EI FOR OPEN BURNING SECTOR: ABC EIM approach

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Open burning and emission

Content

- Introduction to ABC emission inventory manual
- Open burning sources
- EI for agroresidue open burning

ABC EIM Project

- **Sponsored by UNEP-ABC**
- **Objective**: to provide a framework of emission inventory of Atmospheric Brown Clouds (ABC) relevant pollutants which is suitable for use in different Asian countries.
- **Activities**:
  - Develop a comprehensive EI Manual
  - Develop excel workbook
  - Case studies of Indonesia and Thailand

Coverage of Pollutants in ABC EIM

Shrestha, R.M., Kim Oanh N. T. Shrestha, R., Rupakheti, M., Rajbhandari, S., Permadi, D.A. and Thongchai, K., 2010. Atmospheric Brown Cloud (ABC) Emission Inventory Manual

- Primary aerosols:
  - PM10, PM2.5
  - Particulate BC and OC
- Gaseous pollutants:
  - SO2
  - NOx
  - NH3
  - CO
  - NMVOC
- Greenhouse gases:
  - CO2, N2O and CH4

Highlights of ABC Emission Inventory Manual (EIM)

- Compiles $PM_{2.5}$, BC/OC EF from various updated research (in addition to other trace gases and GHGs)
- Adds emphasis on biomass open
- Provides detail treatment of spatial and temporal variation of emission from each source sector
- Identifies and compiles the Asian specific region emission factors which are recorded in the EXCEL database and can be updated in by users
- Provides simple tool (EXCEL) and guidance to encourage the national focal experts in gathering national specific data for better emission inventory

Emission from “Non-Open Burning Sector”

"Open Burning Sector":

Activity Data & Emission Factors

Source Sectors	Activity Data	Sources of Emission Factors
Crop Residue Open Burning	- Crop production data - Harvesting area	Jenkins et al. (1994), Streets et al. (2001), Andreae and Merlet (2001), **Wang et al., (2002),** Dennis et al. (2002), Christian et al. (2003), Reddy and Ventakataraman (2002), **Sahai et al. (2007), Cao et al. (2008), Zhang et al. (2008)**
Forest Fires	Burned area	Andreae and Merlet (2001)
MSW Open Burning	Population	Economopoulos (1993), AP-42 USEPA (1995), Bond et al., (2004),

Temporal and Spatial Distribution

Source Sector	Temporal Variation	Spatial Variation
Crop Residue Open Burning	- Crop production data - Remote sensing based hotspot pixels and landuse	- Crop production data - Remote sensing based hotspot pixels and landuse
Forest Fires	- Ground/field data - Remote sensing based hotspot pixels and landuse	- Ground/field data - Remote sensing based hotspot pixels and landuse
MSW Open Burning	Seasonal variations (weather conditions)	- Population density

EI for agro-residue burning

- Open agro-residue burning:
  - Any deliberate burning of various types of crop residue that occurs on-site (field burning)
  - Off-site burning or biofuel combustion is excluded (appear in the related sectors)
- Pollutants to be covered: PM (PM_{10}, $PM_{2.5}$) particulate BC & OC, gaseous emission (CO, CO_2, nitrogen oxides, NMHC, CH_4, SO_2, and NH_3)

Emission estimation

Emission: $$Em_{x,l} = \sum_{l} M_l \bullet EF_{x,l}$$

- EF: emission factors of pollutant *(g/kg biomass)*
- M: amount of burned crop residue *(kg/year)*
- Challenges:
  - M is estimated with very high uncertainty
  - EF data is not available for all crops and also with high uncertainty

Estimation of M: Approach 1

- Based on total crop production, P (kg/year):

$$M_l = P_l \bullet N_l \bullet D_l \bullet B_l \bullet F$$

P: National crop production (kg/year)

N: Crop specific residue-to-production ratio

D: Dry matter-to-crop residue ratio

B: Fraction of dry matter in total residue burned in field

F: Burning efficiency (fraction oxidized)

COMPILED ACTIVITY INFORMATION (from different sources)

Parameter	Crop Type									
	Rice	Wheat	Soya	Maize	Potatoes	Jute	Oil crops	Groundnut	Sugarcane	Root/tubers
Residue to crop ratio (N)[a]	1.76	1.75	0.21[e]	0.33 [f]	0.4[g]	2.15[f]	0.6[d]	2.0[f]	0.3	0.2[d]
Dry-matter-to-crop residue ratio (D)[a]	0.85	0.83	0.21	0.4[g]	0.45[g]	0.8[h]	0.6	0.8[h]	0.3	0.2
Fraction burned in field (B)[b,g]	0.17 - 0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25	0.17-0.25
Burn efficiency ratio (F)[d]	0.89	0.86	0.68	0.9[g]	0.9[g]	0.9[g]	0.82	0.9[g]	0.68	0.68

Remarks:

[a] Compiled by Streets et al. (2003) from Koopmans and Koppejan (1997).

[b] Compiled by Streets et al. (2003) from Ventakaraman (2001) and Hao and Liu (1994). This component is a large source of uncertainty and need detail specific data from farmers burning practices. IPCC (1996) suggestes to use 0.25 (developing countries) and <0.17 (developed countries).

[c] Compiled by Streets et al. (2003) from Turn et al. (1997).

[d] Compiled by Streets et al. (2003) from Lu (1993).

[e] Compiled by Streets et al. (2003) from Strehler and Stutzle (1987).

[f] Compiled by Vallack in GAPF EI manual (2007) from TIFAC (1991)

[g] Compiled by Vallack in GAPF EI manual (2007) from IPCC (1996). Originally in IPCC (1996) a broader range was provided.

[h] Compiled by Vallack in GAPF EI manual (2007) from Bhattacharya and Mitra (1998)

Considerations

- Large uncertainty of all data
- Range for *B* can be large (~ 0.1-0.9)

  Example: in BMR, Thailand B=0.9 for rice paddies (AIT survey, 2004)
- Country statistics vs. international data

Estimation of M: Approach 2

- Based on burned area (km^2/year):

$$M_l = Y_{R,l} \bullet AB_l$$

- Area burned (AB): Limited information
  - Plantation area and harvest area: not the same
  - AIT research for rice straw: 2.3 crops/area/year for paddy in BMR
- Residue yield per hectare, $Y_{R,l}$

  $Y_{R,l}$ is not readily available, thus estimation to be made based on production yield (FAOSTAT) and other data similar to approach 1

Formula based on yield and harvest area (approach 2)

$$M_l = Y_l \bullet N_l \bullet D_l \bullet B_l \bullet A_l \bullet F$$

- Y: Crop yield (kg/ha)
- N: Crop specific residue-to-production ratio
- D: Dry matter-to-crop residue ratio
- B: Dry matter residue burned in the field (fraction)
- A: Harvest area in a year (ha/year)
- F: Burning efficiency (fraction oxidized)

EMISSION FACTORS

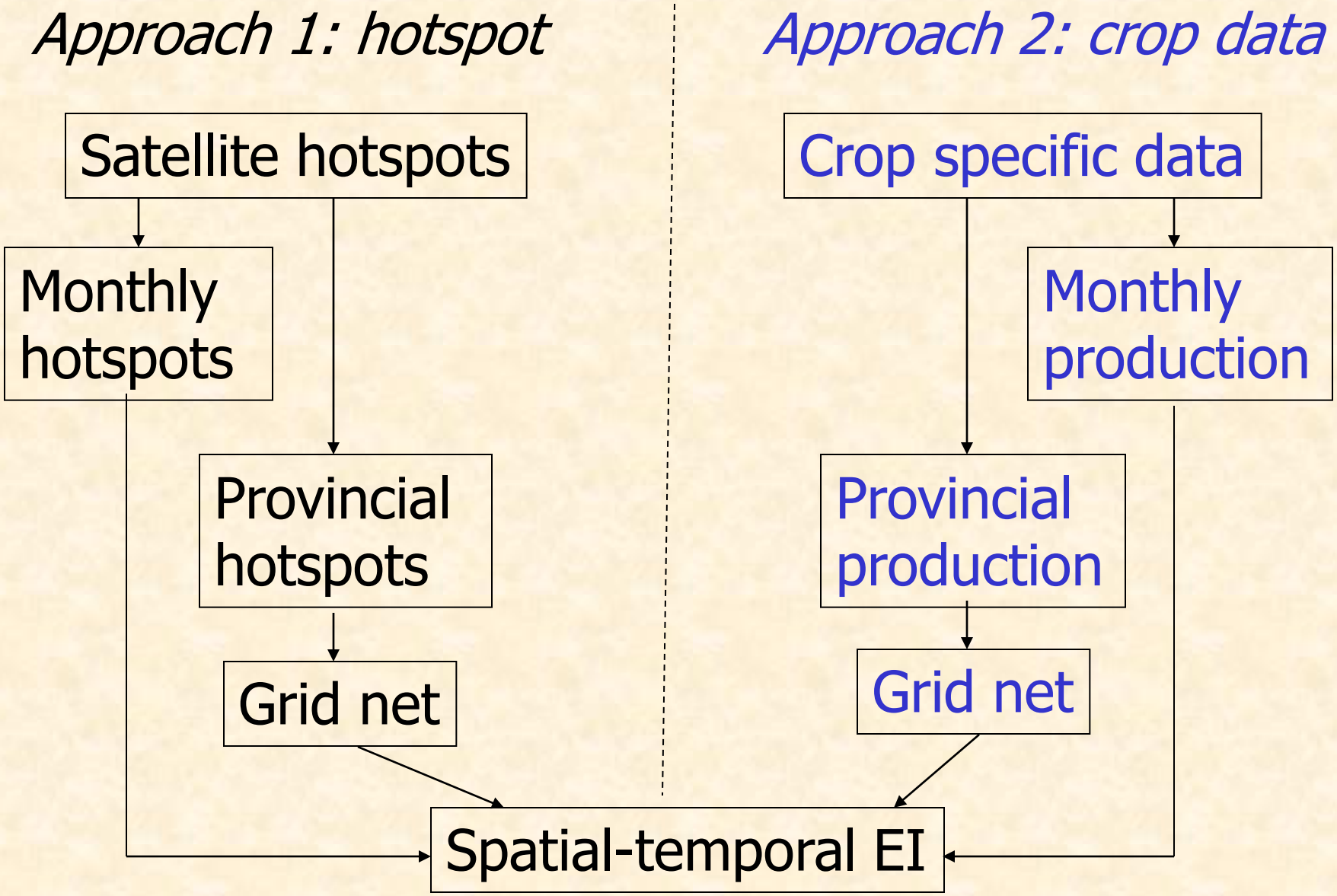
Pollutants	Agro residual type (g/kg dry mass of residue)									
	Rice	Wheat	Soya	Maize	Potatoes	Jute	Oil crops	Groundnut	Sugarcane	Root/tubers
$PM_{2.5}$	3.2[e]	3.7[c]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.7[c]	3.9[a]
PM_{10}	3.5[e]	3.9[c]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.9[a]	3.9[c]	3.9[c]
PM	13[a]	4[c]	13[a]	13[a]	13[a]	13[a]	13[a]	13[a]	4[c]	13[a]
SO_2	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]	0.4[a]
CO_2	1216[d]	1613[a]	1613[a]	1613[a]	1613[a]	1613[a]	1613[a]	1613[a]	1613[a]	1613[a]
CO	180[d]	28[b]	36.4[c]	36.4[c]	36.4[c]	36.4[c]	36.4[c]	36.4[c]	34.6[c]	34.6[c]
NO_x	0.62d	1.7[b]	1.7[b]	1.7[b]	1.7[b]	1.7[b]	1.7[b]	1.7[b]	2.6[c]	1.7[b]
NH_3	4.1[d]	0.95[c]	1.3[a]	1.3[a]	1.3[a]	1.3[a]	1.3[a]	1.3[a]	0.95[c]	1.3[a]
CH_4	9.6[d]	3.55[b]	2.7[a]	2.7[a]	2.7[a]	2.7[a]	2.7[a]	2.7[a]	0.4[c]	2.7[a]
NMHC	7[a]	2.16[c]	7[a]	7[a]	7[a]	7[a]	7[a]	7[a]	2.16[c]	7[a]
BC	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.52[c], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]	0.73[f], 0.69[a], 0.47[g]
OC	0.7[h], 3.3[a]	0.7[h], 1.26[c]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]	0.7[h], 3.3[a]

[a] Andreae and Merlet (2001),[b] **Sahai et al., (2007)**, [c] Dennis et al., (2002), [d] **Christian et al., (2003),**[e] Jenkins et al., (1994), [f] **Streets et al., 2001.** [g] **Wang et al., 2002.** [h] **Reddy and Ventakataraman, 2002a**

Different burning practices
➔ different EF !

Rice straw burning in VN and Thailand

Spatial-temporal EI



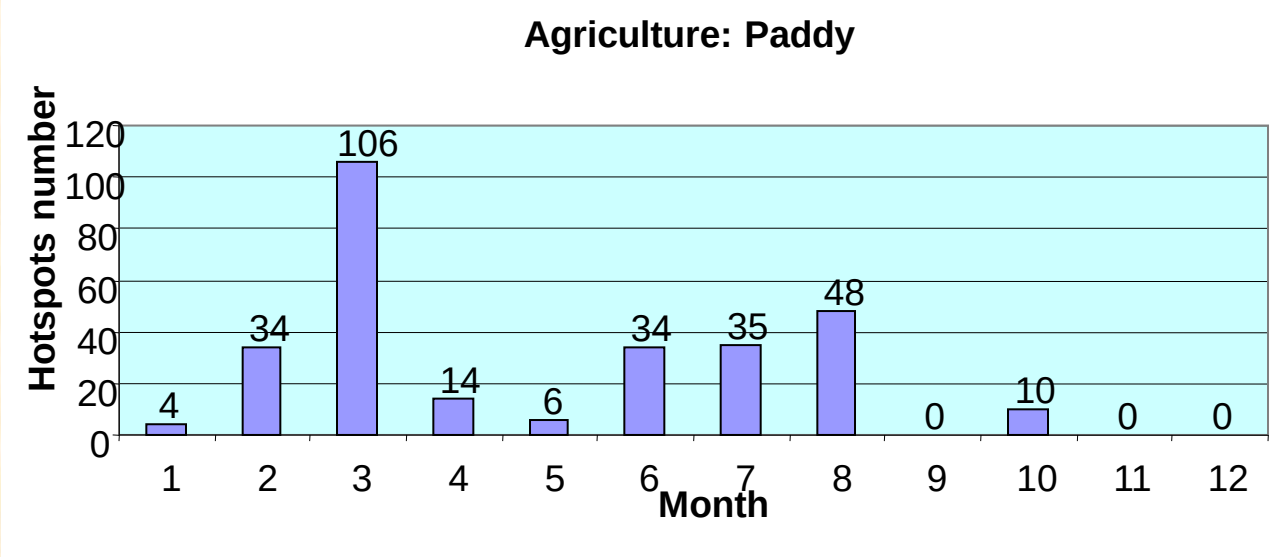
Temporal and spatial distribution (1)

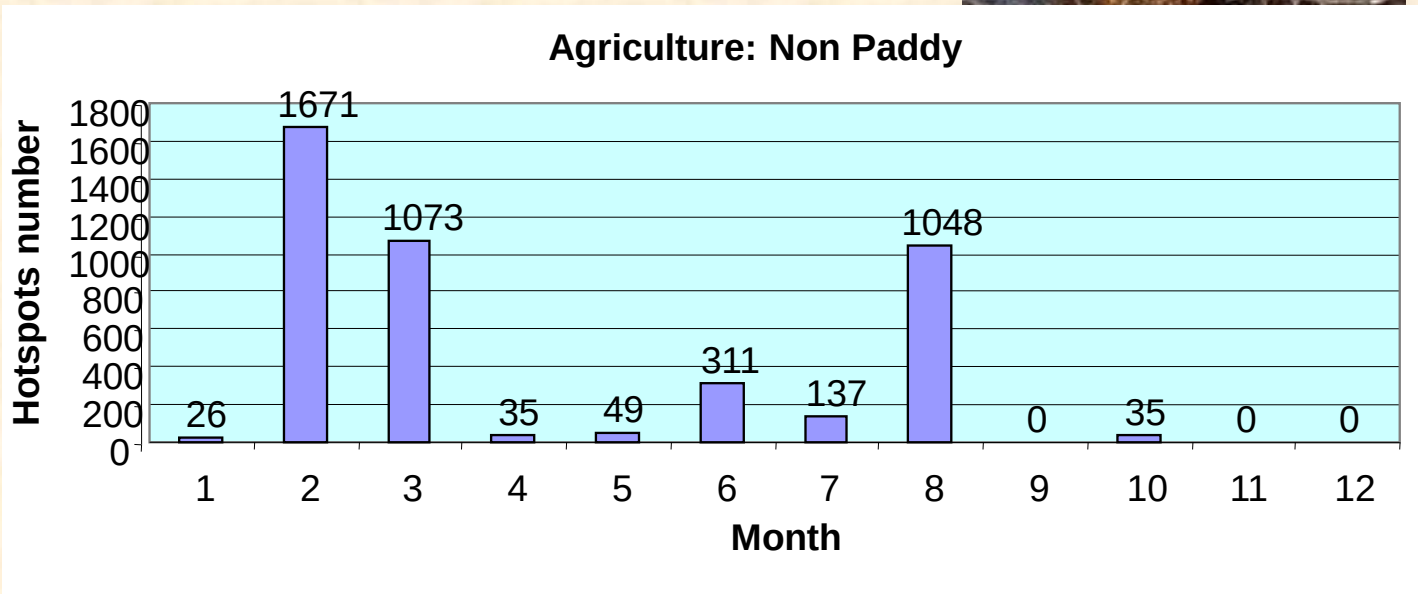
- Approach 1: estimation based on hotspots
- Problems:
  - Small burn area, short burning period (~h)

    Ex. AIT research: burning rice paddies~ 1-2 thousand m^2, for 40-70 minutes
  - MODIS satellite images available for limited time per day (10:00, 13:00) may not be the burning time

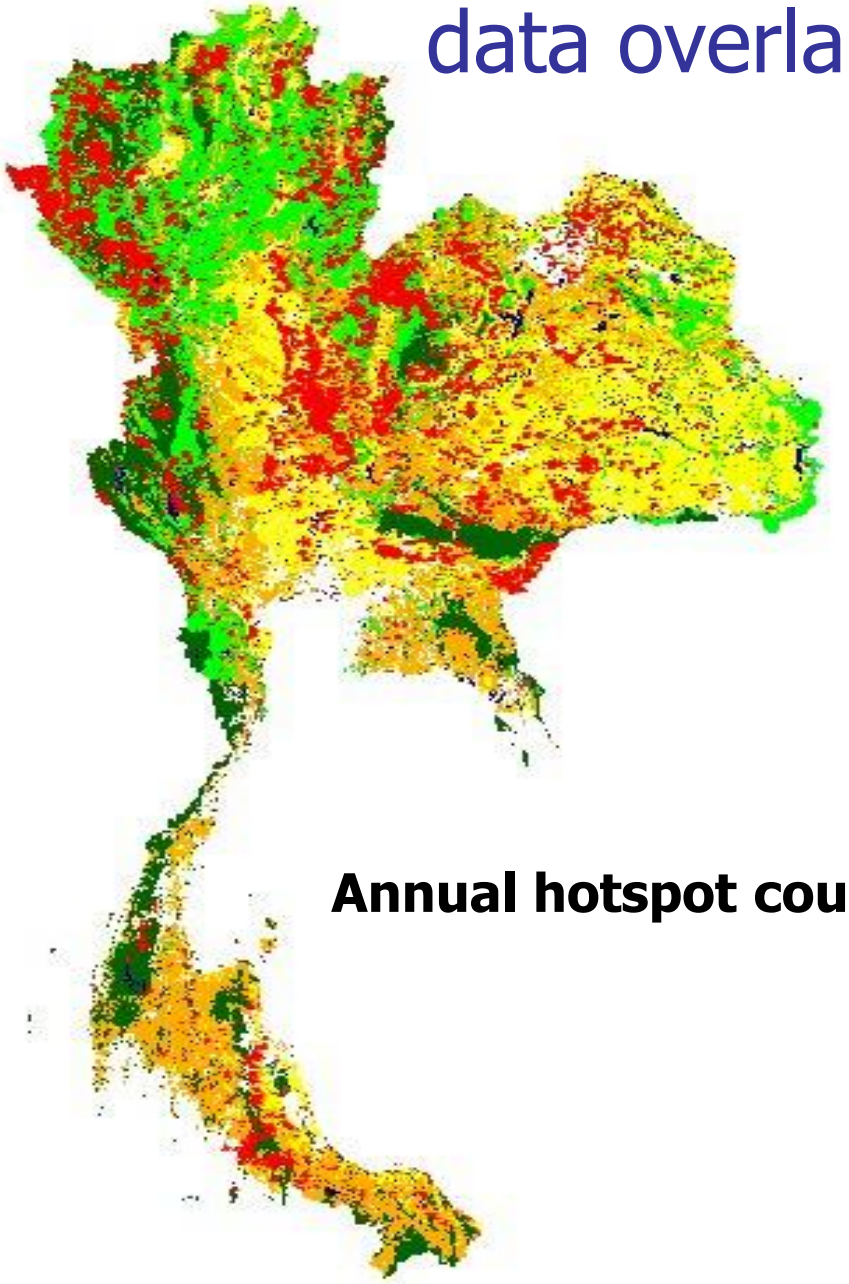
  ➔ hotspot may not accurately represent burning activities ➔ but long term data would provide certain reliability

Hotspot counts for temporal variation (Sumatera island, Indonesia)





Burning intensity (hotspot) from Satellite data overlaid with land-use

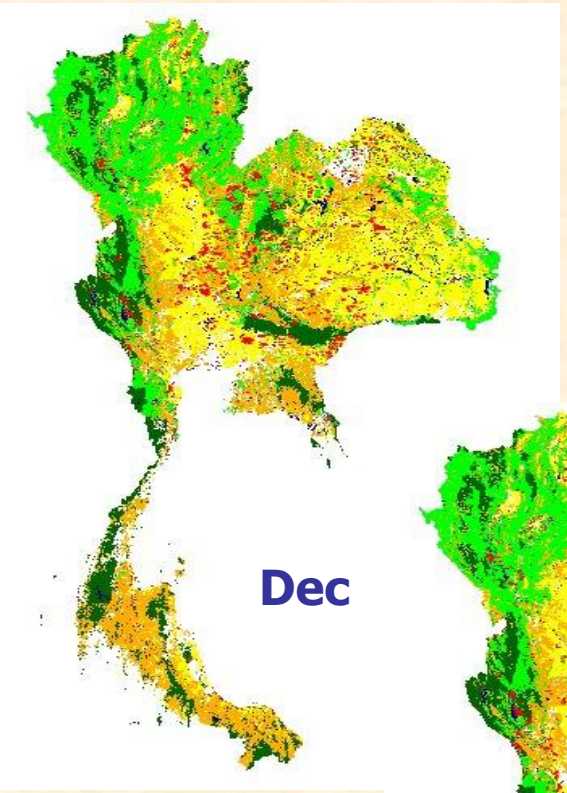


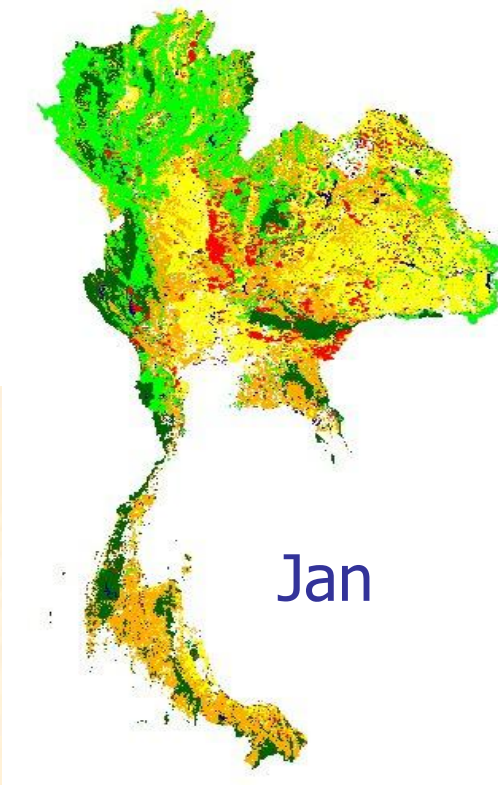
Annual hotspot counts

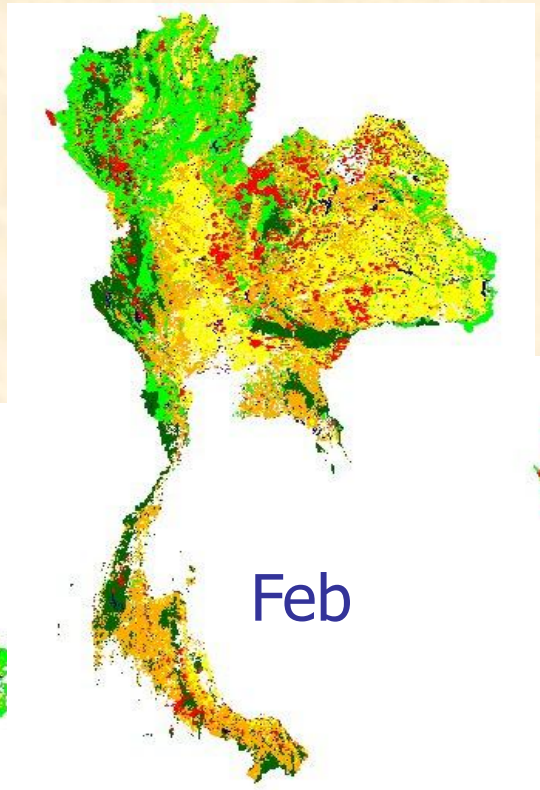
- Paddy field
- Mixed agriculture
- Savanna grass
- Sub-tropical forest
- Tropical forest
- Water body
- Others

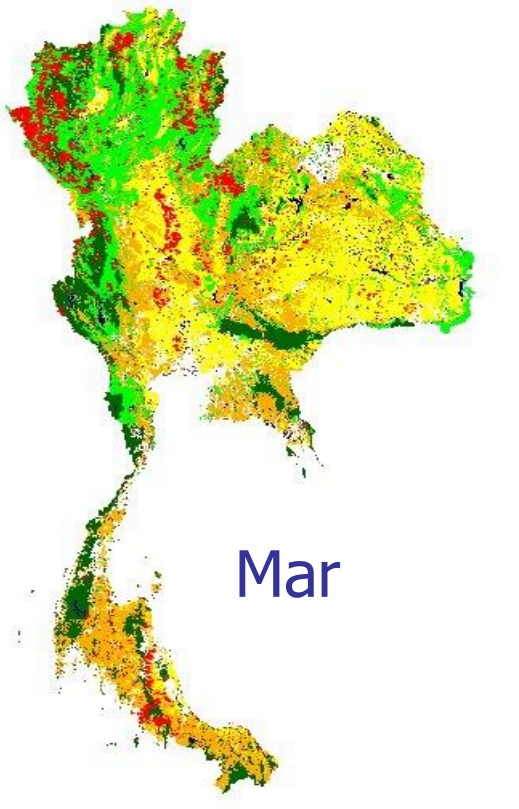
Burning product retrieved from ftp://ba1.geog.umd.edu

Satellite data: example of monthly hotspots







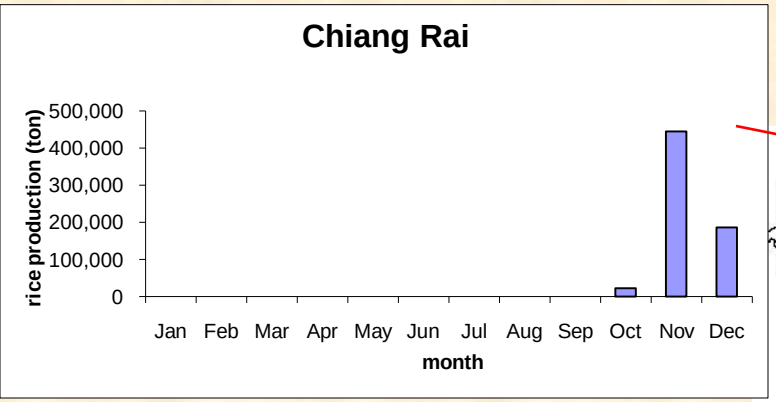


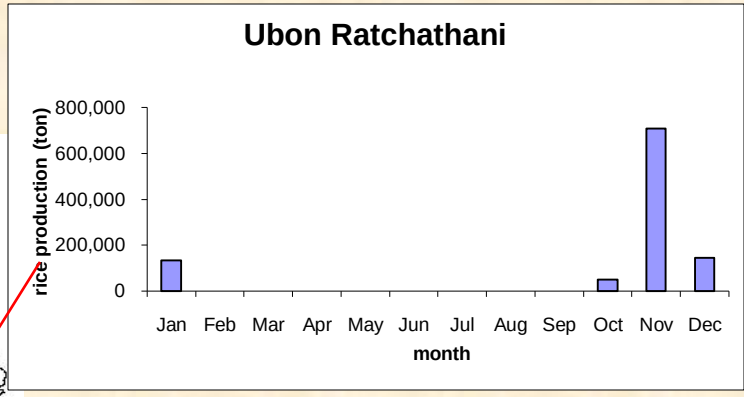
Burning product retrieved from ftp://ba1.geog.umd.edu

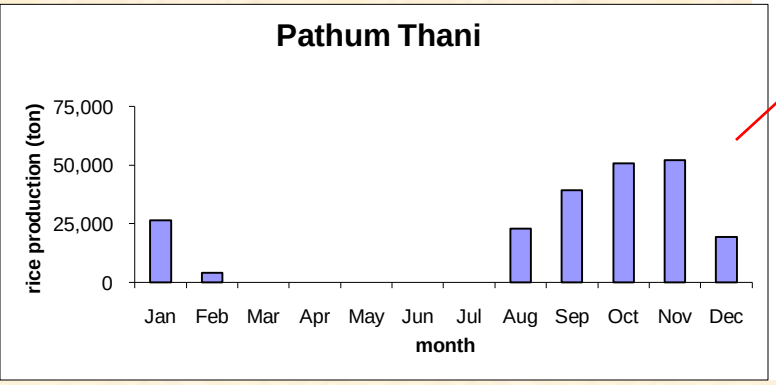
Temporal and spatial distribution (2)

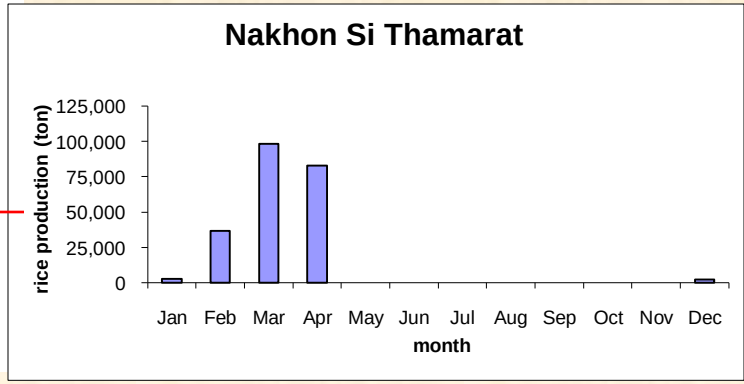
- Approach 2: crop specific data
  - Temporal: temporal crop production data, e.g. monthly rice production data
  - Spatial distribution, e.g. provincial level data: plantation area per province or crop production per province
  - Detail land-use and crop specific data are required → data normally available in National Statistics

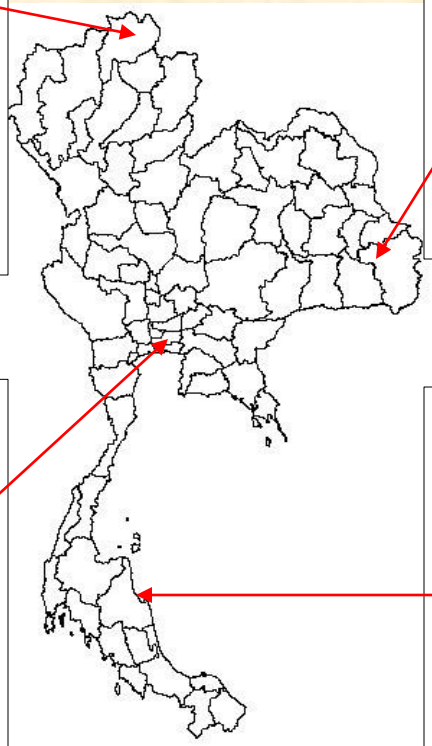
Harvest time for specific crop: monthly rice production at provincial level ➔ temporal





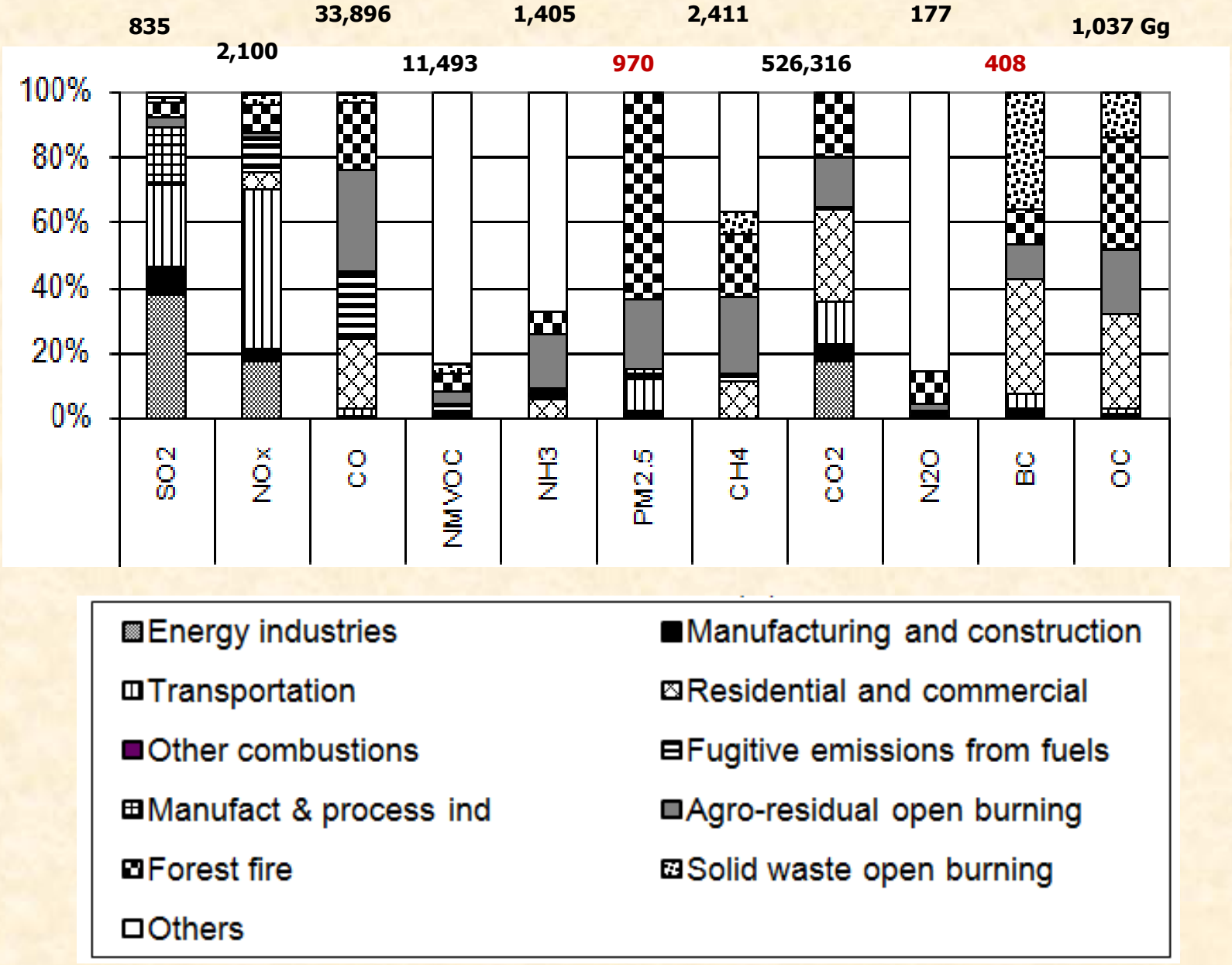






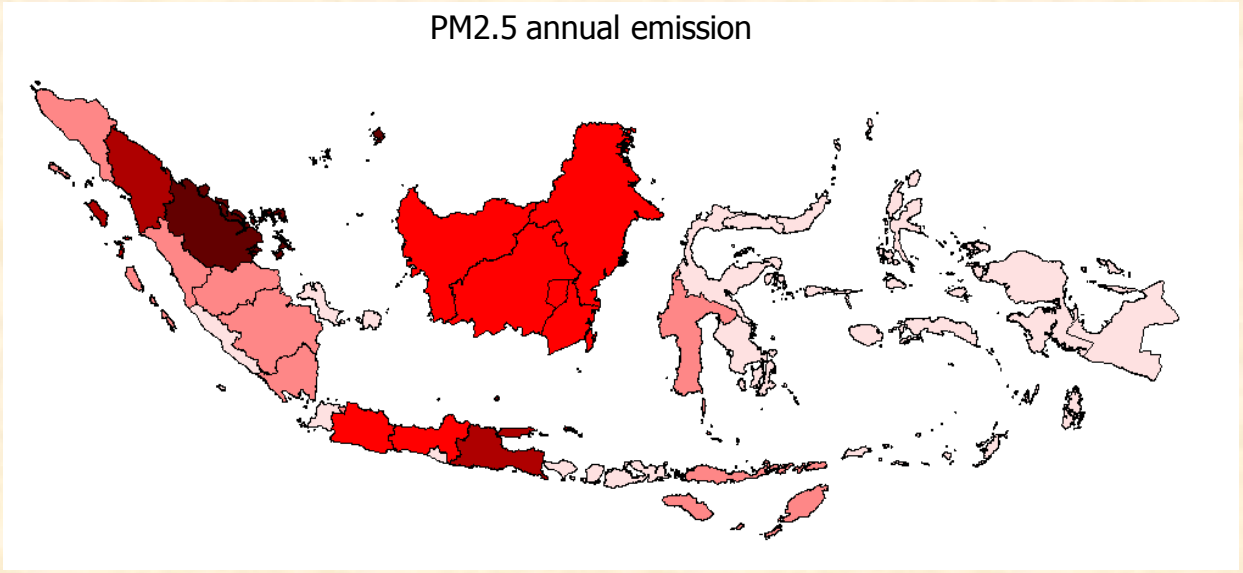
Monthly rice production in different regions of Thailand

Results: source Sector Shares (Indonesia, 2005)



Indonesia: Emission Spatial Distribution

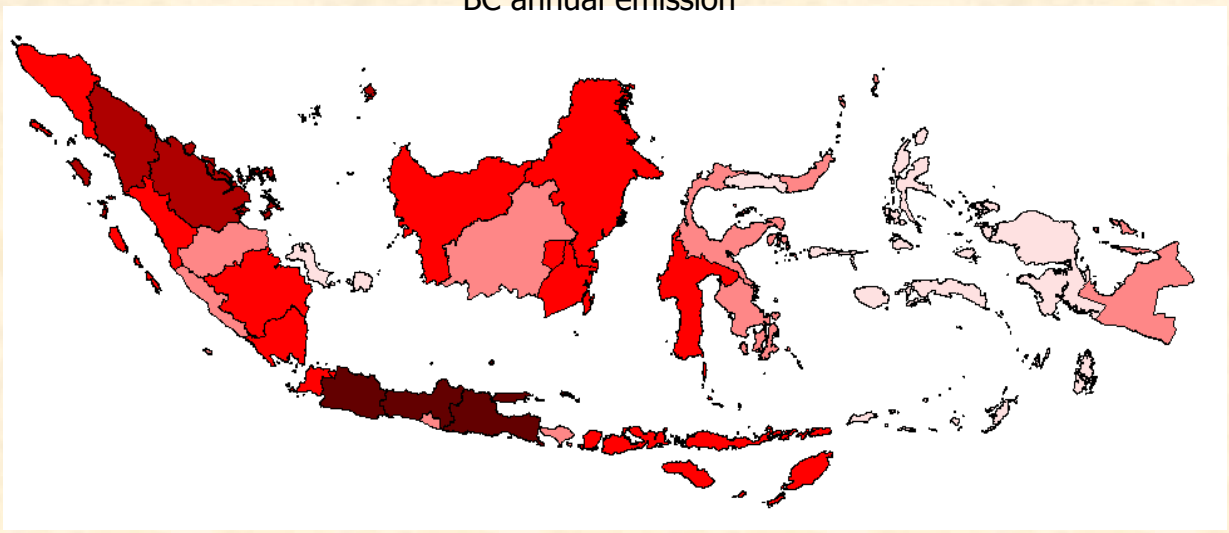
PM2.5 annual emission



Emission (tonnes/year)

752 - 7106
7107 - 18495
18496 - 45724
45725 - 85078
85079 - 407043

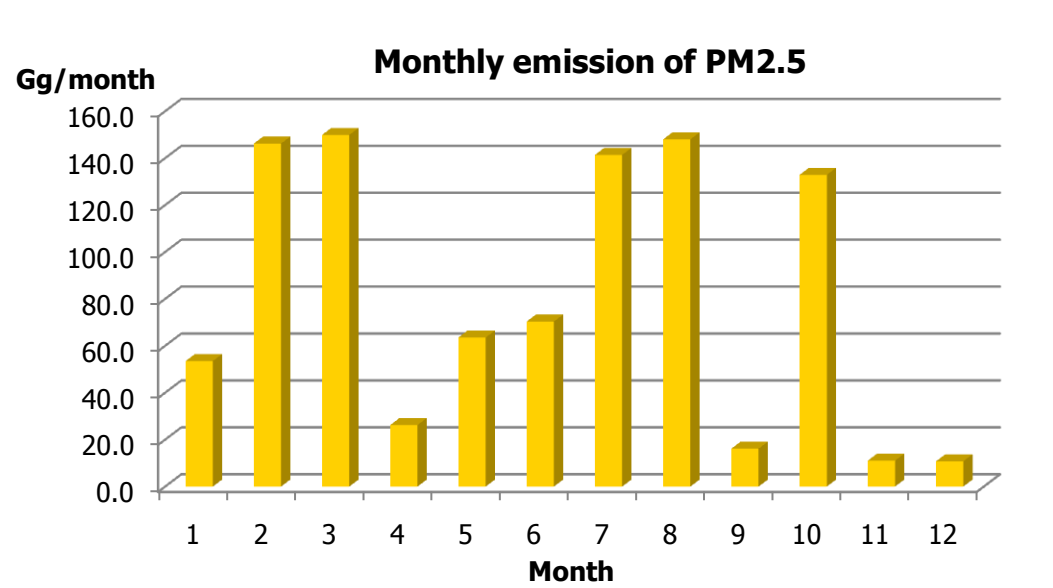
BC annual emission



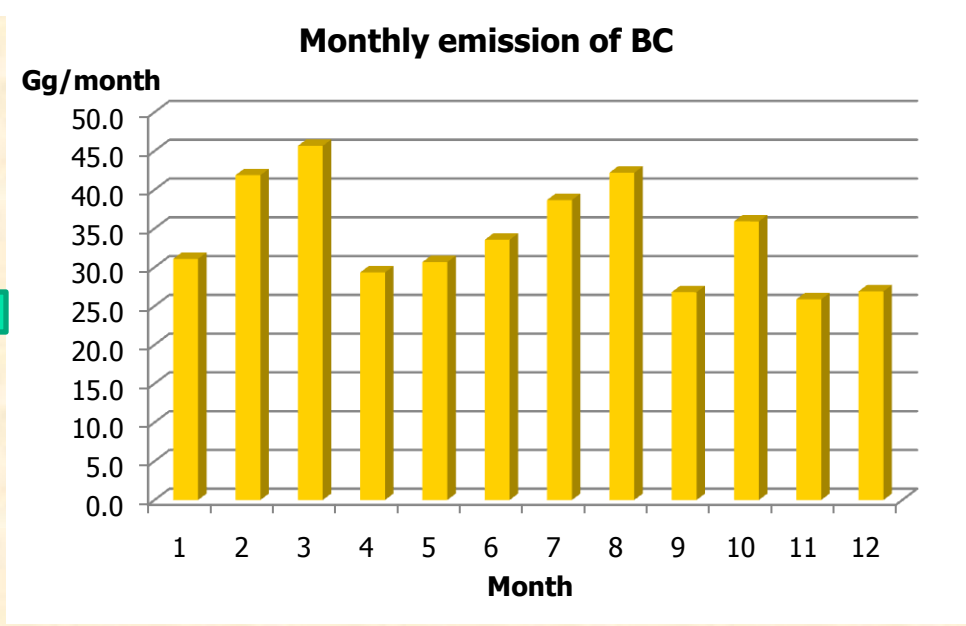
Emission (tonnes/year)

1005 - 2289
2290 - 6049
6050 - 15322
15323 - 36956
36957 - 61694

Indonesia: Emission Temporal Variation

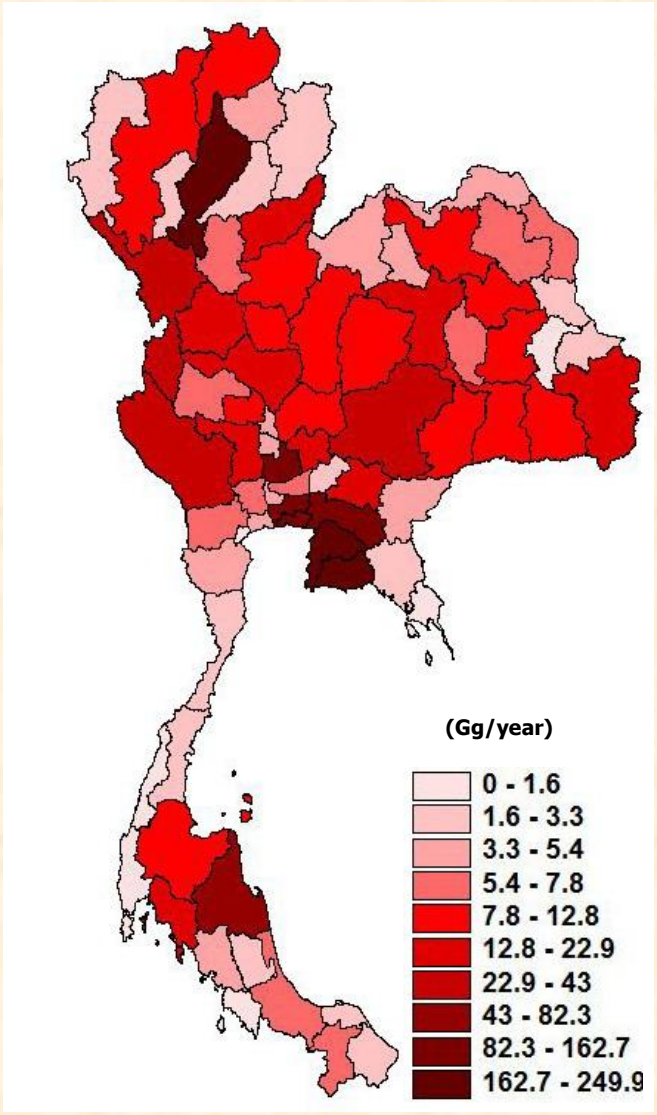


Large variation is due to forest fire as the largest source contributor → high in dry season

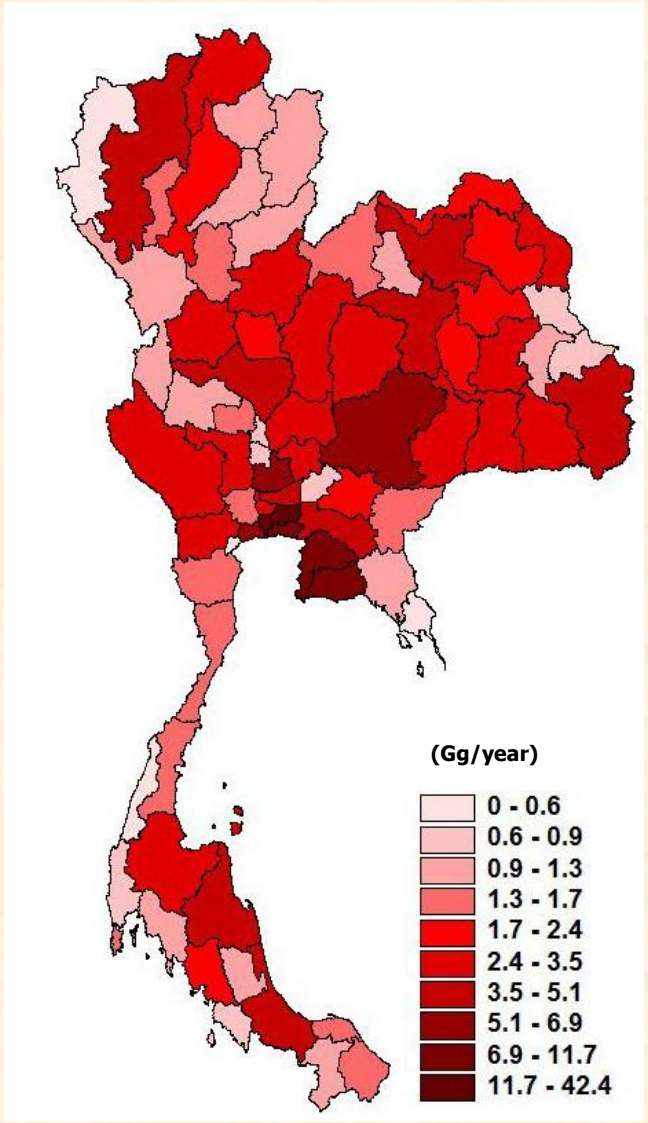


Small variation is due to relatively constant monthly activity magnitude of residential sector and solid waste open burning activity

Thailand: Spatial Distribution of Emissions

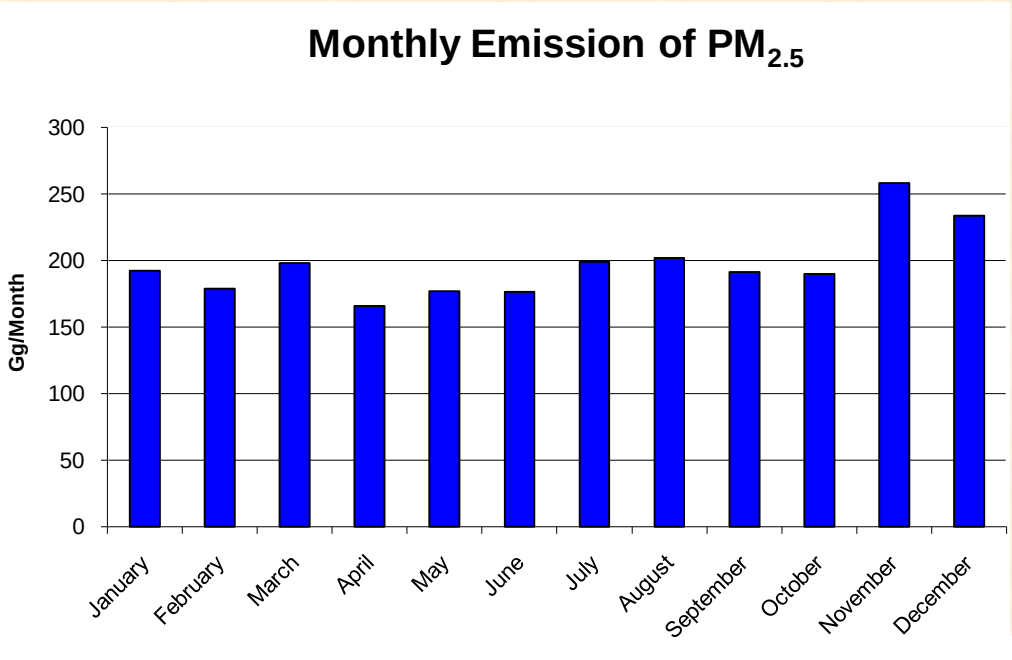


PM2.5 annual emission

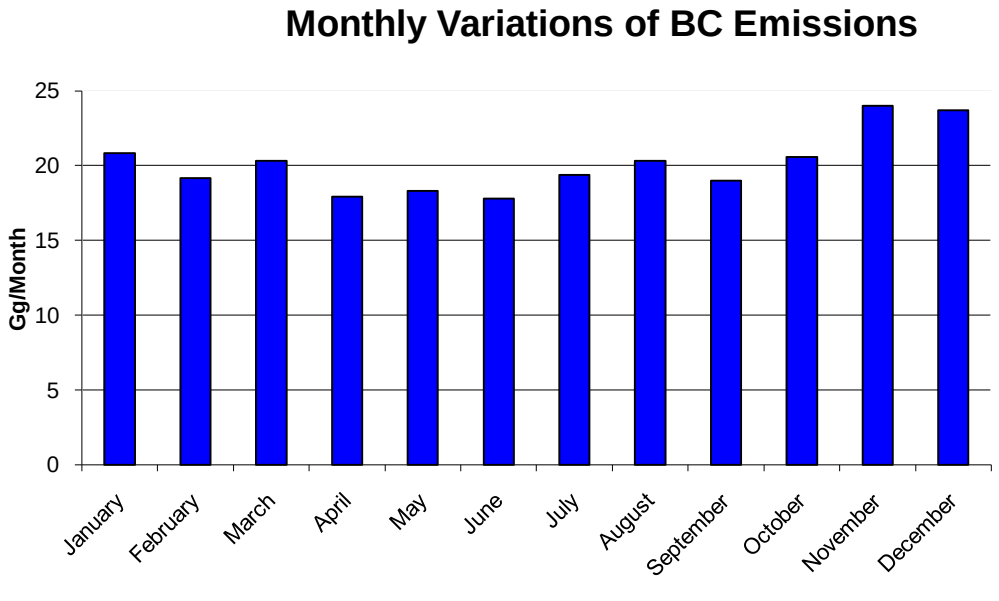


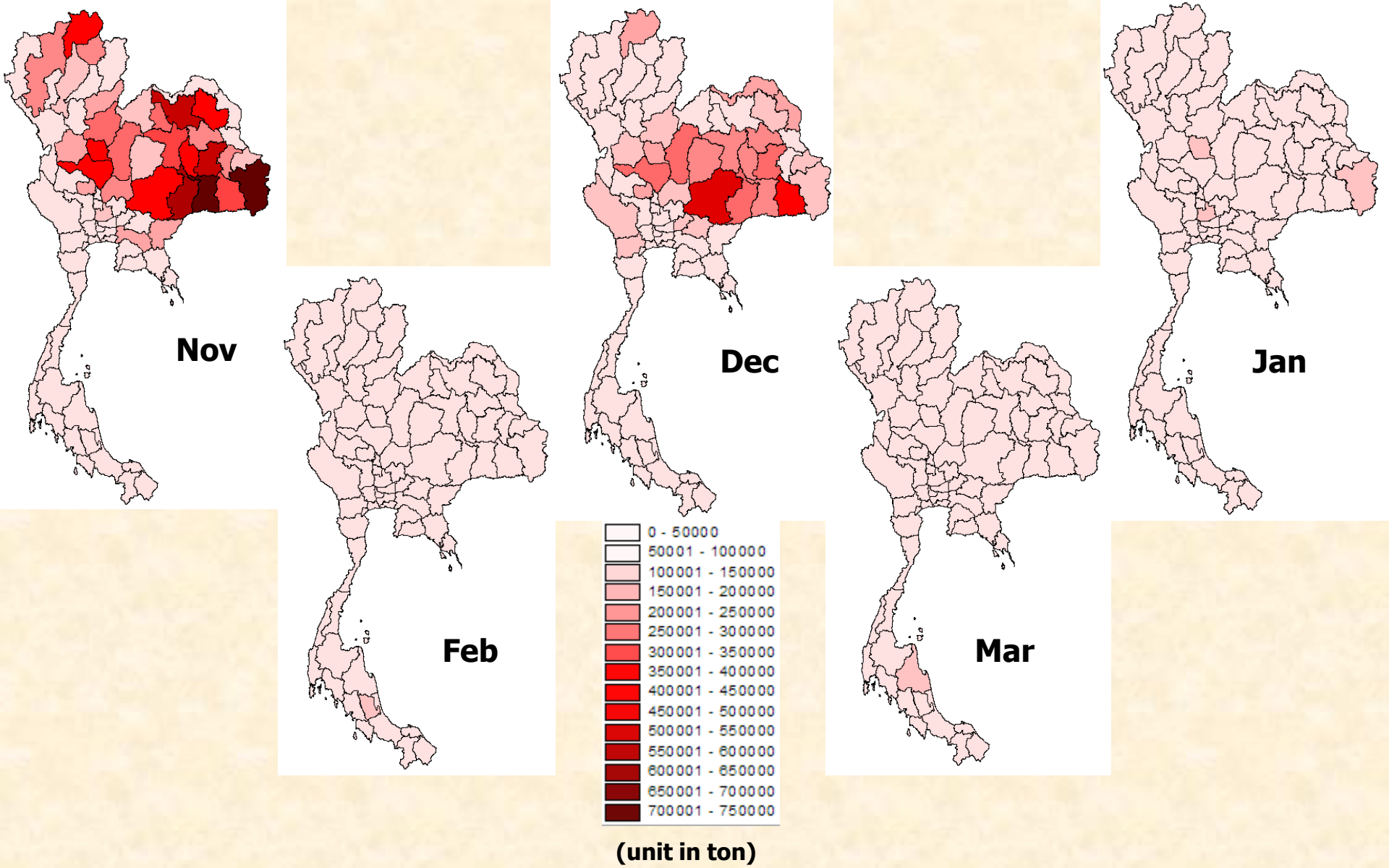
BC annual emission

Temporal Variation of Emissions (Thailand)



PM2.5 emissions from crop residue burning is high during November – December.





Spatial-temporal EI: monthly distribution of rice production by 76 provinces in Thailand

Way Forward (Outlook)

- Development of ABC EI for Asia for a recent base year
- Development of national/regional level emission scenarios under various socio-economic development and land use scenarios in medium and long term.
- Identification of major ABC emission cost effective mitigation options and measures (both technological and policy) and analysis of their potential for emission abatement at national/subnational levels in Asia..
- Development of national capacity for the above

There is no perfect EI but we can always improve to create a better one!

Acknowledgement

UNEP-ABC for funding
International and regional experts
Peer-reviewers for time

Municipal solid waste open burning

- Commonly done in developing countries which have inadequate Solid Waste Management
- SW burning activities:
  - Open burning at source/onsite (at community)
  - Burning at SW disposal facilities (dumpsite burning)
  - MSW incineration is excluded (C9: Other sources)
- Pollutants to be covered: PM_{10}, $PM_{2.5}$, particulate BC, OC, and gaseous emission (CO, NOx, NMHC, CH_4, SO_2)

Emission estimation for on-site burning (IPCC, 1996)

- Emission: $Em_x = M \bullet EF_x$
- M, amount of burned MSW (kg/day):

$$M = P \bullet P_{frac} \bullet MSW_{GR} \bullet \eta$$

P = population (capita)

P_{frac} = fraction of population burning waste (fraction)

MSW_{GR} = per capita MSW generation factor (kg waste/capita/day)

η = fraction of SW that is burned/oxidized relative to the total amount of waste burned (fraction oxidized)

Note: Time period can be month, season and year

Formula for dumping site burning

- Emission: $Em_x = M \bullet EF_x$

- M, amount of burned MSW (kg/day):

$$M = P \bullet MSW_{GR} \bullet \varepsilon \bullet \delta \bullet \eta$$

P = population (capita)

MSW_{GR} = per capita MSW generation factor (kg waste/capita/day)

ε = MSW collection efficiency (fraction that is dumped/landfilled)

δ = Fraction of the waste that is actual burned relative to the total amount of waste dumped at a dumpsite

η = Burning/oxidation efficiency (fraction)

Note: Time period can be month, season and year

Considerations

- P_{frac} and δ: Limited information
  - P_{frac} for source (on-site, backyard) burning vs. δ for burning at landfill/dumpsite should be obtained by field survey for the inventory region
- Large uncertainty and involves assumptions:
  - Urban/Rural population
  - Regional/national SWM projects
  - Cities SWM reports (UN habitat)
  - Regulation and enforcement
  - Other available research data

EMISSION FACTOR

Extracted from AP-42 USEPA (1995)

Parameters	EF (kg Mg^{-1})
PM	8
SO_2	0.5
CO	42
NO_x	3
CH_4	6.5
NMHC	15
BC	5.5 (Bond et al, 2004)
OC	5.5 (Bond et al, 2004)

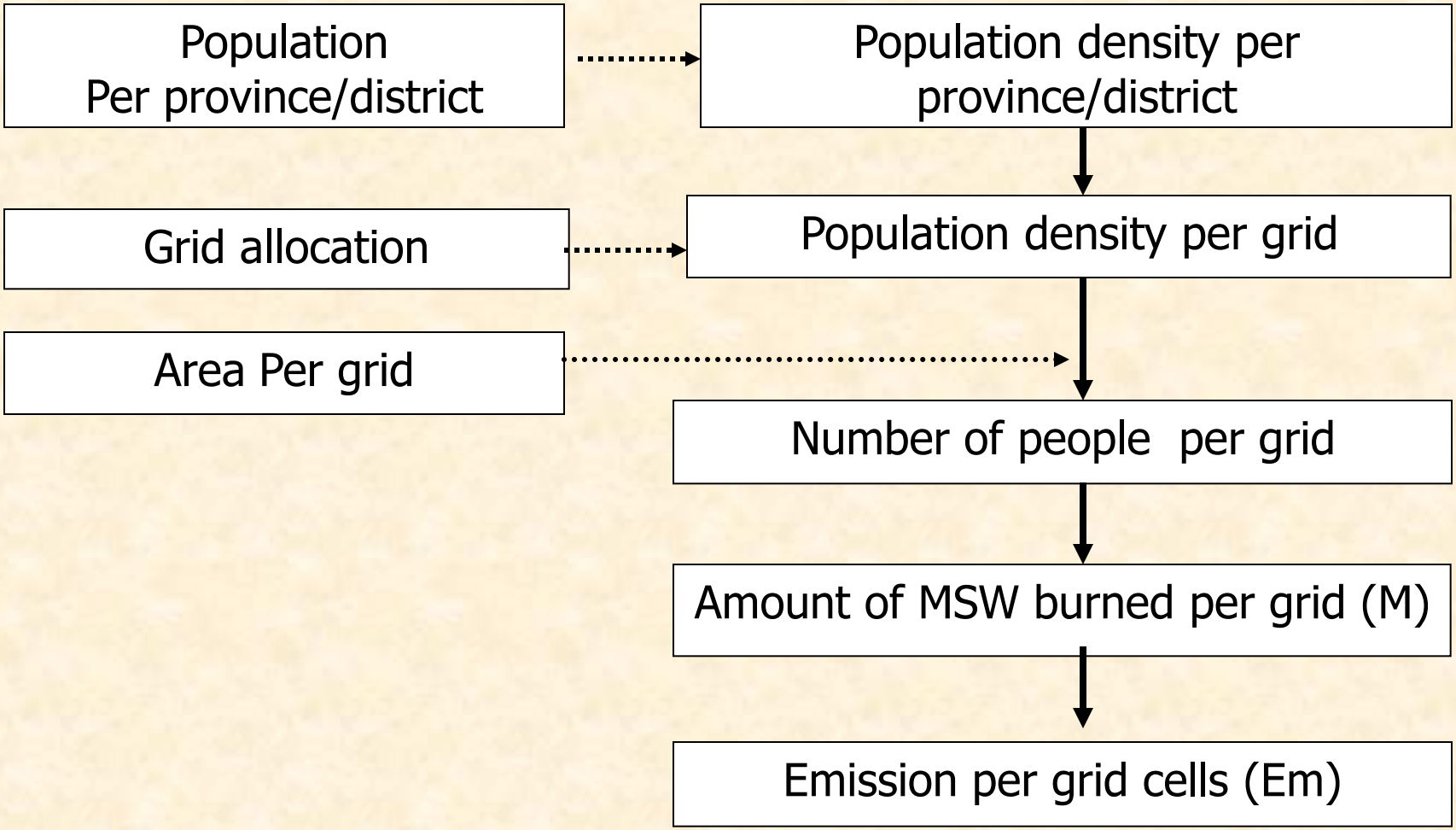
No information on NH_3 EF

TEMPORAL DISTRIBUTION

- Burning may be every day
- Seasonal variations (dry vs. wet season)
- Regulation and enforcement: eg. ban of SW burning in dry season, etc.

➔ Specific activity data at local level is required

SPATIAL DISTRIBUTION BASED ON POPULATION DATA



Thank You!