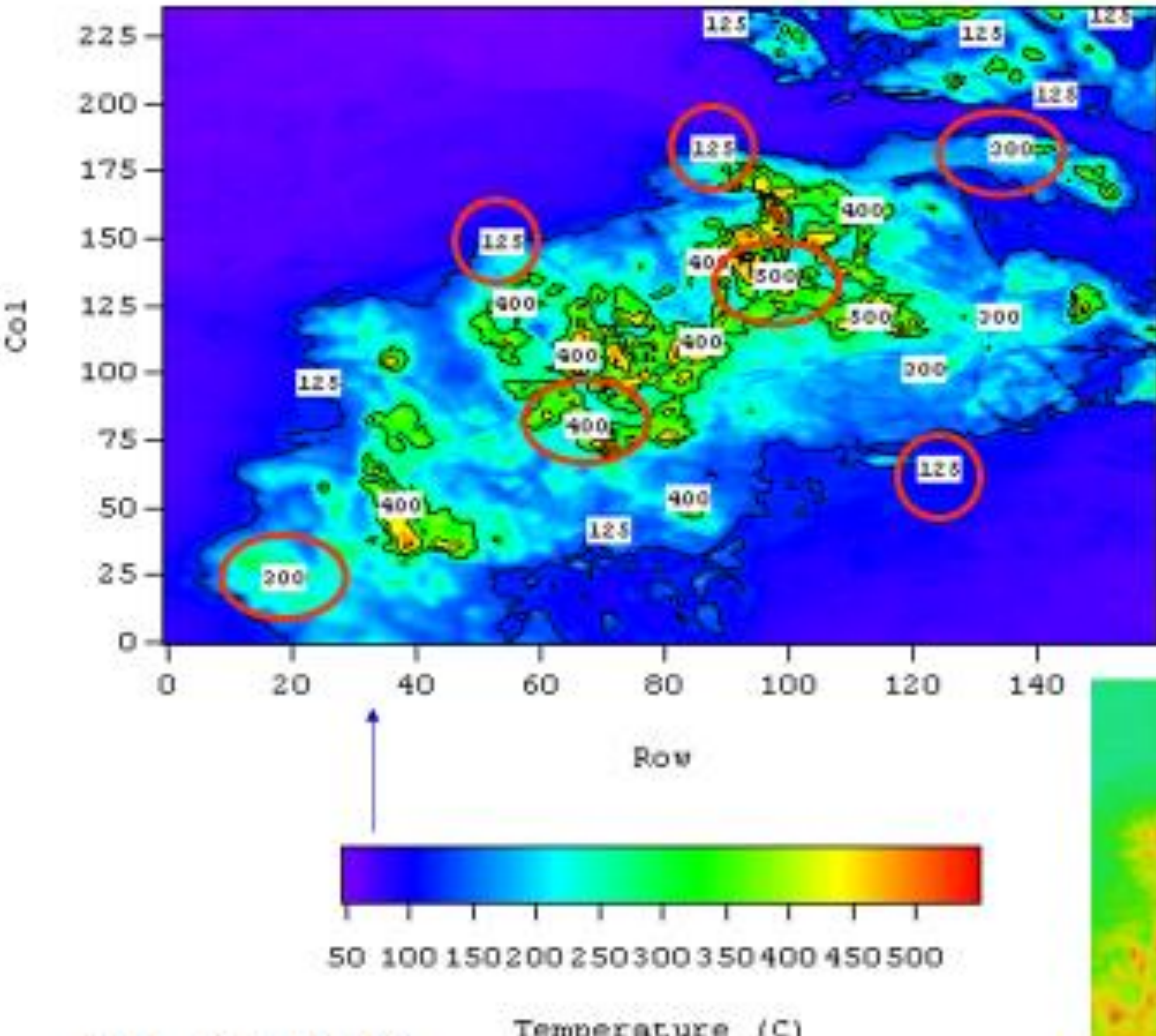


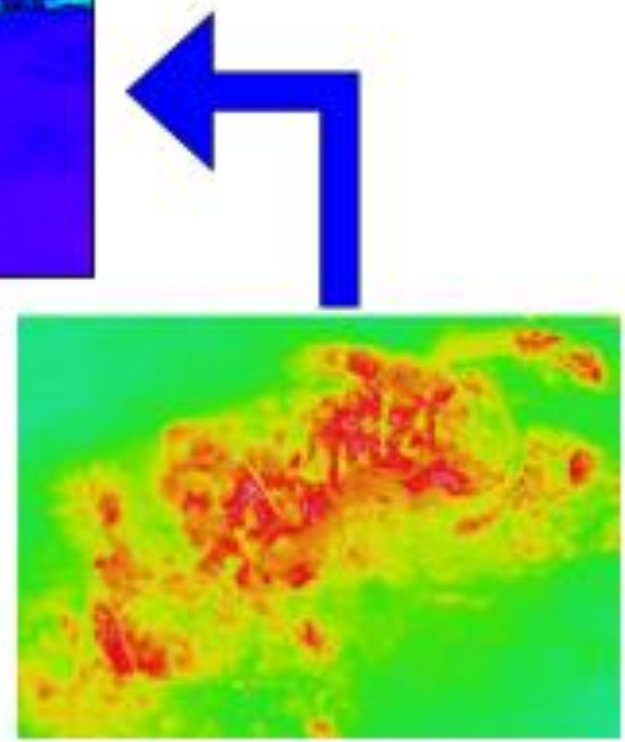
Peat moisture near smoldering zone at plot 3 and 5

Peat moisture near smoldering zone in Seney NWR Michigan USA (Hungerford, 1996)

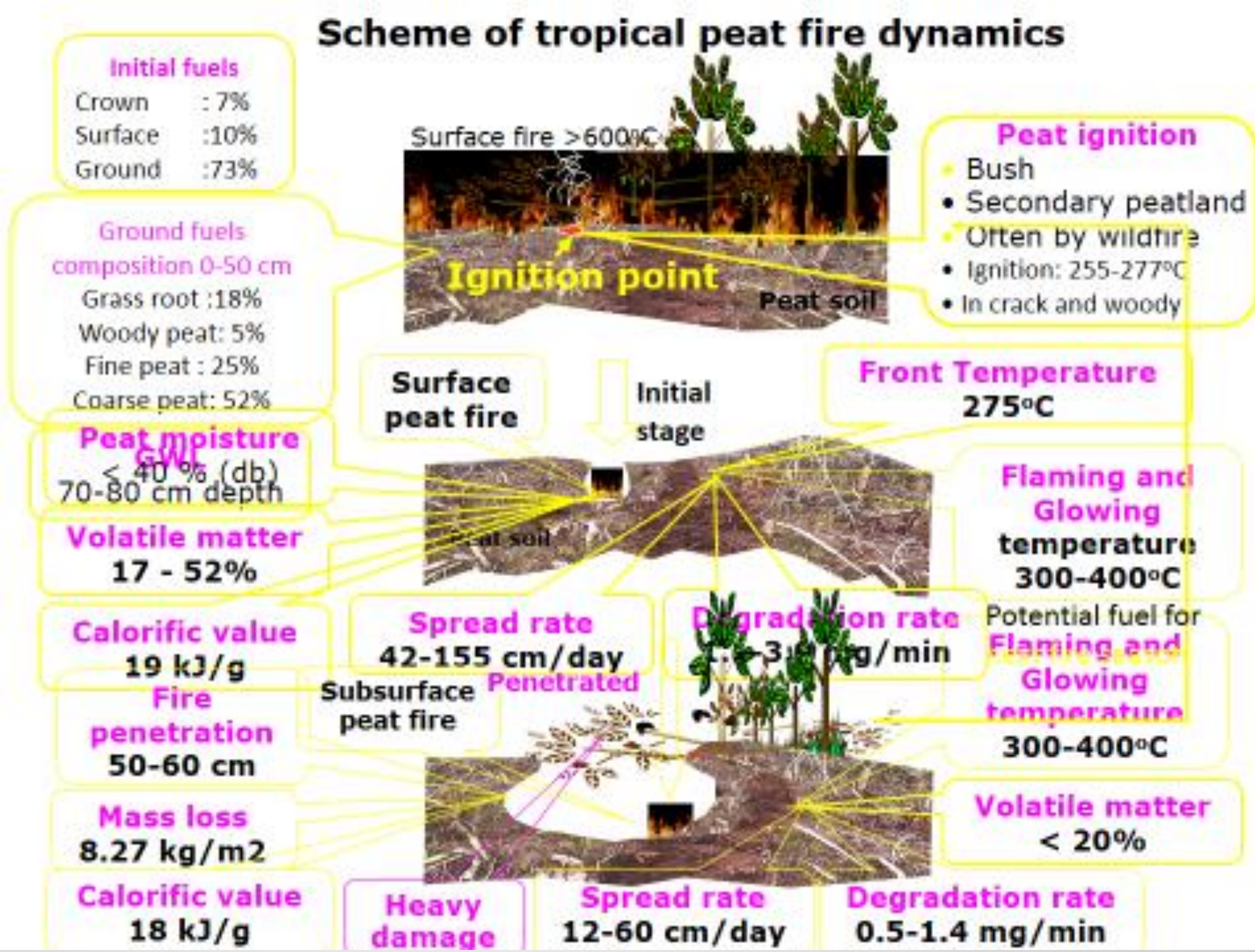
(Usuf, 2011)

Temperature in peat layer during a fire event





(Usuf, 2011)



Scheme of tropical peat fire dynamics
Initial fuels
Crown : 7%
Surface :10%
Ground :73%
Surface fire >600°C
Peat ignition
Bush
Secondary peatland
Often by wildfire
Ignition: 255-277°C
In crack and woody
Ignition point
Peat soil
Ground fuels composition 0-50 cm
Grass root :18%
Woody peat: 5%
Fine peat : 25%
Coarse peat: 52%
Surface peat fire
Initial stage
Front Temperature 275°C
Peat moisture < 40 % (db)
GWL 70-80 cm depth
Flaming and Glowing temperature 300-400°C
Volatile matter 17 - 52%
Calorific value 19 kJ/g
Spread rate 42-155 cm/day
Degradation rate
Potential fuel for Flaming and Glowing temperature 300-400°C
Fire penetration 50-60 cm
Subsurface peat fire
Penetrated
Mass loss 8.27 kg/m2
Volatile matter < 20%
Calorific value 18 kJ/g
Heavy damage
Spread rate 12-60 cm/day
Degradation rate 0.5-1.4 mg/min

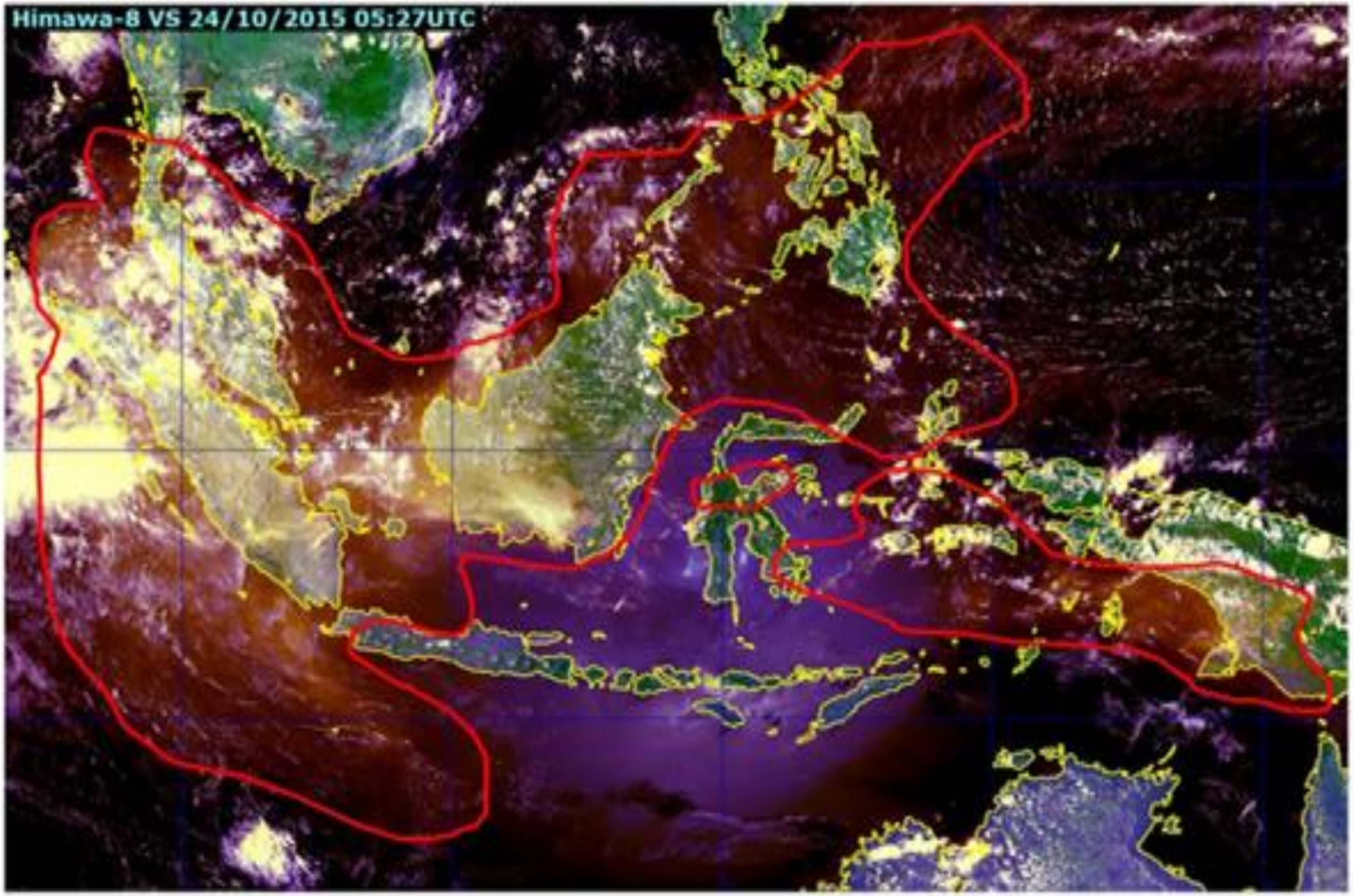
4

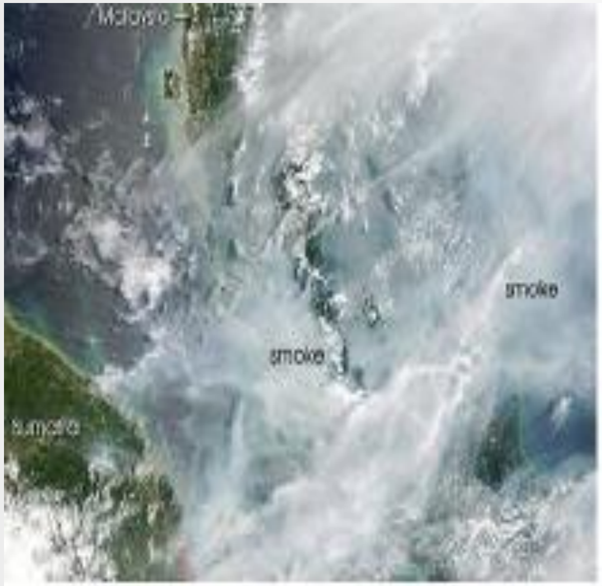
ENVIRONMENTAL IMPACTS

Palangkaraya 26 September 2015, 04.00 PM

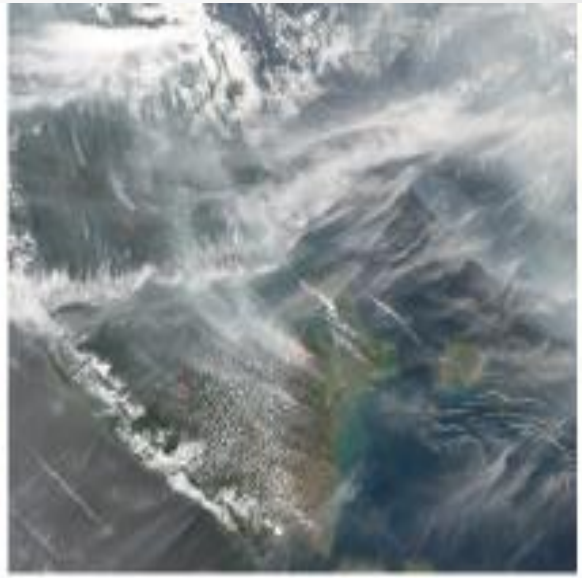
Palangkaraya, 27 September 2015, 04.34 AM

RGB Citra Satelit Cuaca Himawari
Sebaran Asap 24 Oktober 2015 12.30 WIB

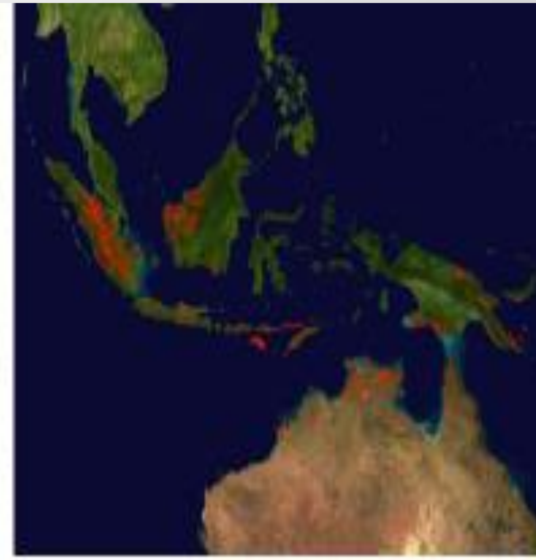




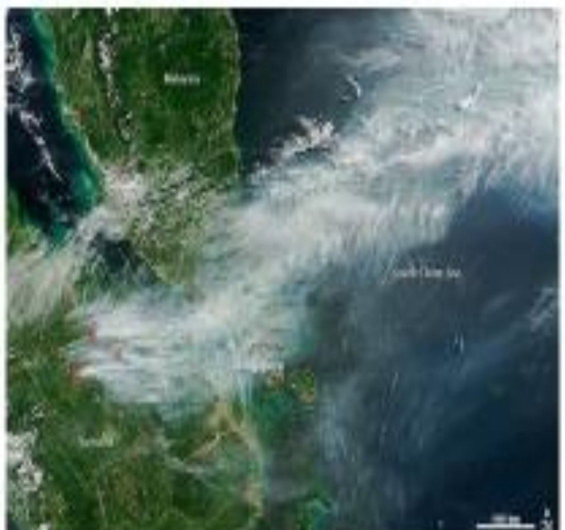
NASA (2005)



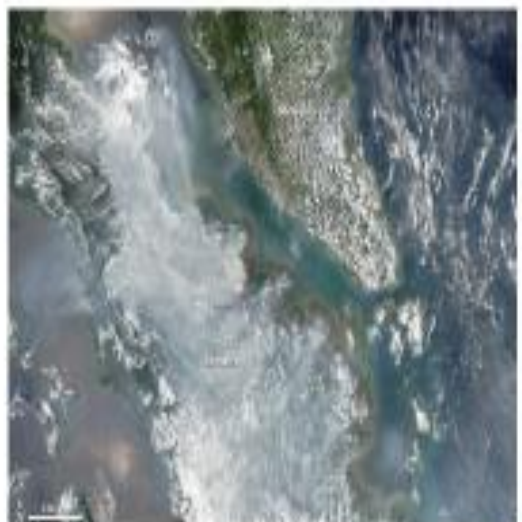
NASA (2006)



NASA (2008)



NASA (2013)

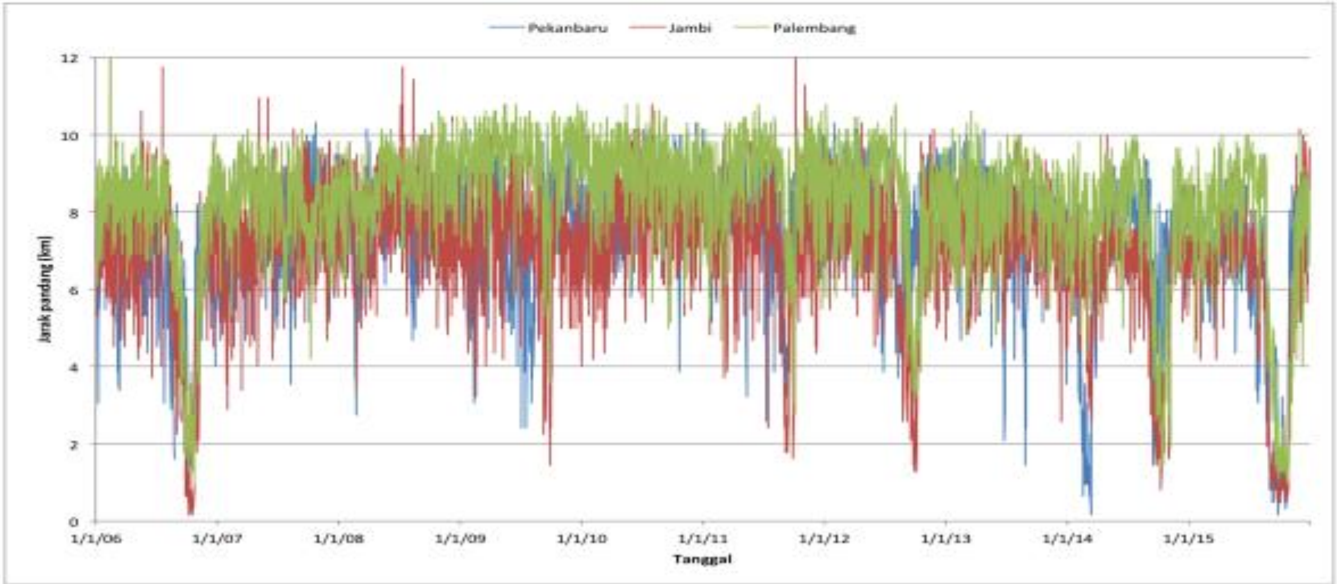


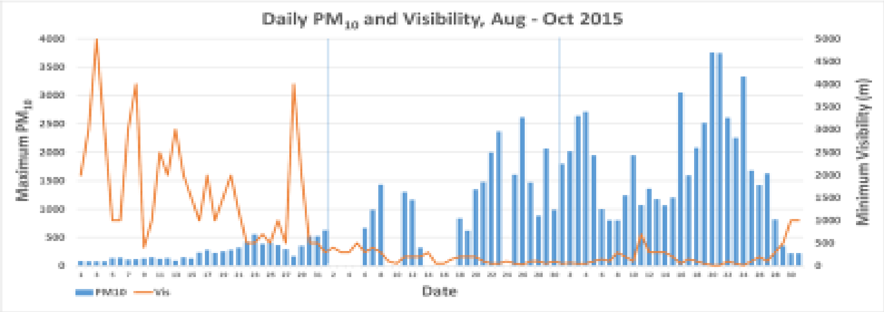
NASA (2014)

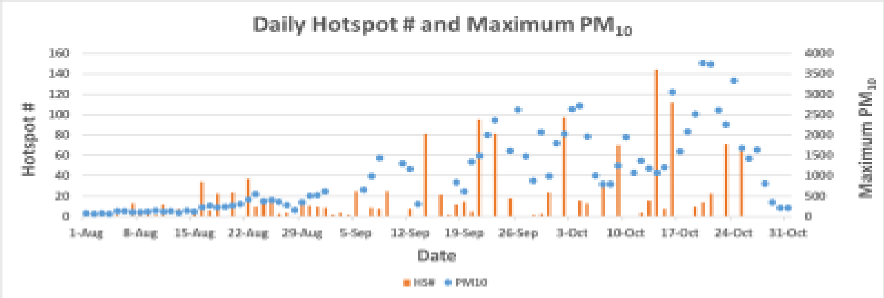
NASA (2015)

Transboundary haze pollution

Visibility, Palembang, Jambi, Palembang, 2006,2009,2015







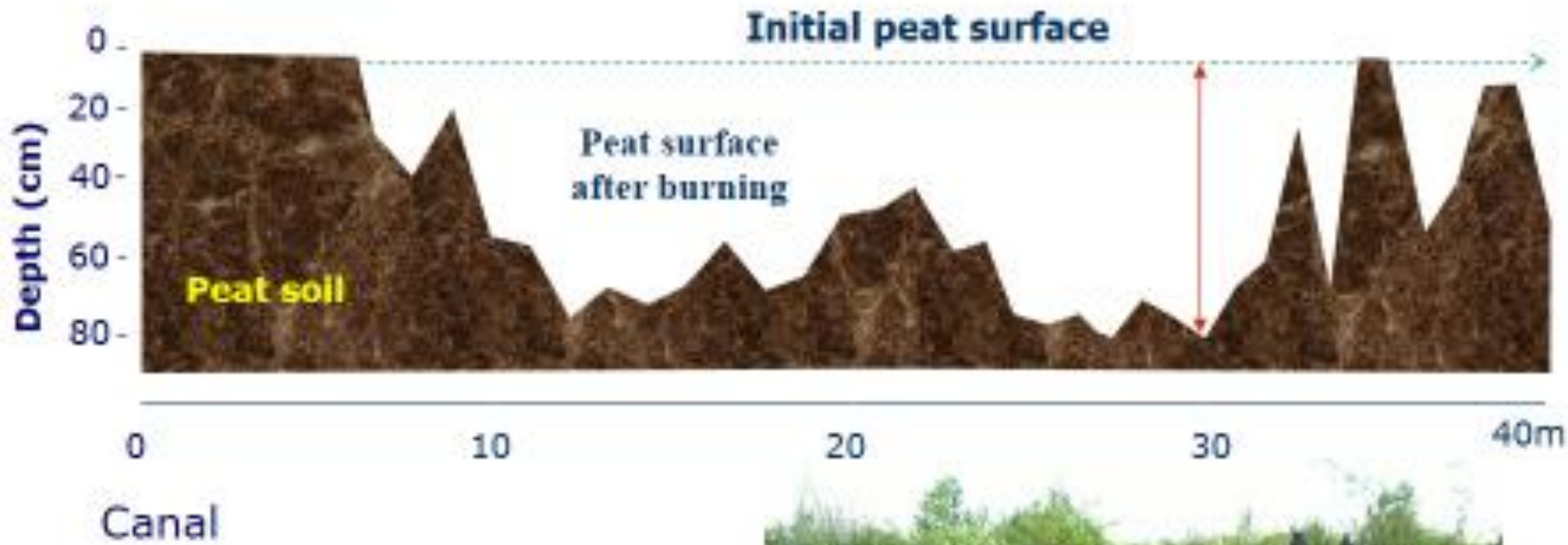
Measurement approach: mobility/info compromise: UM FTIR, flask, filter off road lab

Several gases sampled from 90 gas takedn during peat fires in Central Kalimantan (Stockwell et al, 2016)

Compound (formula)	Study avg (stdev) (g/kg)
Carbon Dioxide (CO_2)	1564(77)
Carbon Monoxide (CO)	291(49)
Methane (CH_4)	9.51(4.74)
Dihydrogen (H_2)	1.22(1.01)
Acetylene (C_2H_2)	0.121(0.066)
Ethylene (C_2H_4)	0.961(0.528)
Propylene (C_3H_6)	1.07(0.53)
Formaldehyde (HCHO)	0.867(0.479)
Methanol (CH_3OH)	2.14(1.22)
Formic Acid (HCOOH)	0.180(0.085)
Acetic Acid (CH_3COOH)	3.89(1.65)
Glycolaldehyde ($C_2H_4O_2$)	0.108(0.089)
Furan (C_4H_4O)	0.736(0.392)
Hydroxyacetone ($C_3H_6O_2$)	0.860(0.433)
Phenol (C_6H_5OH)	0.419(0.226)
1,3-Butadiene (C_4H_6)	0.189(0.157)
Isoprene (C_5H_8)	5.28E-2(4.33E-2)
Ammonia (NH_3)	2.86(1.00)
Hydrogen Cyanide (HCN)	5.75(1.60)

Peat Fire Damage

Change of micro topography



Peat loss by fire:
Maximum = 80 cm
Averages = 56 cm
Measured at 1 m interval


Peat fire damage (Usuf, 2011)

Burned area and mean depth of peat fire penetration of each plot study

Plot	Peat Damage		Forest damage level*)
	Burned area (ha)	Depth (cm)	
P1	2.0	46	Heavy
P2	3.0	38	Heavy
P3	1.2	30	Heavy
P4	2.6	53	Heavy
P5	1.4	33	Heavy
P6	5.0	38	Heavy
P7	1.2	40	Heavy
P8	**0.9**	**20**	Medium
P9	1.2	32	Heavy
University	3.0	56	Heavy
Mean	**2.15**	**39**	Heavy

***) ITTO, 1994**
Forest damage level: Dead of trees caused by fire (%)
Light damage < 20%; medium; heavy > 60%

Biomass burning is a significant global source of gaseous and particulate emissions to the atmosphere.

Gases produced by biomass burning include

(1): GHG gases, CO_2, CH_4 and N_2O that lead to global warming,

(2) Chemically active gases, NO, CO, CH_4 and NMHCs, which lead to the photochemical production of ozone (O_3) in the troposphere, and

(3) CH_3Cl, and CH_3Br which lead to the chemical destruction of ozone in the stratosphere (Levine, 1985).

SMOKE AND HAZE

- Smoke and "haze" from forest fires produce some of the most visible costs to society.
- People suffer respiratory problems, which puts pressure on meager medical facilities in many tropical countries.
- Estimates suggest that between 20 million and 70 million people were adversely affected by smoke from the Indonesian fires and at least 40,000 people were hospitalized both in Indonesia and neighboring countries (Barber and Schweithelm, 2000; Asian Development Bank, 1999; Glover and Jessup, 1999; Schwela *et al.*, 1999).
- Smoke reduces visibility, provoking transportation accidents and airport shutdowns.
- This often leads to transboundary smoke pollution, which provokes international indignation (ADB, 1999; Goh *et al.*, 1999; Schwela *et al.*, 1999).

- HAZE consists of sufficient smoke, dust, moisture, and vapour suspended in air to impair visibility.
- HAZE pollution can be said to be "transboundary" if its density and extent is so great at source that it remains at measurable levels after crossing into another country's air space.
- HAZE is caused by particulate matter from many sources including smoke, road dust, and other particles emitted directly into the atmosphere, as well as particulate matter formed when gaseous pollutants react in the atmosphere.
- These particles often grow in size as humidity increases, further impairing VISIBILITY.
- Sources hundreds or even thousands of miles away can contribute to VISIBILITY problems at remote locations.
- VISIBILITY often is measured as the farthest distance from which a person can see a landscape feature.

- Literature review showed that the health impacts of air pollution, the ambient concentration levels of PM10 (i.e. particles that are 10 microns or less in diameter) observed in Brunei Darussalam, Indonesia, Malaysia and Singapore during the 1997 and 1998 haze episodes are associated with:
- - increased daily mortality;
- - increased hospitalization;
- - increased visits to emergency rooms;
- - increased respiratory symptoms;
- - exacerbation of asthma; and
- - decreased lung function.

- **Indonesian case**
- Fires in Indonesia have resulted in human exposure to levels of air pollutants far in excess of those stipulated in the WHO guidelines.
- Chemical pollutants such as SO_2, NOx, O_3, CO and respirable fine particulate are harmful to human health.
- Air quality monitoring data (PSI or pollutant standards index) obtained from various institutions during the peak haze period showed that in areas close to the fires, the levels of air pollutants were 4-8 times higher than the values which have a significant health impact.
- Data collected through active surveillance from September to November 1997 in eight provinces showed increases in the incidence of bronchial asthma and ARI (acute respiratory infection).

Number of cases of asthma, bronchitis, acute respiratory infection (ARI) and deaths in 8 provinces in Indonesia, September-November 1997

Province	Population at risk	Asthma	Bronchitis	ARI	Death
Riau	1,701,000	41,028	7,995	199,107	75
West Sumatera	2,411,000	58,164	11,332	282,087	106
Jambi	1,478,000	35,650	6,947	172,926	65
South Sumatera	2,355,000	56,803	11,069	275,535	104
West Kalimantan	1,478,000	44,574	8,686	216,216	74
Central Kalimantan	716,000	17,574	3,366	83,772	29
South Kalimantan	1,733,000	41,800	8,145	202,716	69
East Kalimantan	118,000	2,846	555	13,806	5
Total	12,360,000	298,125	58,095	1,446,120	527

Source: Directorate-General, Communicable Disease Control & Environmental Health, Ministry of Health, Indonesia

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LOKAKARYA: "P

Please Note: Schedule still subject to change

Study Estimates 100,000 Premature Deaths From Indonesia Haze

THE ASSOCIATED PRESS (STEPHEN WRIGHT)
September 19, 2016 — 11:09 AM WIB
Updated on September 19, 2016 — 11:11 AM WIB

Indonesian police extinguish a fire in the Kampar District of Riau Province, Indonesia on Aug. 28, 2016.

Photographer: Afrianto Silalahi/NurPhoto via Getty Images

Jakarta, Indonesia (AP) -- Indonesian forest fires that choked a swath of Southeast Asia with a smoky haze for weeks last year may have caused more than 100,000 premature deaths, according to new research that will add to pressure on Indonesia's government to tackle the annual crisis.

The study by scientists from Harvard University and Columbia University to be published in the journal Environmental Research Letters is being welcomed by other researchers and Indonesia's medical profession as an advance in quantifying the suspected serious public health effects of the fires, which are mostly set to clear land for farming. The number of deaths is an estimate derived from a complex analysis that has not yet been validated by analysis of official data on mortality.

The research has implications for land-use practices and Indonesia's vast pulp and paper industry. The researchers showed that peatlands within timber concessions, and peatlands overall, were a much bigger proportion of the fires observed by satellite than in 2006, which

PSI and health effects

Air Pollution and Health Effects

PSI	Health Category	Health Effects	Preventive Measures
Up to 50	Good	None	None
51 - 100	Moderate	None or limited for the general population	Not necessary
101 - 200	Unhealthy	Moderate symptoms for sensitive individuals, followed by irritation in healthy population	Individuals with light heart and respiratory problems have to reduce physical movement and outdoor activities
201 - 300	Very unhealthy	Significant symptoms as well as drop in tolerated body movement or exercise in heart and lung patients; general symptoms among healthy population	Aged and sick individuals have to stay indoors and reduce physical exercise; the public has to avoid excessive outdoor activity
Above 300	Hazardous	Appearance of certain early diseases in addition to clear and significant problems as well as decrease in tolerated body movement or exercise for health population index of more than 400 could potentially cause premature death for sick people and the aged if not treated properly; healthy individuals will have symptoms that restrict normal activity	Aged and sick individuals have to stay indoors and avoid physical activity; at index level of more than 400, people have to avoid physical outdoor activities; everybody has to stay indoors, close all windows and doors, and limit physical activity

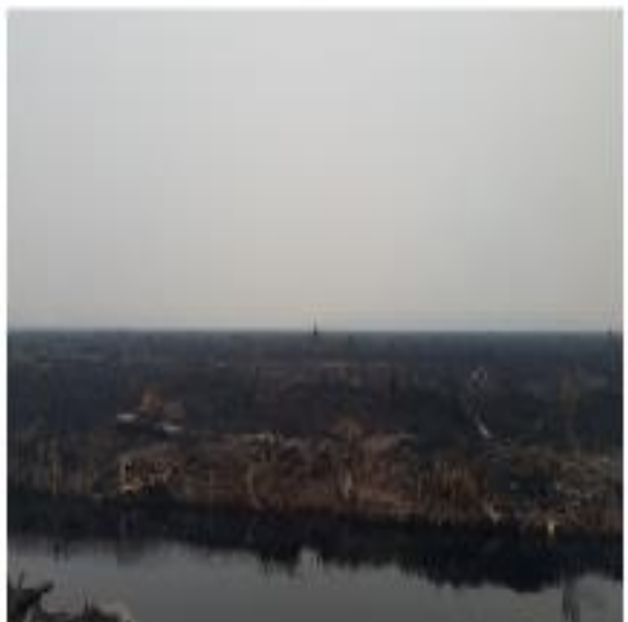
Source: World Health Organization

SAGO PLANTATION

GIAM SIAK KECIL NATURAL RESERVE

FORESTRY PLANTATION

OIL PALM PLANTATION



PROTECTED AREA


04-09-2016 10:02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Fire investigation


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