Emission Inventories of Air Pollutants from Biomass Open Burning in Agricultural Area and Forest Areas in Thailand During 2010 - 2013

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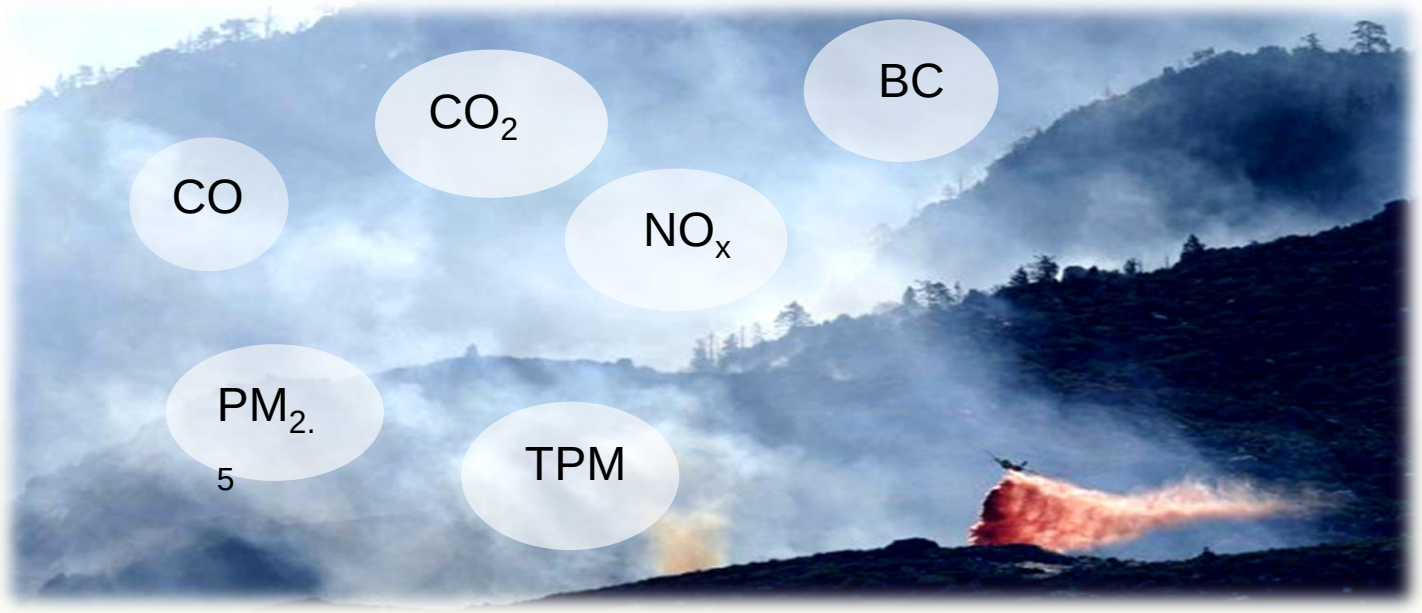
Outlines

- Objective
- Background
- Methodology
- Results and Discussions
- Conclusions

Objectives

Estimate air pollutants emission from biomass open burning in agricultural and forest area by using the Satellite based and ground report fire data for year 2010-2013.

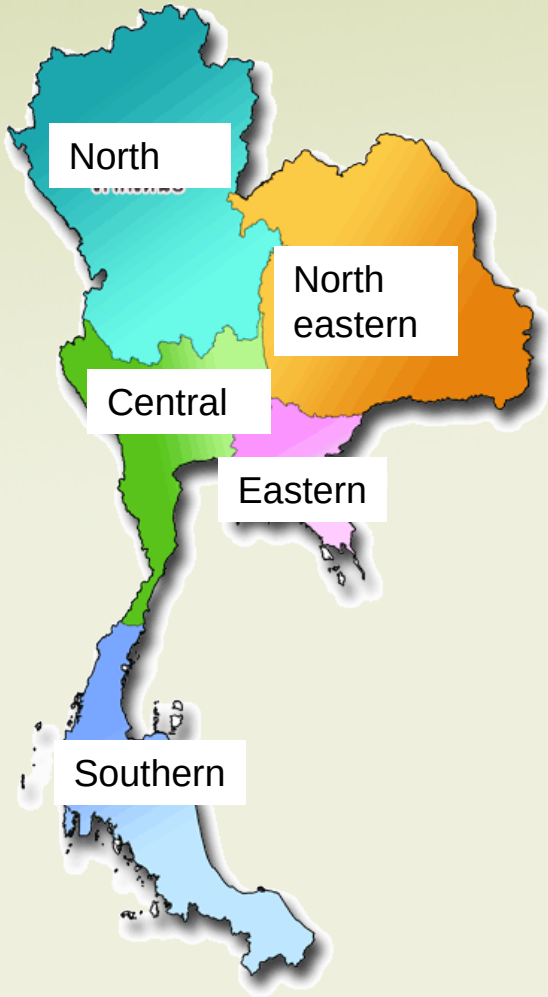


Background

THAILAND

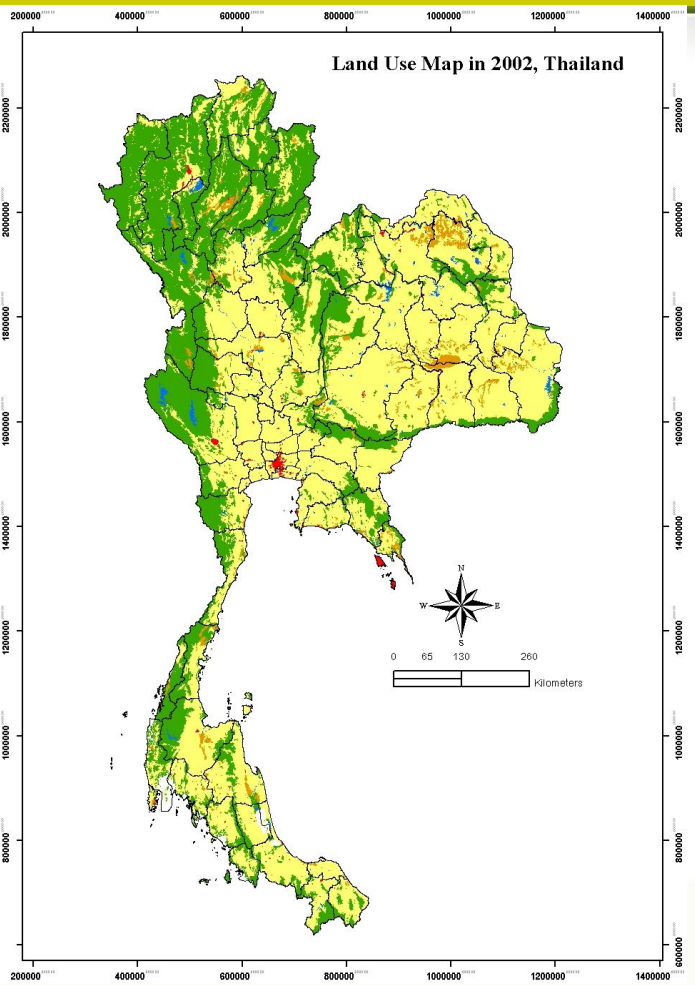
Total Land 514,310 km^2 (5 regions)

- **Forestland 183,899 km^2**
- **Cropland 305,642 km^2**
- **Urban Area 2,957 km^2**
- **Grassland 17,742 km^2**
- **Irrigation Area 4,070 km^2**



Source : http:www. yodthanaza.wordpress.com

Background



1. Evergreen

1.1 Tropical Rain Forest
1.2 Dry Evergreen Forest
1.3 Hill Evergreen Forest
1.4 Pine Forest
1.5 Swamp Forest
1.6 Mangrove Swamp Forest
1.7 Beach Forest

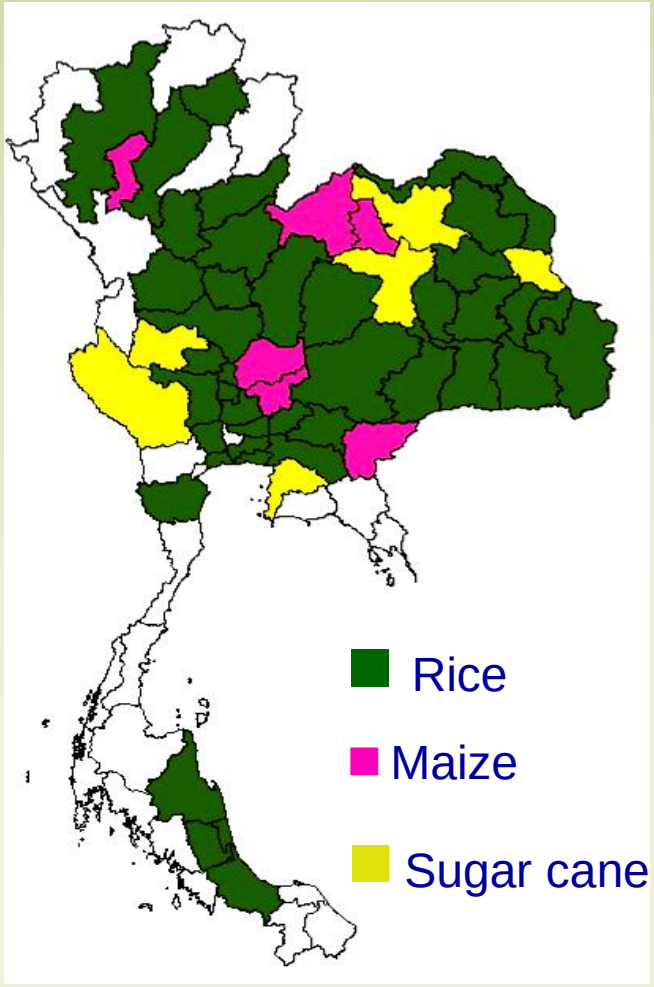
2.Deciduous

2.1 Mixed Deciduous Forest
2.2 Deciduous Dipterocarp Forest
2.3 Grassland

➢**Forest area classify by region in 2013**

Region	Region area (km^2)	Forest area (km^2)	Per cent
North	171,981	90,054	52.36
North East	167,717	25,302	15.09
Central	67,498	22,132	32.79
East	36,621	8,222	22.45
South	73,813	17,681	23.95
Total	517,630	163,391	31.57

Background

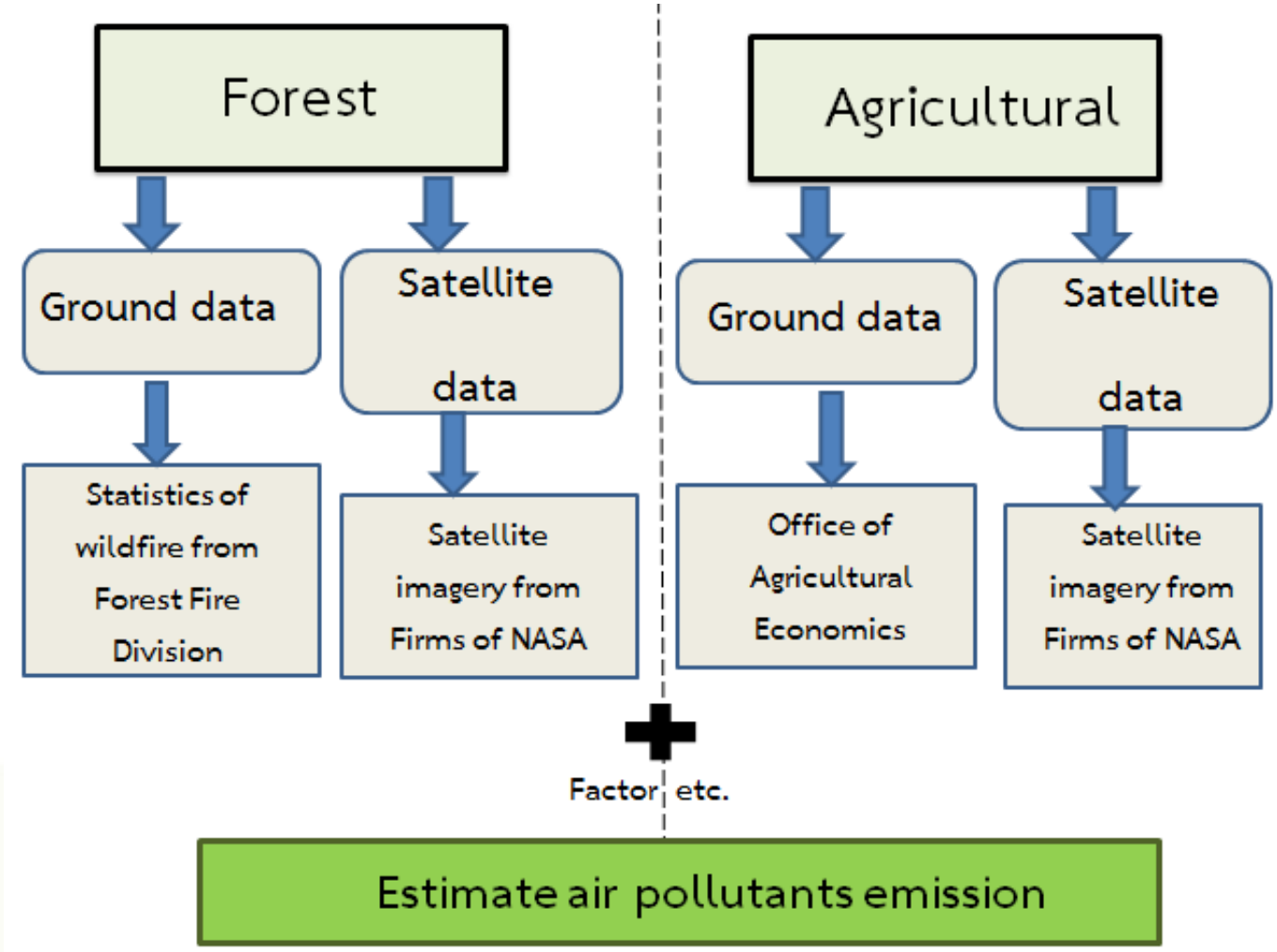


Crop type	Production (million tons/year)			
	2010	2011	2012	2013
Rice	34.61	36.08	39.17	36.85
Maize	4.86	5.02	4.97	4.97
Sugarcane	68.81	95.95	98.04	99.6

Region	Region area (km^2)	Agricultural area (km^2)	Percent
North	171,981	48,028	27.94
North East	167,717	76,498	45.61
Central	67,498	26,320	38.99
East	36,621	5,527	15.09
South	73,813	2,372	3.21
Total	517,630	158,745	30.67

Source :Office of Agricultural Economics

Methodology



Methodology

$$E_i = M \times EF_i$$

E_i = Emission (g)

M = Amount of biomass burned (kg)

EF_i = Emission factor (g/kg of dry biomass)

i = Species of air pollutant

Methodology

Amount of biomass burned (kg), M

$$M = A \times B \times E \times F$$

A = Burned area (m^2)
B = Dry biomass density (kg/m^2)
E = Combustion efficiency
F = Fraction burned

Forest Fire

1. Ground report from Forest Fire Control Division
2. Satellite data algorithm MOD14
3. Satellite data algorithm MCD45

Agricultural burning

1. Satellite data algorithm MOD14
2. Satellite data algorithm MCD45

$$M = P \times D \times \beta \times F \times C$$

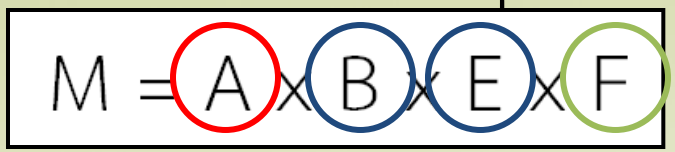
P = Annual production of crop (kg)
D = Ratio of residue to crop product
β = Combustion efficiency
F = Fraction burned
C = Burned area percent

Agricultural burning

Agricultural statistics from Office of Agricultural Economics

Emission estimation method for Forest area

Forest Fire : Ground report from Forest Fire Control Division



Garivait S. et al (2007)

Michel C. et al (2005)

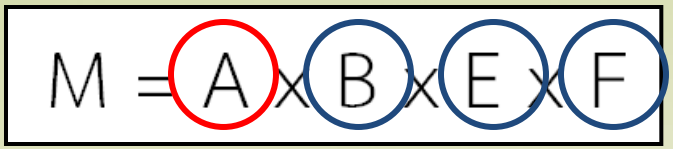
A = Burned area (m^2)
B = Dry biomass density (kg/m^2)
E = Combustion efficiency
F = Fraction burned

Forest type	Fraction burned	Combustion efficiency	Dry biomass density (g/m^2)
Evergreen needleleaf forest	0.93	0.25	36,700
Evergreen broadleaf forest	0.93	0.25	23,350
Deciduous needleleaf forest	0.93	0.25	18,900
Deciduous broadleaf forest	0.93	0.25	20,000
Mixed forest	0.93	0.25	22,250
Woodland	0.93	0.35	10,000
Wooded grassland	0.93	0.40	3,300
Closed shrubland	0.93	0.50	7,200
Open shrubland	0.93	0.85	1,600
Grassland	0.93	0.95	1,250
Cropland	0.90	0.60	5,100

	A	B	C	D	E	F	G	H	I	J	K	L
1							Forest area (rai)					
2	Date	Time	Tumbon	Amphar	Province	UTM	Deciduous Dipterocarp Forest	Mixed Deciduous Forest	Pine Forest	Dry Evergreen Forest	Tropical Rain Forest	Swamp Forest
3	01/01/2010	6:10 PM	ท่ากระดาน	ศรีสวัสดิ์	กาญจนบุรี	47P 0517239 1587262	0	12	0	0	0	0
4	01/01/2010	4:00 PM	ปรังเผล	สังขละบุรี	กาญจนบุรี	47P 0452671 1666255	0	0	0	0	0	0
5	01/01/2010	10:00 AM	บ้านผือ	หนองเรือ	ขอนแก่น	48Q 0350322 1880759	4	0	0	0	0	0
6	01/01/2010	7:20 PM	บ้านผือ	หนองเรือ	ขอนแก่น	48Q 0349215 1878706	5	0	0	0	0	0
7	01/01/2010	1:00 PM	อ่าวน้อย	เมือง	ประจวบคีรีขันธ์	47P 0581672 1321202	0	0	0	0	0	0

Emission estimation method for Forest area

Forest Fire : Satellite data algorithm MOD14 and MCD45



A = Burned area (m^2)
B = Dry biomass density (kg/m^2)
E = Combustion efficiency
F = Fraction burned

Michel C. et al (2005)

Forest type	Fraction burned	Combustion efficiency	Dry biomass density (g/m^2)
Evergreen needleleaf forest	1	0.25	36,700
Evergreen broadleaf forest	1	0.25	23,350
Deciduous needleleaf forest	1	0.25	18,900
Deciduous broadleaf forest	1	0.25	20,000
Mixed forest	1	0.25	22,250
Woodland	1	0.35	10,000
Wooded grassland	1	0.40	3,300
Closed shrubland	1	0.50	7,200
Open shrubland	1	0.85	1,600
Grassland	1	0.95	1,250
Cropland	1	0.60	5,100

algorithm MCD45

	A	B	C
1	Month	Date	Area (km^2)
2	2013032	59	9.65
3	2013032	58	0.22
4	2013032	59	0.22
5	2013032	59	0.45

algorithm MOD14

	A	B	C	D	E	F	G	J	K
1	Acq_date	Acq_time	Latitude	Longitude	x	y	Brightness	Satellite	Confidence
2	20130227	63	18.572000	97.365000	327462.00	2054256.00	326.00	A	79
3	20130124	64	18.595000	97.367000	327697.00	2056799.00	324.00	A	77
4	20130207	70	18.579000	97.388000	329897.00	2055008.00	324.10	A	68
5	20130219	41	18.528000	97.393000	330374.00	2049359.00	323.90	T	77

❖ 1 hotspot = burned area 1 km^2
❖Confidence level > 60 %

Emission estimation method for Forest area

$$E_i = M \times EF_i$$

E_i = Emission (g)
M = Amount of biomass burned (kg)
EF_i = Emission factor (g/kg of dry biomass)
i = Species of air pollutant

M.O. Andreae et al (2001)

Forest type	Emission factor (g/kg of dry biomass)				
	CO	CO_2	NO_x	TPM	$PM_{2.5}$
Evergreen needleleaf forest	107	1,569	4.60	17.60	13.00
Evergreen broadleaf forest	104	1,580	2.45	9.10	8.50
Deciduous needleleaf forest	107	1,569	4.60	17.60	13.00
Deciduous broadleaf forest	107	1,569	4.60	17.60	13.00
Mixed forest	107	1,569	4.60	17.60	13.00
Woodland	86	1,591	5.29	12.98	9.20
Wooded grassland	65	1,613	5.98	8.36	5.40
Closed shrubland	86	1,591	5.29	12.98	9.20
Open shrubland	65	1,613	5.98	8.36	5.40
Grassland	65	1,613	5.98	8.36	5.40
Cropland	92	1,515	3.83	13.00	3.90

Emission estimation method for agricultural area

Agricultural Burning : Agricultural statistics from Office of Agricultural Economics

$$M = P \times D \times \beta \times F \times C$$

Kanokkanjana K. (2010)

P = Annual production of crop (kg)
D = Ratio of residue to crop product
β = Combustion efficiency
F = Fraction burned
C = Burned area percent

Crop type	Fraction burned	Combustion efficiency	Ratio of residue to crop product	Burned area percent
Maize	0.15	0.67	0.97	0.15
Rice	0.37	1	0.72	0.5
Sugarcane	0.56	1	0.28	0.5

ตารางที่ 4 ข้าวนาปี : เนื้อที่ ผลผลิต และผลผลิตต่อไร่ เป็นรายภาค และรายจังหวัด ปี 2553-2555
Table 4 Major Rice : Area, production and yield by region and province, 2010-2012

ภาค/จังหวัด	เนื้อที่เพาะปลูก (ไร่) Planted area (Rais)			เนื้อที่เก็บเกี่ยว (ไร่) Harvested area (Rais)			ผลผลิต (ตัน) Production (Tons)			ผลผลิตต่อไร่ (กก.) Yield per rai (Kgs.)			Region/ Province
	2553 (r) 2010	2554 (p) 2011	2555 (f) 2012	2553 (r) 2010	2554 (p) 2011	2555 (f) 2012	2553 (r) 2010	2554 (p) 2011	2555 (f) 2012	2553 (r) 2010	2554 (p) 2011	2555 (f) 2012	
รวมทั้งประเทศ	64,574,071	65,303,711	64,997,781	59,690,203	56,752,413	60,606,555	25,742,917	25,867,373	26,950,327	431	456	445	Whole Kingdom
เหนือ	14,331,994	15,154,331	15,085,772	13,403,839	12,201,340	14,113,802	7,315,131	7,121,027	7,873,856	546	584	558	Northern
ตะวันออกเฉียงเหนือ	39,841,420	39,565,392	39,367,962	36,720,691	35,476,307	36,571,776	12,984,135	13,452,032	13,208,883	354	379	361	Northeastern
กลาง	9,213,059	9,544,587	9,531,171	8,471,420	8,115,695	8,973,321	5,014,112	4,876,834	5,462,249	592	601	609	Central Plain
ใต้	1,187,598	1,039,401	1,012,876	1,094,253	959,071	947,656	429,539	417,480	405,339	393	435	428	Southern
เชียงราย	1,261,022	1,348,827	1,351,430	1,235,659	1,233,556	1,297,890	684,735	726,211	740,923	554	589	571	Chiang Rai
พะเยา	643,608	705,811	698,289	628,846	673,721	669,889	337,894	375,873	370,486	537	558	553	Phayao

Emission estimation method for agricultural area

Agricultural Burning : Satellite data algorithm MOD14 and MCD45

$$M = A \times B \times E \times F$$

A = Burned area (m^2)
B = Dry biomass density (kg/m^2)
E = Combustion efficiency
F = Fraction burned

Kanokkanjana K. (2010)

Crop type	Fraction burned	Combustion efficiency	Dry biomass density (g/m^2)
Maize	1	0.67	610
Rice	1	1	360
Sugarcane	1	1	1,007

- 1 hotspot = 1 km^2 burned area
- confidence level > 60 %

algorithm MCD45

	A	B	C
1	Month	Date	Area (km^2)
2	2013032	59	9.65
3	2013032	58	0.22
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algorithm MOD14

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i = Species of air pollutant

Kanokkanjana K. (2010)

Crop type	Emission factor (g/kg of dry biomass)			
	CO	CO_2	$PM_{2.5}$	BC
Maize	68.11	1,186	8.72	0.55
Rice	133	1,185	28	0.77
Sugarcane	123.76	1,181	20.31	071

Results and discussions

Fires Statistics

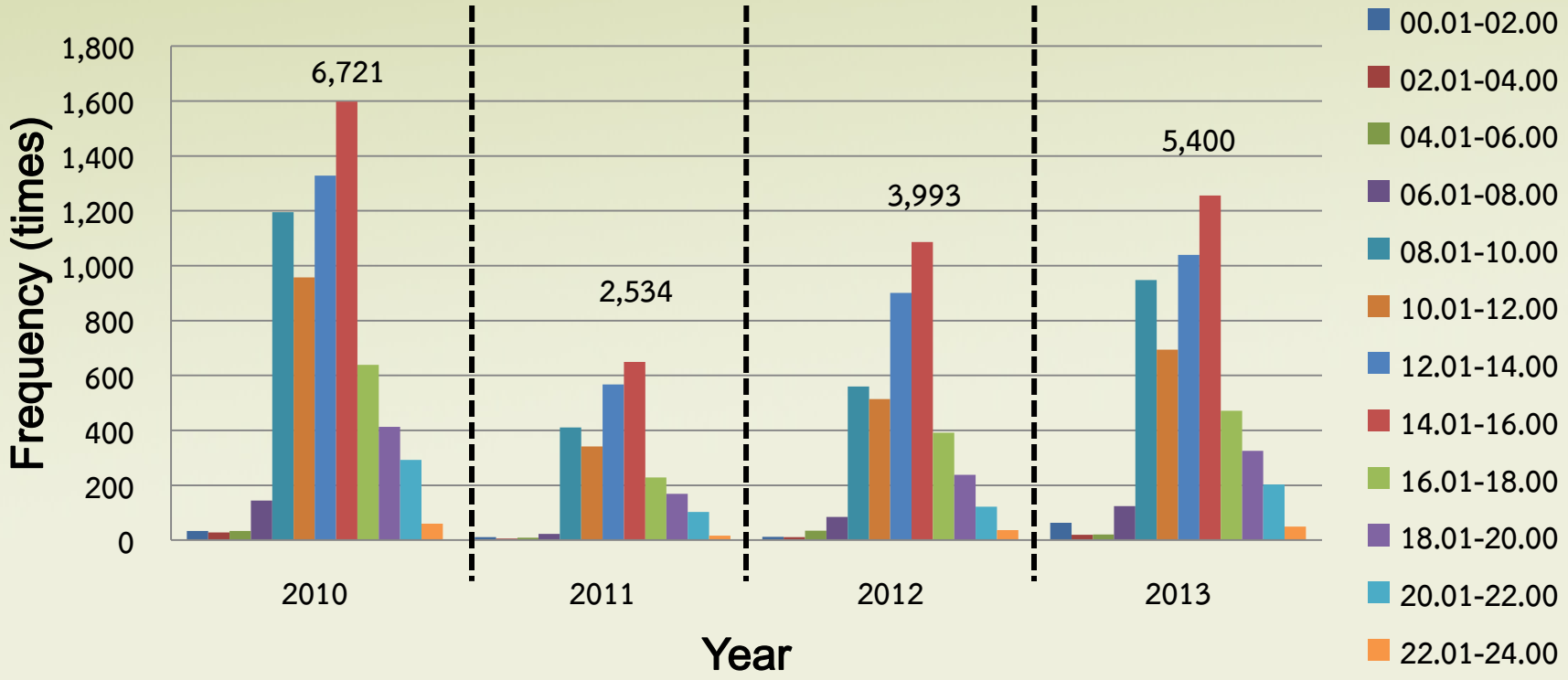
Emissions in forest areas

Emissions in Agricultural areas

Comparison of annual air emissions

Fires Statistics: Forest Fires

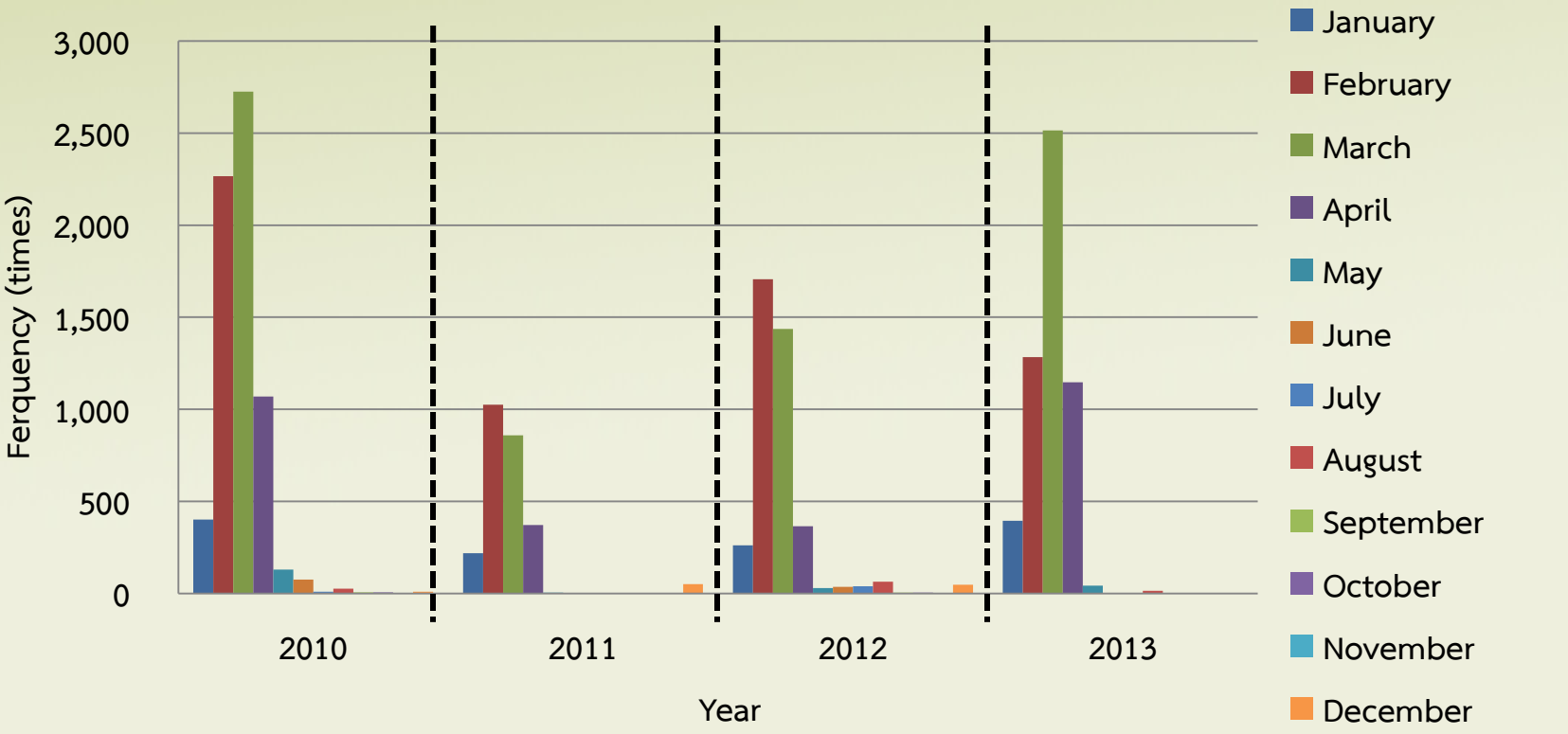
Temporal distribution classified by time of occurrences: Ground data



Time : 2 PM – 4 PM ,follow by noon – 2 PM and 8 AM – 10 AM

Fires Statistics: Forest Fires

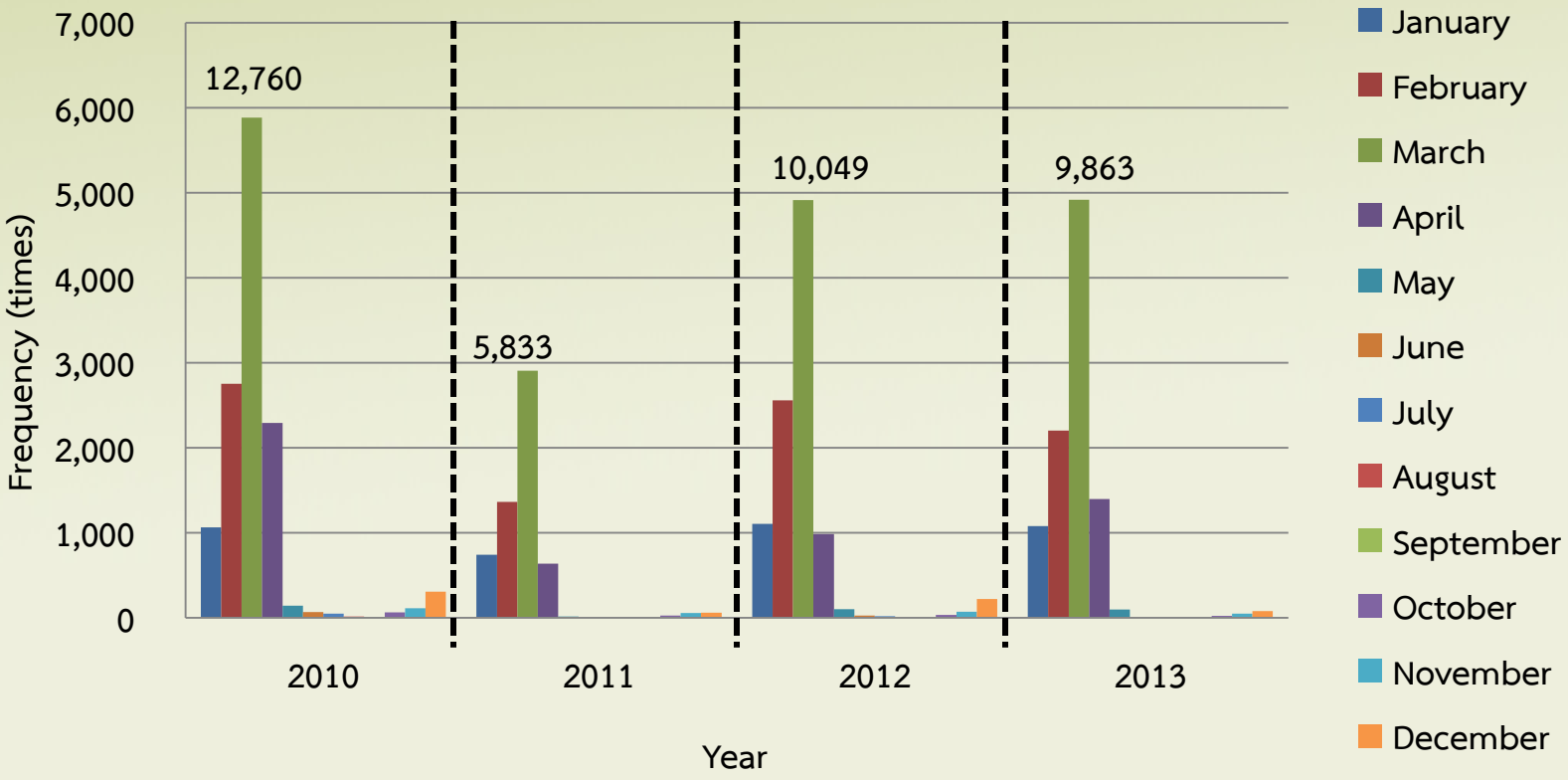
Temporal distribution classified by month of occurrences: Ground data



Peak Month : February and March ,followed by April and January

Fires Statistics: Forest Fires

Temporal distribution classified by month of occurrences: MOD 14

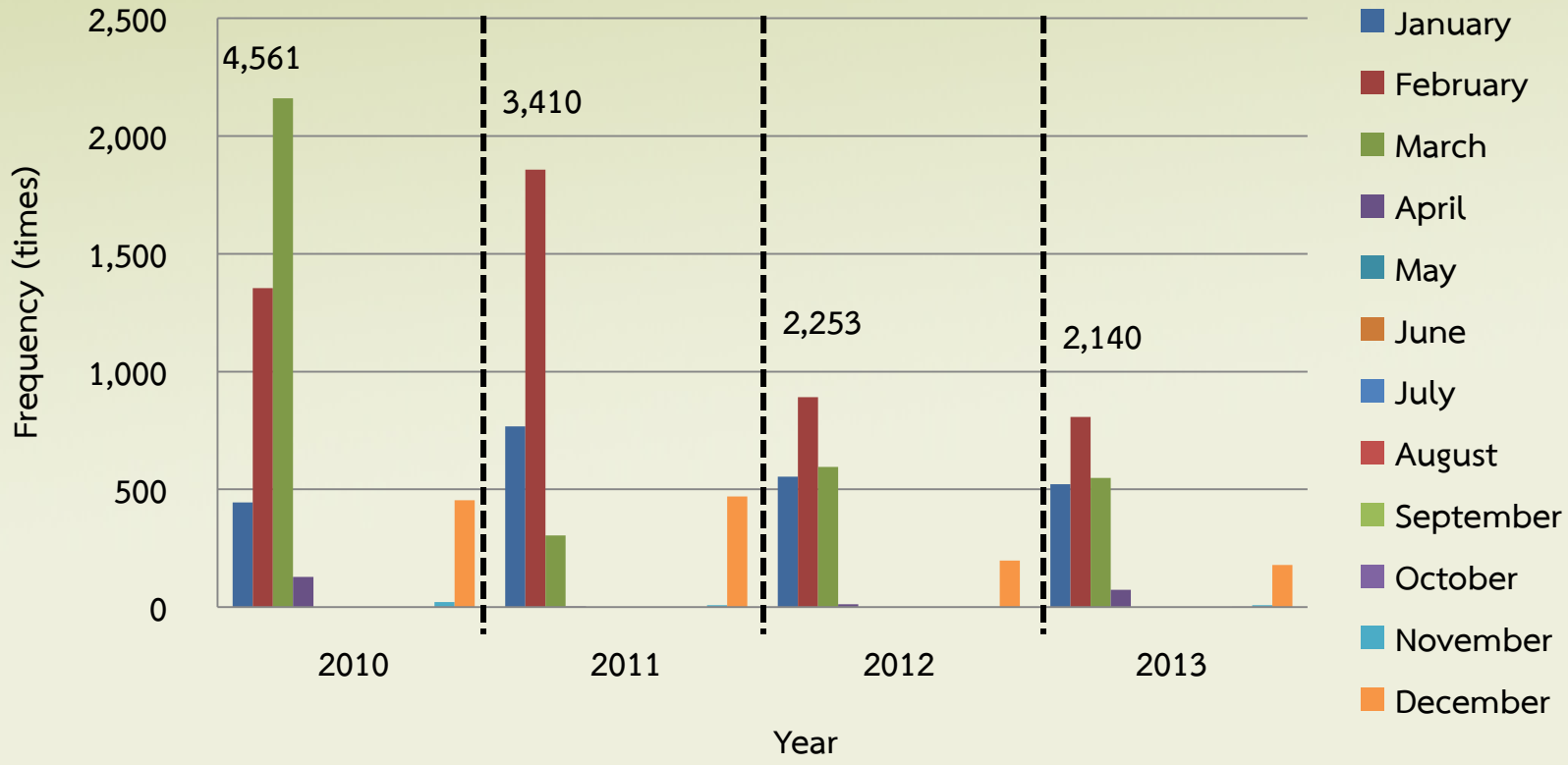


Peak Month : March ,follow by February April and January

Rational: Similar trends to ground data

Fires Statistics: Forest Fires

Temporal distribution classified by time of occurrences: MCD 45



Peak Month : March and February , followed by April and January

Rational: Differ from ground data trend

Burned Area in Forest Area

Burned area for forest fire from 2010 - 2013

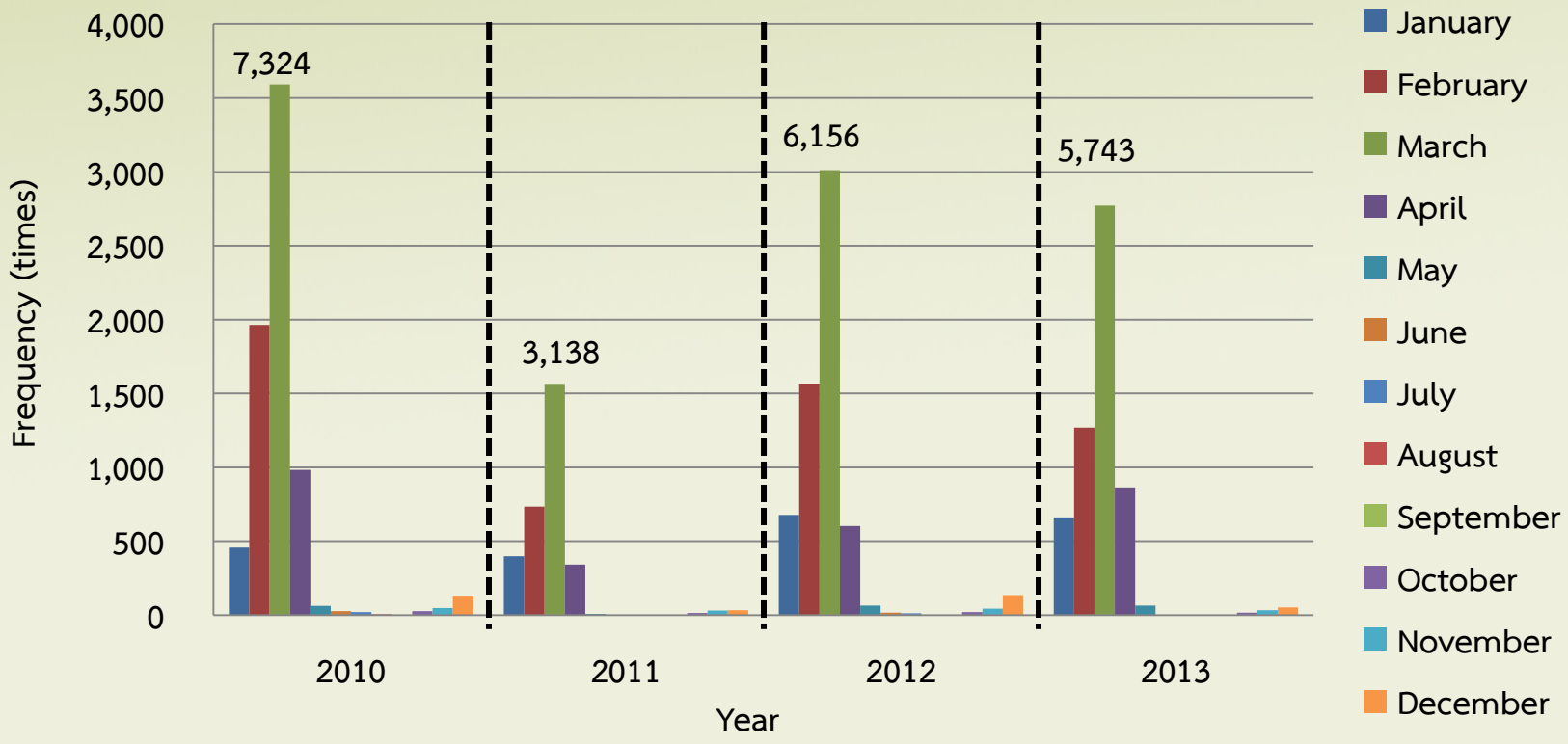
Forest type	Burned area (km^2)											
	2010			2011			2012			2013		
	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45
a	38.44	8,357	969.40	17.55	2,940	877.29	20.34	6,957	647.11	38.40	6,640	511.88
b	1,545.28	269	10.57	17.44	121	11.73	22.58	210	20.93	42.96	183	11.70
c	4.45	-	-	0.14	-	-	1.29	-	-	2.18	-	-
d	28.68	-	-	2.26	-	-	2.21	-	-	4.25	-	-
e	1.39	1,825	37.41	0.16	351	41.64	0.21	1,403	12.26	0.68	1,482	33.73
f	31.03	115	0	0.01	5	0	19.30	50	0	1.45	6	0
g	-	329	59.60	-	226	63.39	-	257	9.60	-	253	131.56
h	-	146	10.92	-	108	21.72	-	119	25.92	-	122	51.22
Total	1,649.27	11,041	1,087.90	37.56	3,751	1,015.77	65.94	8,996	715.82	89.92	8,686	740.09

a = Deciduous Dipterocarp Forest b = Mixed Deciduous Forest c = Pine Forest d = Dry Evergreen Forest

e = Tropical Rain Forest f = Swamp Forest g = Swamp Forest h = Grassland

Fires Statistics: Agricultural Burning

Temporal distribution classified by month of occurrences: MOD 14

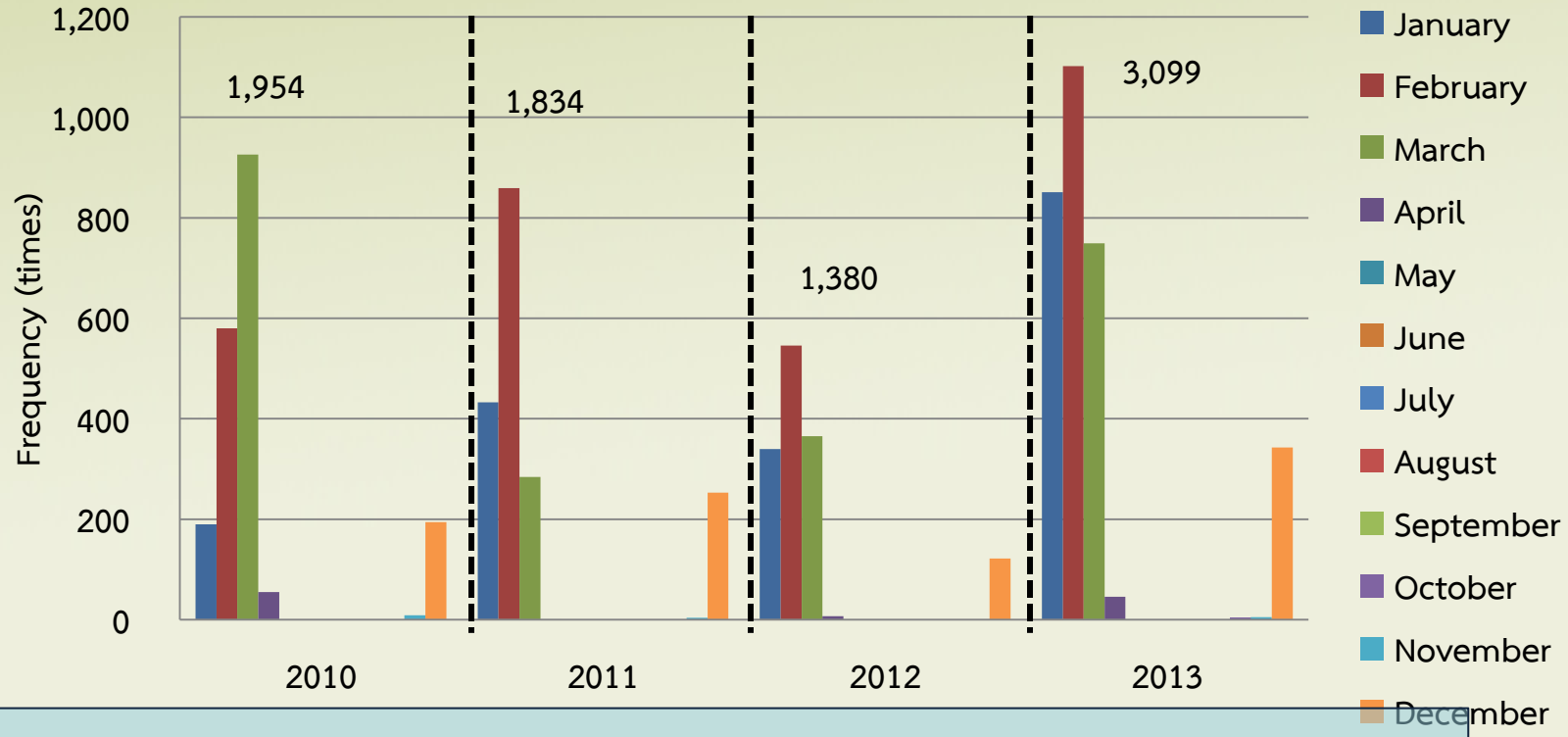


Month : March ,follow by February April and January

Is this trend consistence with ground data?

Fires Statistics: Agricultural Burning

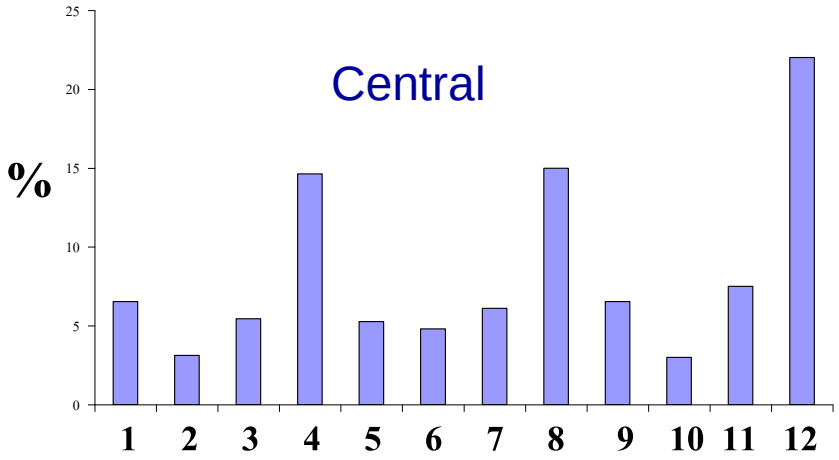
Temporal distribution classified by month of occurrences: MCD 45

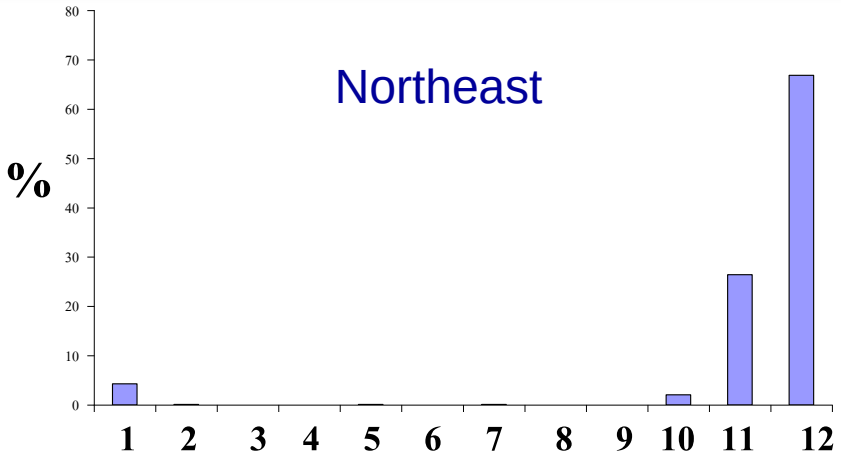


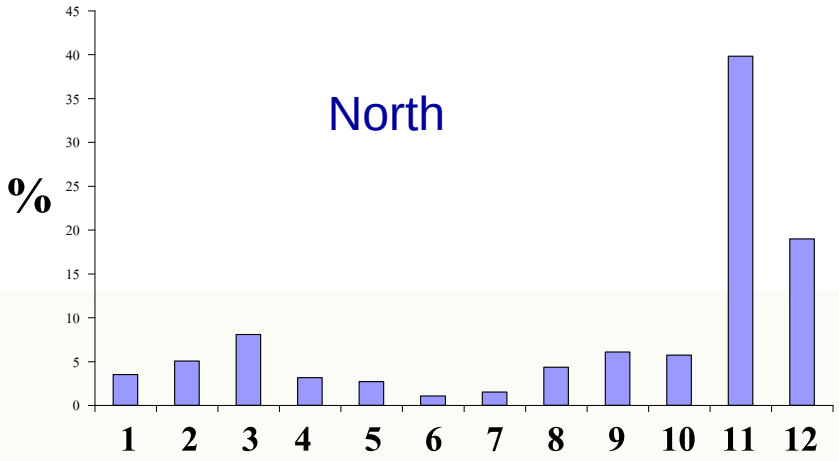
Month : February and March ,follow by January and December

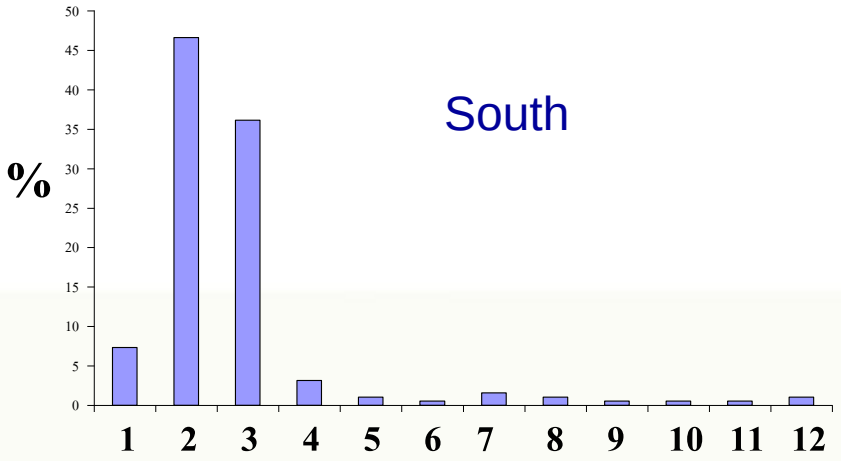
Is this trend consistence with ground data?

Rice: Harvesting Months

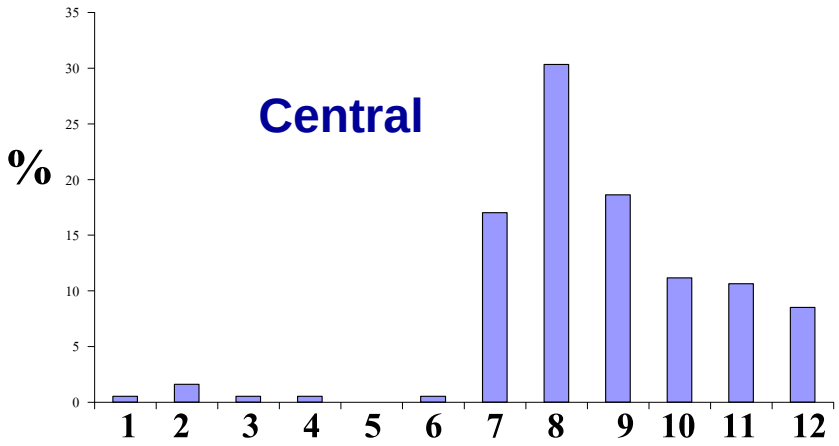


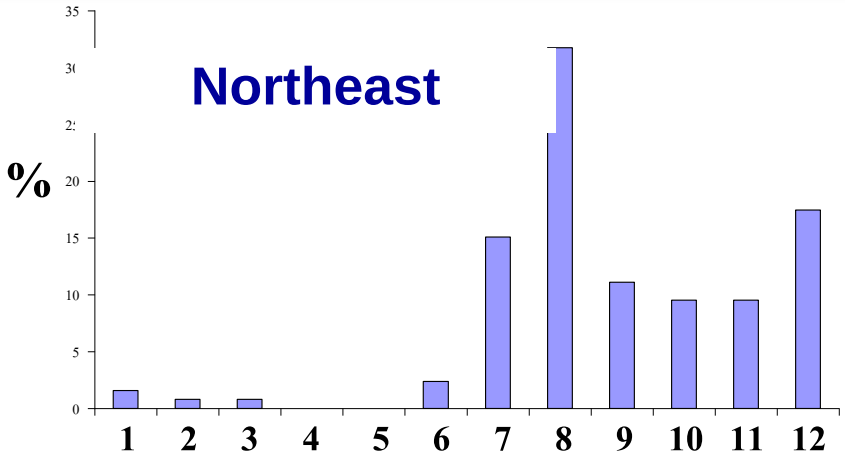


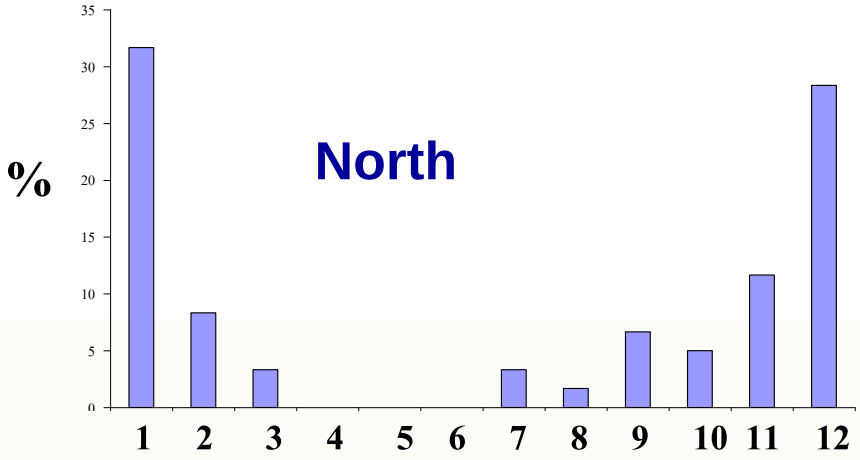




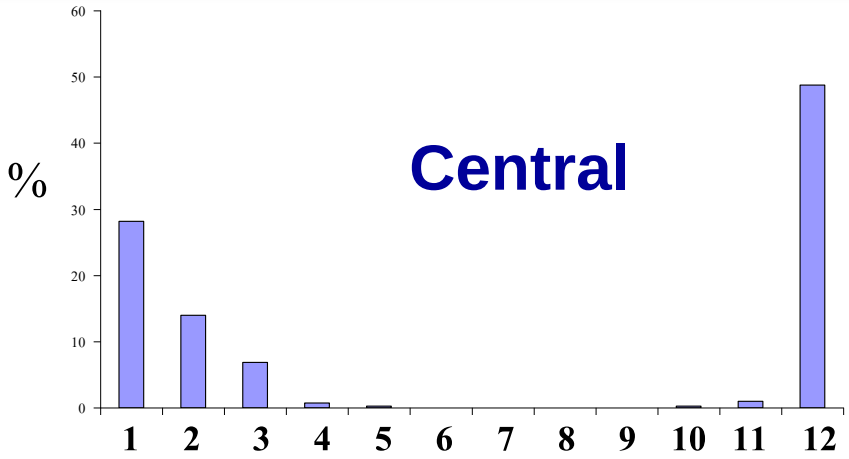
Maize: Harvesting Months

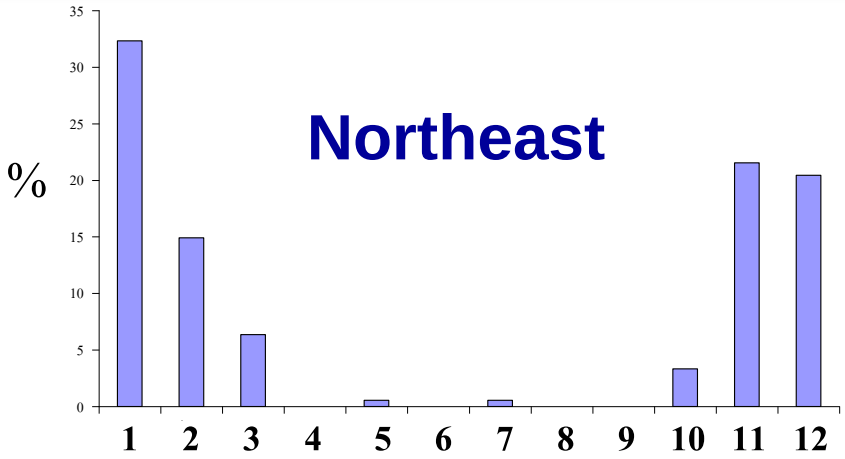


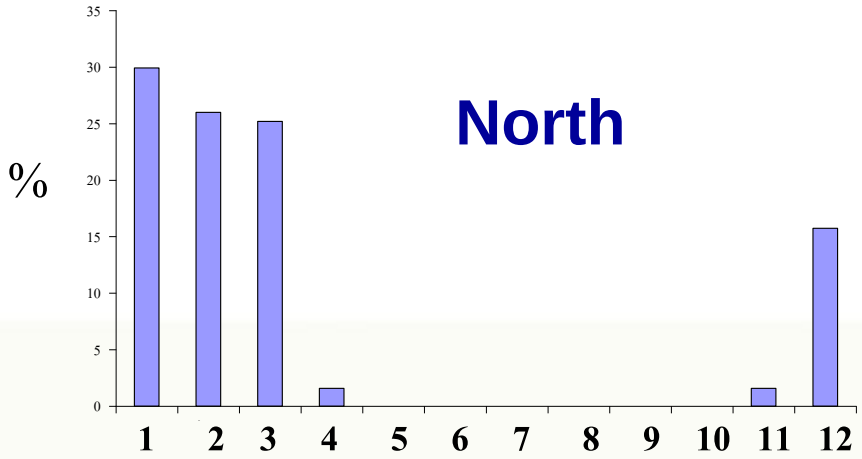




Sugar cane: Harvesting Months







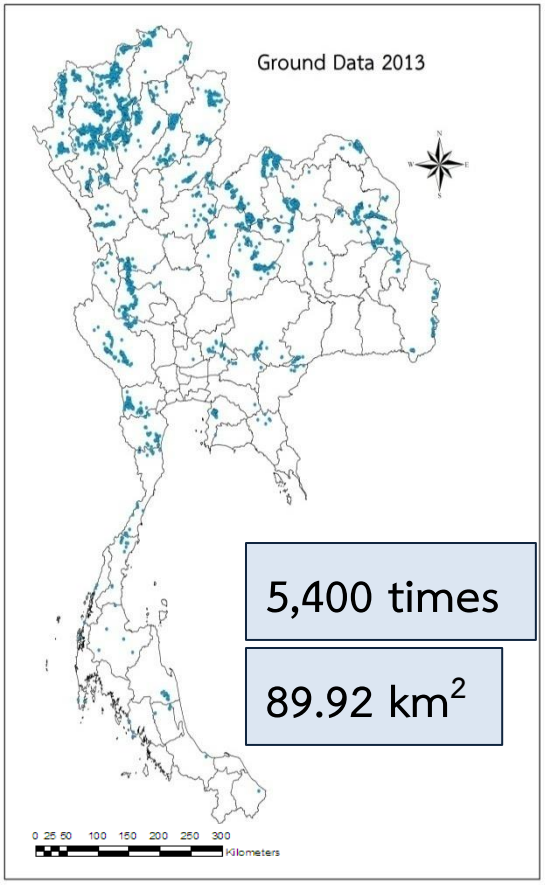
Only MCD45 that have peak period in December

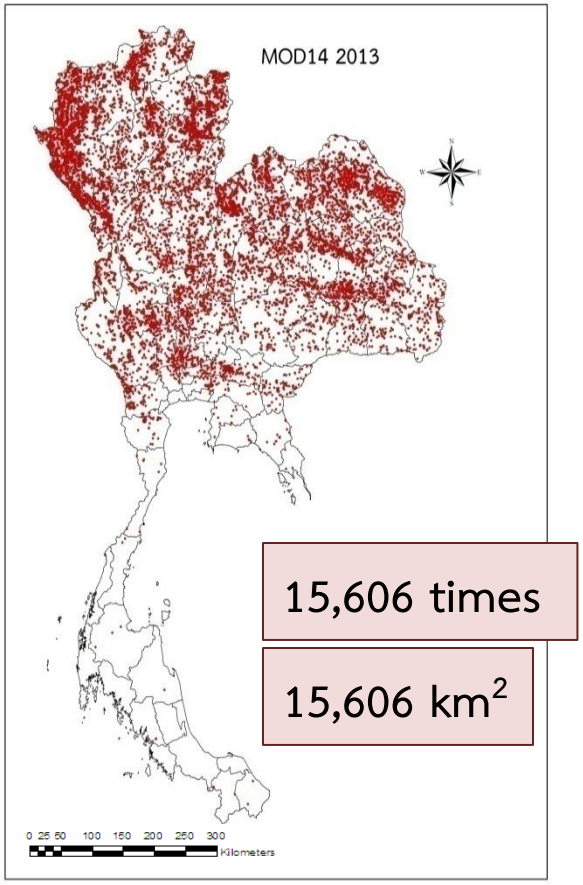
Burned Area in Agricultural area

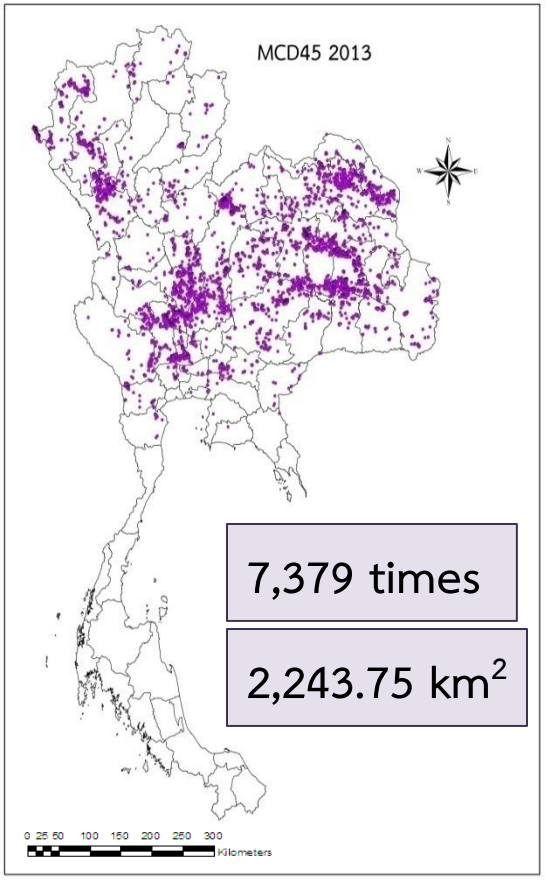
Table 18 Burned area for agricultural burning between 2010 - 2013

Crop type	Burned area (km^2)											
	2010			2011			2012			2013		
	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45	Ground data	MOD14	MCD45
Rice	-	5,153	724.95	-	3,443	831.64	-	4,265	397.80	-	4,312	1,207.12
Maize	-	2,948	649.35	-	858	52.05	-	2,035	117.27	-	1,601	148.48
Sugarcane	-	952	26.22	-	919	41.19	-	909	35.18	-	1,007	148.06
Total	-	9,053	1,400.52	-	5,220	924.88	-	7,209	550.25	-	6,920	1,503.66

Spatial Distribution of Fire in 2013







Emissions from forest area

Annual Emissions of each Air Pollutant from 2010 - 2013

Species of Air Pollutant	Emission (tons)											
	2010			2011			2012			2014		
	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45
CO	68,050	5,920,998	566,927	19,909	1,939,351	522,913	36,063	4,817,158	374,870	48,477	4,652,430	346,009
CO_2	1,008,22	87,965,519	8,404,517	292,191	28,905,117	7,812,592	535,291	71,511,766	5,539,171	712,74	69,094,906	5,280,949
NO_x	2,545	234,142	24,314	847	80,878	22,435	1,312	191,904	16,156	1,996	184,368	15,425
TPM	9,684	881,629	91,223	3,238	301,110	83,740	4,988	723,151	60,953	7,697	694,314	54,643
$PM_{2.5}$	7,488	670,750	67,676	2,400	225,692	62,178	3,894	548,762	45,104	5,747	527,828	40,481

Forest type	Emission factor (g/kg of dry biomass)				
	CO	CO_2	NO_x	TPM	$PM_{2.5}$
Evergreen needleleaf forest	107	1,569	4.60	17.60	13.00
Evergreen broadleaf forest	104	1,580	2.45	9.10	8.50
Deciduous needleleaf forest	107	1,569	4.60	17.60	13.00
Deciduous broadleaf forest	107	1,569	4.60	17.60	13.00
Mixed forest	107	1,569	4.60	17.60	13.00
Woodland	86	1,591	5.29	12.98	9.20
Wooded grassland	65	1,613	5.98	8.36	5.40
Closed shrubland	86	1,591	5.29	12.98	9.20
Open shrubland	65	1,613	5.98	8.36	5.40
Grassland	65	1,613	5.98	8.36	5.40
Cropland	92	1,515	3.83	13.00	3.90

CO_2 > CO > TPM > $PM_{2.5}$ > NO_x

MOD14 > MCD45 > ground data

Emissions from Agricultural burning

Annual Emissions of each Air Pollutant from 2010 - 2013

Species of Air Pollutant	Emission (tons)											
	2010			2011			2012			2013		
	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45
CO	1,285,512	447,432	56,054	1,575,224	303,266	46,401	1,653,686	374,141	26,695	1,624,207	376,524	80,371
CO_2	11,917,318	4,759,401	55,198	14,666,636	2,977,608	28,993	15,380,266	3,886,894	268,383	15,124,967	3,813,125	762,913
$PM_{2.5}$	239,245	81,919	10,158	287,999	56,559	9,411	303,418	68,835	5,147	296,673	69,766	15,723
BC	7,418	2,772	366	9,082	1,894	272	9,535	2,289	162	9,364	2,275	474

Crop type	Emission factor (g/kg of dry biomass)			
	CO	CO_2	$PM_{2.5}$	BC
Maize	68.11	1,186	8.72	0.55
Rice	133	1,185	28	0.77
Sugarcane	123.76	1,181	20.31	071

$CO_2 > CO > PM_{2.5} > BC$

Ground data> MOD14 > MCD45

CO_2 Emissions by Region between 2010 - 2013

Region	CO_2 Emission (tons)											
	2010			2011			2012			2013		
	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45
North	3,751,337	2,329,370	416,256	4,247,348	776,036	165,295	4,794,730	2,009,408	151,924	4,704,110	1,543,633	180,898
North East	4,729,947	1,610,302	172,512	6,169,731	1,384,877	158,507	6,056,608	1,099,255	61,394	5,885,798	1,576,910	390,190
Central	2,819,330	623,069	51,076	3,482,588	654,615	53,197	3,816,896	695,108	52,314	3,808,022	581,869	182,861
East	523,010	186,848	15,354	671,902	162,080	51,994	611,114	115,710	2,752	626,941	110,287	8,964
South	93,695	9,812	0	95,066	0	0	100,918	3,413	0	99,296	427	0
Total	**11,917,318**	**4,759,401**	**655,198**	**14,666,636**	**2,977,608**	**428,993**	**15,380,266**	**3,886,894**	**268,283**	**15,124,967**	**3,813,125**	**762,913**

40 % 34 % 26 %

North and Northeast are major sources

MCD45 : could not detect fire in South province

Region	Region area (km^2)	Agricultural area (km^2)	Percent
North	171,981	48,028	27.94
North East	167,717	76,498	45.61
Central	67,498	26,320	38.99
East	36,621	5,527	15.09
South	73,813	2,372	3.21
Total	517,630	158,745	30.67

CO_2 Emission Classified by Crop Type between 2010 - 2013

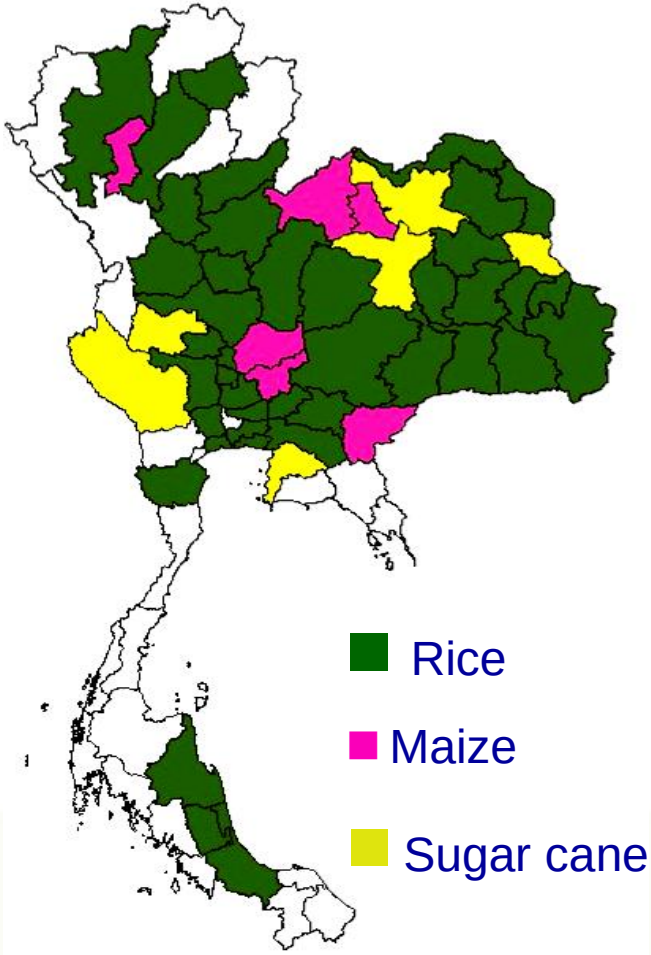
Crop type	CO_2 Emission (tons)											
	2010			2011			2012			2013		
	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45	Ground Data	MOD14	MCD45
Rice	5,462,078	2,198,270	309,264	5,695,453	1,468,784	354,778	6,183,228	1,819,449	169,702	5,817,170	1,839,499	514,859
Maize	84,298	1,428,949	314,752	87,095	415,888	25,230	86,100	986,402	56,845	86,100	776,034	71,971
Sugarcane	6,370,942	1,132,182	31,183	8,884,087	1,092,936	48,986	9,110,938	1,081,044	41,838	9,221,698	1,197,592	176,083
Total	**11,917,312**	**4,759,401**	**655,198**	**14,666,636**	**2,977,608**	**428,993**	**15,380,266**	**3,886,894**	**268,283**	**15,124,967**	**3,813,125**	**762,913**

Crop type	Production (million tons/year)				Residue to crop ratio
	2010	2011	2012	2013	
Rice	34.61	36.08	39.17	36.85	0.72
Maize	4.86	5.02	4.97	4.97	0.97
Sugarcane	68.81	95.95	98.40	99.60	0.28
Cassava	22.01	21.91	29.41	27.14	0.09
Oil Palm	8.22	10.78	11.33	12.38	0.69

Major source: Rice for MOD 14 & MCD 45
Sugar cane for ground data

Which type of fire data more reasonable?

Crop Production



Crop type	Production (million tons/year)			
	2010	2011	2012	2013
Rice	34.61	36.08	39.17	36.85
Maize	4.86	5.02	4.97	4.97
Sugarcane	68.81	95.95	98.04	99.6

Source :Office of Agricultural Economics

Emission Factors for Agricultural Burning Assessment

Combustion efficiency, Dry biomass density (kg/m^2), Burned area percent, Fraction burned and Ratio of residue to crop product from Kanokkanjana K. (2010)

Crop type	Fraction burned	Combustion efficiency	Ratio of residue to crop product	Dry biomass density (g/m^2)	Burned area percent
Maize	0.15	0.67	0.97	610	0.15
Rice	0.37	1	0.72	360	0.5
Sugarcane	0.56	1	0.28	1,007	0.5

Emission Factors for Agricultural Burning Assessment (Cont.)

Table 12 Emission factor from Kanokkanjana K. (2010)

Crop type	Emission factor (g/kg of dry biomass)			
	CO	CO_2	$PM_{2.5}$	BC
Maize	68.11	1,186	8.72	0.55
Rice	133	1,185	28	0.77
Sugarcane	123.76	1,181	20.31	071

Ground data made more sense than satellite!

Comparison of Annual Air Pollutants Emissions

Table 13 Air pollutants emission in 2010

Vegetable type		Emission (tons)					
		CO	CO_2	NO_x	TPM	$PM_{2.5}$	BC
Forest Fire	Ground data	68,050	1,008,224	2,545	9,684	7,488	-
	MOD14	5,922,002	87,965,519	234,142	881,629	670,750	-
	MCD45	566,927	8,404,517	24,314	91,223	67,676	-
Agricultural Burning	Ground data	1,285,512	11,917,138	-	-	239,245	7,418
	MOD14	447,432	4,759,401	-	-	81,919	2,772
	MCD45	56,054	655,198	-	-	10,158	366

Table 14 Air pollutants emission in 2011

Vegetable type		Emission (tons)					
		CO	CO_2	NO_x	TPM	$PM_{2.5}$	BC
Forest Fire	Ground data	19,909	292,192	847	3,238	2,400	-
	MOD14	1,939,351	28,905,117	80,878	301,110	225,692	-
	MCD45	522,913	7,812,592	22,435	83,740	62,177	-
Agricultural Burning	Ground data	1,575,224	14,666,636	-	-	287,999	9,082
	MOD14	303,266	2,977,608	-	-	56,559	1,804
	MCD45	46,401	428,993	-	-	9,411	272

Comparison of Annual Air Pollutants Emissions

Table 15 Air pollutants emission in 2012

Vegetable type		Emission (tons)					
		CO	CO_2	NO_x	TPM	$PM_{2.5}$	BC
Forest Fire	Ground data	36,063	535,291	1,312	4,988	3,894	-
	MOD14	4,817,853	71,511,766	191,904	723,151	548,762	-
	MCD45	374,870	5,539,171	16,156	60,953	45,104	-
Agricultural Burning	Ground data	1,653,686	15,380,266	-	-	303,418	9,535
	MOD14	374,141	3,886,894	-	-	68,835	2,290
	MCD45	26,695	268,383	-	-	5,147	162

Table 16 Air pollutants emission in 2013

Vegetable type		Emission (tons)					
		CO	CO_2	NO_x	TPM	$PM_{2.5}$	BC
Forest Fire	Ground data	48,477	712,746	1,996	7,697	5,747	-
	MOD14	4,652,430	69,094,906	184,368	694,314	527,828	-
	MCD45	346,009	5,280,949	15,425	54,643	40,481	-
Agricultural Burning	Ground data	1,624,207	15,124,967	-	-	296,673	9,364
	MOD14	376,524	3,813,125	-	-	69,766	2,275
	MCD45	80,371	762,913	-	-	15,723	474

Conclusion

- Emissions in Forest Fire Area
  - MOD 14 was the best of the three sources of data due the larger coverage area and similar trend to ground data. However, emissions were systematic overestimated since average of burned area in Thailand is far less than 1 km^2 approximation.
- Emissions in Agricultural Area
  - Ground based data gave more reasonable amount of emissions but lack of spatial and temporal distribution.
  - Satellite Based data, MCD45 was better than MOD 14 from capability to discover peak of fire in Dec.
- Emissions from Forest Fire were greater than crop residue burning. However, the difference of this two sources was closer for certain year.

acknowledgement

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