CHAPTER 1
INTRODUCTION

1.1 Rationale/Problem Statement

In Thailand, there are many types of forest depending on light, temperature, climate, atmospheric moisture, rain, geography or site, soil and living organisms in each land. Evergreen forest and deciduous forest are the two major types classified in Thailand. Deciduous forest consists of dry dipterocarp forest (DDF) and mixed deciduous forest (MDF), which cover Thailand in the north and north east, represent about 8.8 and 2.4 million ha, respectively (www.forest.go.th).

DDF and MDF have high capacities as carbon sinks (Terakumpisut *et al.*, 2007 and 2000). Both of forest types is usually located at altitude from 50 – 1,000 m asl., especially in area with drought more than 4 months and rainfall in range of 900-1200 mm per year. Plant families of these forest types consist of Dipterocapaceae, Leguminosae, Combretaceae, Verbenaceae and bamboo which are growing up on the barren slope and hillside.

During the dry season (from December to April), trees in both types of forest shed their leaves. The forest fires have been occurred during dry season due to leaf shedding of the vegetation which is the main component in biomass fuels, and fire activities from the local communities. The composition of biomass fuels on ground cover composes of the leaf litter, twig, grass, herb, shrub, climber and seedling. Forest land is usually burned by human activities as the main causes by gathering of non-timber forest product, facilitate hunting and agricultural debris (Report of Forest Fire Control Office, 2005). However, the fuel consumption is 95% as a result of anthropogenic surface burning (Samran, 2005).

The fire intensity is the key index to estimate the amount of fuel burned and pollutant released which dependent to the fuel load, height and moisture content, humidity and temperature of environment. In DDF, the fuel load is in range of 5.44-5.93 tons/ha, releasing about 1.61 m of flame length and fire intensity 543-735 kW/m (Akaakara *et al.*, 2003). The high frequency of fire can drastically modify the structure and composition of aboveground biomass and influence to the carbon cycle in the ecosystem. In the annual area, the lowest growth of diameter and basal area was 0.237cm/year and 0.0007m^2/year, respectively. On the other hand, the growth diameter and basal area of the triennial burn

and control plots are the higher than biennial and quadrennial burn plots, respectively. Moreover, surviving the burning depended on the diameter base. The seedlings with diameter base less than 1 cm were completely dead (Suthivanit, 1989). Wildfire does not only directly affects biomass fuel i.e. undergrowth, litter and twig but also affects soil properties and processes, and nutrient dynamics (Wanthongchai *et al.*, 2008). However, the heat from fire directly affects insects on the ground or under the bark wood and also activates natural regeneration and development of undergrowth (Suthivanit, 1989). Furthermore, the fire management for maintain plant structure and ecosystem in the forest should be need, especially the high frequency fire occurrence area.

In March 2007, the Pollution Control Department of Thailand reported that the particulate matter concentration in the atmosphere were approximately as 383μg/m^3. In Thailand, the smog was released as 50-70% from forest fires and agricultural burned sources, 10% from fossil fuel sources and the rest from other sources and long range transport, respectively (Kreasuwan, 2008). The combustion sources of forest clearing fires releases the pollutant gases and particulate matter such as carbon dioxide, carbon monoxide, methane and $PM_{2.5}$ are of 452-1,946 ppmv, 26-241 ppmv, 2-22.8 ppmv, and 4.48 x10^3-14.32x10^3 μg/m^3, respectively (Neto *et al.*, 2009). Therefore, biomass open burning is one of major important source to release the primary air pollutants and precursors of secondary pollutants on the Earth (Crutzen and Andreae, 1990).

In year 2000, the satellite data is showed forest areas constituted 33.4% (17,204,998.88 hectares) of the whole area of Thailand. In the same year, the statistic of forest fire reported the area burned of 0.44% (76,189.25 hectares) of whole forest area. Thus the annual large area burned affect to the economic damage more than one billion per year (Pollution Control Department, 2005). The estimation of economic damage of each forest type at Hauy Kha Khaeng Wildlife Sanctuary in 1997 was 6,178.65 and 9,564.24 baht/rai of DDF and MDF, respectively (Sompoh and Kaitpraneet, 2000). According to the pollutants released from the forest fires have been affected to the human health, wildlife, animals and environment such as visibility and climate change.

The forest area burnt on average during 2006 to 2008 in North and North-East was 5,877.97 ha and 4,566.35 ha, respectively (Table 1.1). During 2002 to 2006, mixed deciduous forest and dry dipterocarp forest are the highest average area burnt as 40.68% and 40.30%, respectively (Figure 1.1). The causes of forest fire was occurred by man-made

who need to burn for gathering of forest non-timber products, agricultural debris burning, Incendiary fire, carelessness, hunting, illegal logging, and cattle raising, respectively.

Table 1.1 Forest land and area burned in each region of Thailand during 2005-2008

Region	Forest land (ha)		Forest area burned (ha)		
	2005	2006	2006	2007	2008
North	8,938,099.00	8,836,811.00	4,229.76	8,764.32	4,639.84
North-East	2,533,460.00	2,454,988.00	3,341.12	6,272.64	4,085.28
Central	2,067,858.00	2,055,507.00	844	3,035.84	2,296.96
East	793,582.00	788,362.00	-	-	-
South	1,767,131.00	1,729,591.00	206.72	710.56	307.68
Total	16,100,130.00	15,865,259.00	8,621.6	18,783.36	11,329.76

Source: www.dnp.go.th

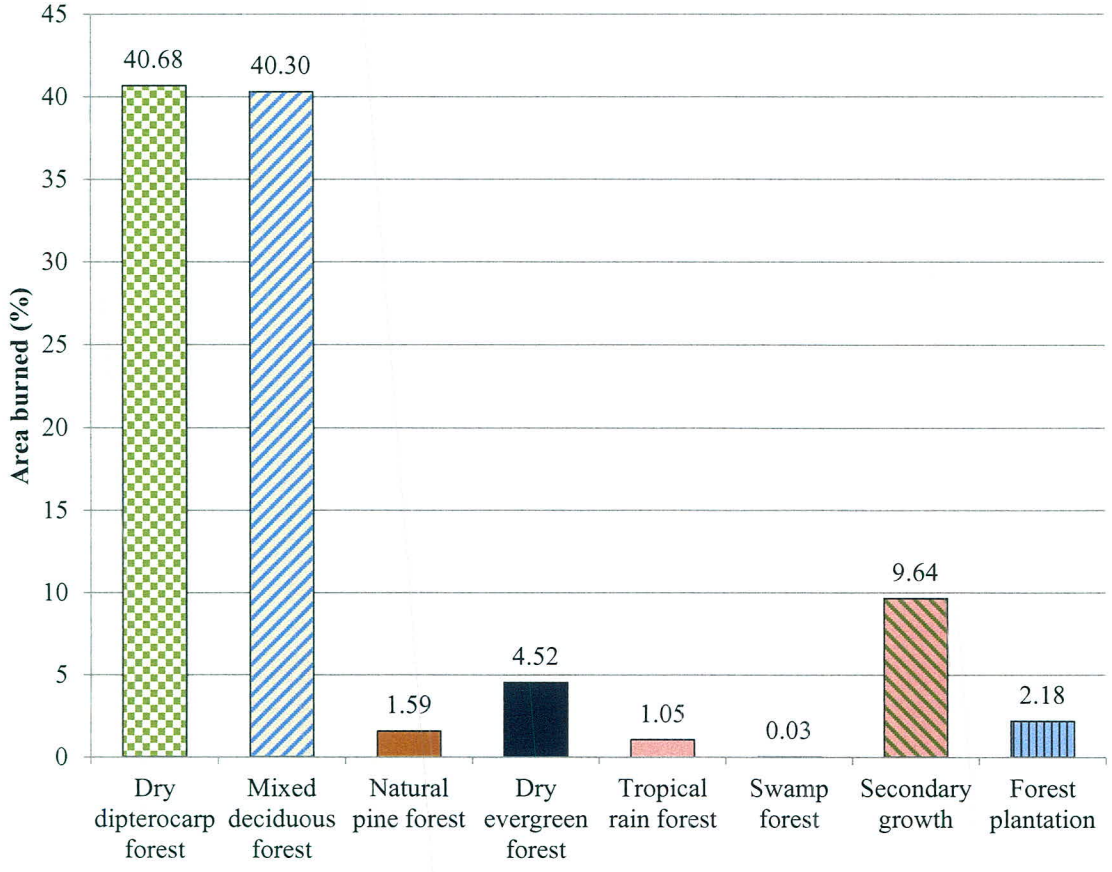

Figure 1.1 Average of percent area burned of each forest type during 2002-2006

Gases and particulate matter emitted from forest fires contribute the global warming and cooling in the atmosphere. The cloud condensation nuclei (CCN) and radiation budget is influenced by aerosol particle released to the atmosphere. Black carbon has the light – absorbing properties and also is playing an important role in visible reduction and aerosol radiative forcing (Larson and Cass, 1989; Crutzen and Andreae, 1990; Jacobson, 2001). The atmospheric brown clouds are form from the mixture of black carbon transported over long distance with other aerosols along the way. The vertical of their form of 3 to 5 km is contributed to current global warming (Ramanathan and Carmichael, 2008). Carbonaceous aerosols are the major component of particulate matter emitted from combustion processes. The majors component of carbonaceous aerosols are included black carbon, organic carbon and inorganic species such as sulfate, nitrate, formate, chloride, potassium, ammonium, sodium, etc. (Lee et al., 2005) and trace metals. The specifically of black carbon are extended six-member ring of carbon atoms and has the properties to absorb all visible light radiation. Black carbon is sometimes also called elemental or graphitic carbon that is primary aerosols released from incomplete combustion sources such as fossil fuel for the generation energy, agricultural residue burning and forest fires. However, black carbon is also generated from pyrolyzed organic carbon (Hadley *et al.*, 2008). Organic carbon is also known as organic matter that consists of primary and secondary aerosol particles. It produced from combustion of fossil fuel, bio-fuel (wood for stoves and heating) and biomass open burning (agricultural burning and forest fires) (Cachier *et al.*, 1995). Some organic aerosols compound released from high-temperature combustion from fossil fuel (Kirchstetter *et al.*, 2004) appear less absorbing than from open biomass burning. The primary and secondary organic aerosols are the wide range of chemicals and physical characteristics. Water- soluble tracers and water-insoluble tracer are the component of organic carbon. They were presented in the global models and can be contribute in the cloud process. The thousands of organic compounds are the component of organic carbon that have the potential mutagens or carcinogens consists of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) (Novakov and Penner, 1993; Cruz and Pandis, 1997).

For the reasons above-mentioned, it is of high relevance to investigate the physical and chemical properties and emission factor of carbonaceous aerosols from forest fire in Thailand. The study site selected in the Ratchaburi province due to the western region still lack the information of pollution emissions from forest fires and this region composed of

the main of forest types subjected to fires: DDF and MDF. The information from the study can be used to represent the general information of the carbonaceous emission factors of similar structure of both DDF and MDF in Thailand.

1.2 Objectives:

1. To develop a methodology to characterize aerosols from forest fires in Ratchaburi Province, Thailand.
2. To develop a methodology to characterize carbon content in aerosols emitted from forest fires in Ratchaburi Province, Thailand.
3. To develop country-specific emission factors of aerosols, black carbon or elemental carbon and organic carbon from forest fires in Ratchaburi Province, Thailand.

1.3 Scopes of Work:

1. The study covered two types of forests, which are the main types subjected to fires in Thailand: Dry Dipterocarp Forest (DDF) and Mixed Deciduous Forest (MDF).
2. Field experiments were conducted at study sites located in the Mae Nam Phachi Wildlife Sanctuary Ratchaburi Province, selected for its representativeness of DDF and MDF.

Field and laboratory measurements and analysis were focused on qualitatively and quantitatively characterization of carbon content in particulate matter from forest fires.