CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 Conclusions

This study documented the emissions of CAs from tropical deciduous forest fires in Thailand. The experimental field works were conducted in-situ based on the selected study site located at the Mae Nam Phachi Wildlife Sanctuary, Ratchaburi Province. The findings from this study and their associate recommendations can be summarized as follows.

8.1.1 Analytical Methods Development for Characterizing Carbonaceous Aerosols from Tropical Deciduous Forest Fires

Table 8.1 Analytical methods used in this study for CAs characterization

Parameter	Real-time analysis	Sampling and laboratory analysis
$PM_{2.5}$	√	√
BC	√	√
TC	-	√
CO/CO_2	√	√
C-released	-	√

Table 8.1 summarizes the measurement methods used in this study. Real-time measurement methods of BC and $PM_{2.5}$ enabled to characterize their respective emission profiles. They were planned to be complimented by the sampling and laboratory analysis, consisting in collection of total particulate matter (TPM) filters, which should be analyzed at laboratory to quantify water solubles, trace elements and total carbon content of the TPM. Unfortunately, all the sampled filters were saturated, and consequently could not be used for the planned analysis. It is recommended for future studied to control the sampling of TPM by monitoring the colour of the sampled filter, and as soon as the colour becomes sufficiently dark, the filter should be changed. Another option to avoid the problem of filter saturation, would be to sample using a regular time step of sampling, i.e. to change filter every 5 or 10 minutes. This option presents an advantage to enable a replicated sampling, which would be monitored and detailed continuous information over the whole fire

experiment by the real-time measurements. All filter replicates can then be analyzed for the BC composition using the optical transmittance technique. After BC analysis, filter replicates can be divided into 3 groups, one for water soluble and trace element composition, one for morphology, and one for total carbon using thermal or organic elemental analysis method.

It should be reminded that the TPM collected form TDF fires that can be analyzed by OT should present a very fine layer on filter. Too dark filters lead to an over/under estimation due to saturation of the absorbance, and so no transmittance detected. Therefore, the regular time step sampling can be defined cased on the darkness of the sampling filter clearing the field experiments.

Another analytical procedure requiring improvement to better quantify the emissions from tropical deciduous forest fires in Thailand, is the sampling of ash and charred leaves after burning. It is important to improve the accuracy of carbon content in residues after burning since this conditions the quality of the estimation of the quantify of carbon released to the atmosphere. The sampling of ash and charred leaved is very difficult in tropical deciduous forest because they tend to be moved quickly by local turbulence or to stick to the soil surface depending on the humidity and the soil moisture

8.1.2 Vegetation Structure and Composition of the Tropical Deciduous Forest at Mae Nam Pachi Wildlife Sanctuary

Vegetation structure

The vegetation structure and aboveground biomass data at the study site were used to compare with the same forest type distributed in different region. Tree species are *Shorea. obtusa*, *S. siamensis*, and *Diperocarpus obtusifolias* of Dipterocarpaceae family one of the three deciduous families found in world. In MDF, *T. siamensis*, a bamboo species is the species dominant vegetation in this area, and contribute the specific characteristic of the forest structure in this region. The L-shape DBH size classes indicates that this site is covered by young trees, i.e. is a secondary forest. The forest structure in DDF has a high density of trees with significant amount of undergrowth scattered all around. The biomass fuel in both DDF and MDF is mainly composed of leaf litter. However, biomass fuels loads in this site are lower than the other area.

Fire Characteristic of DDF and MDF Fires

Although the fire behavior in both DDF and MDF is similar, the combustion completeness in DDF is higher than MDF. Carbon content in residues after burning a mixture of ash and charred leaf is relatively high due to the pyrolysis of the leaf litter. In addition, the residues after burning still have the same shape as the biomass fuel bed change color to darker. The different colours of TPM from DDF and MDF fires can indicate a different quality of combustion. Fires in both DDF and MDF consume about 2-3 g of dry leaf litter to produce 1 g of carbon released. The fireline intensity of fires in both DDF and MDF never exceeds 300 kW/m, which represents the lowest level of fire danger class.

8.1.3 Physical and Chemicals Properties of Biomass Fuel, Burned Residues, Total Particulate Matter and Carbonaceous Aerosols

The carbon content in leaf litter of MDF is lower than DDF may be due to a large presence of bamboo leaves in MDF. The SEM micrographs collected from MDF fires with more that 50% of C-content showed that particulate carbon from these fires may have at least 6 shapes (MA, MD, ME, MF, MI and MJ). The SEM micrographs (MC and MG) indicated that particulate carbon is associated to Cl, K, Ca, and Mg found in the biomass fuel. The SEM DA showed that the dominant shape of carbon from DDF fires is BC, while is also supported by the gray to black colour of filter.

8.1.4 Emission Factor of Co-emitted Gases

The pollutants released to the atmosphere were progressively the diluted by air. The dilution factor can be estimated using the carbon mass balance method. In this study, CO_2 was used as reference gas to estimate the dilution factor. The EF results showed that the EF of CO_2 from DDF is higher than MDF. The emission factor of CO_2 and CO from fires in DDF and MDF as lower than those from other studies, may be due to different biomass fuel load and combustion completeness. The emissions of CO_2, CO, BC, OC and $PM_{2.5}$ from forest fires occurred during 2007-2010 indicated that they were higher from MDF than DDF.

8.1.5 Emission of Carbonaceous Aerosols

The EF of carbonaceous aerosols was estimated from in particles $PM_{2.5}$. Because the carbon composition of PM could not be quantified using filter samples, we have based our estimation on the BC content real-time measurement and the assumption of 60% of $PM_{2.5}$ is constituted by carbon. The results of BC emission factors in both DDF and MDF showed that BC released from a unit of MDF and DDF is of the same order of magnitude. The emission factor of OC is higher than that BC in all field experimental plots. The emissions of DDF are characterized by high BC/OC ratios.

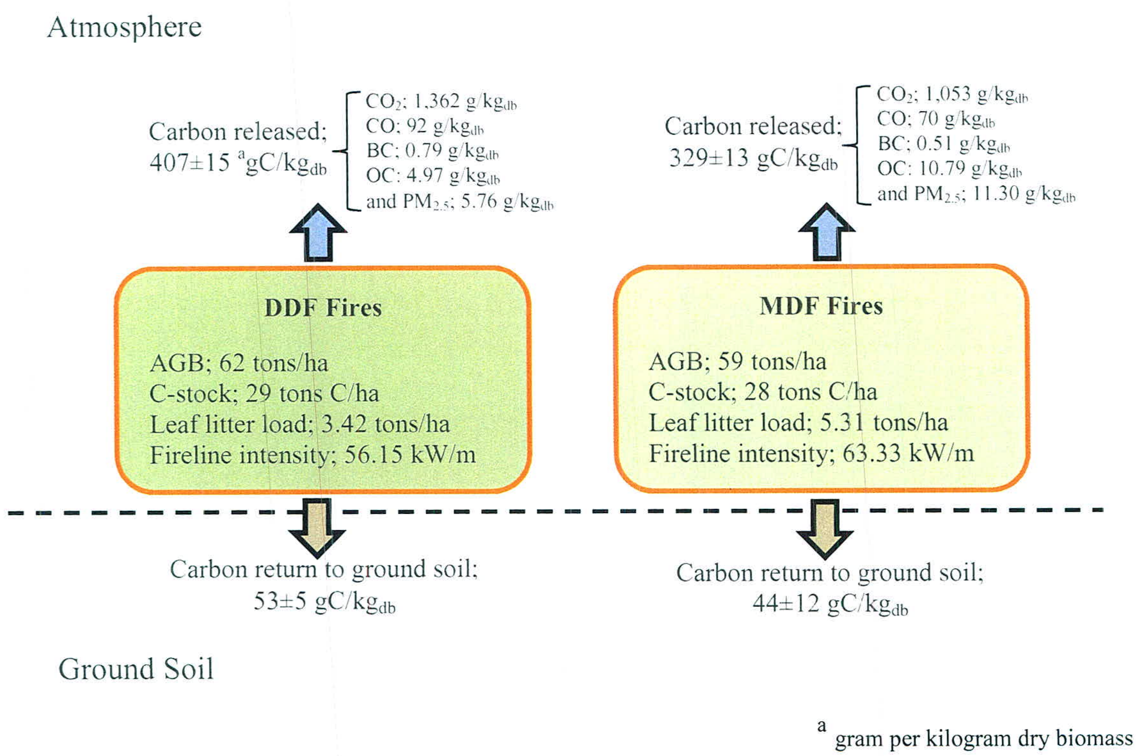

Figure 8.1 Summary of the carbon budget from DDF and MDF fires to the environment.

Regarding the carbon released to the atmosphere, the emission flux of DDF was found to be quite close to that of MDF with 111.07±33.99 gC/m^2 versus 108.87±39.95 gC/m^2. However, normalizing the carbon emission by the unit of fuel, DDF fires emit about 100 gC more than MDF fires, i.e. 407±15 $gC/kg_{dry\ biomass}$ versus 329±13 $gC/\ kg_{dry\ biomass}$. Another important information in this budget results in the BC emission flux: BC emission flux of DDF fires was found to be more than one times higher comparatively to that defined for MDF fires, i.e. 0.30 g/m^2 versus 0.22 g/m^2 (Figure 8.1).

The DDF and MDF fires converted the carbon in biomass fuel into carbon released to the atmosphere and carbon to be returned to soil in the form of ash and charred leaf. It was found that the greater is the fireline intensity the higher is the emission of BC and OC that would affect the climate change, especially emissions of BC and OC.

Also, it was found that the CMB method can be used efficiently to estimate the carbon in the form of CO_2 and can be used to quantify the emission factor of gas and aerosols released from forest fires into the atmosphere. The values of emission factors from tropical deciduous forest fires in this study are in general quite similar to other studies and can be used to estimate the emissions of CO_2, Co, BC and OC from DDF and MDF fires in Thailand. The country-specific information of emission factors BC and OC emitted from DDF are 0.84 and 5.29 $g/kg_{dry\ biomass}$ and in MDF are 0.54±0.18 and 11.37±1.51 $g/kg_{dry\ biomass}$, respectively.

8.2 Potential Future Works

8.2.1 Use of Different Fractions of Carbon Released from Tropical Deciduous Forest Fires to Evaluate the Ecological Change of Tropical Deciduous Forest

From BC emission data it was found that BC released from DDF fires play an important role to contribute to global warming. On the other hand, the OC emitted from MDF fires is 3 times higher than from DDF fires. This underlined that the OC released from MDF fires may lead to cooling.

8.2.2 Application of Measurements and Characterization Methodology to Qualitatively and Quantitatively Determine the Emissions of Carbonaceous Aerosols from Other Type of Biomass Burning

The study research showed that the results can be applied to investigate and characterize the CAs from the other DDF and MDF. The general analytical experimental procedure developed for characterizing the CAs emitted from these forest fires can be applied to investigate other types of vegetation burning. The analytical experimental produce is composed of

1) Characterization of the vegetation structure to evaluate the leaf litter profile,

2) Estimation of volume, dry matter, moisture content, height of living and dead ground biomass,

3) Measurement and characterization of carbon content and chemical composition of particulate matter;

4) Measurement of the meteorological parameters,

5) Measurement of fire behavior parameters temperature released from fires, and sampled TPM on filter and measure the CO_2, CO, BC and $PM_{2.5}$ using real-time measurement and

6) After burning measurement of carbon fraction in all samples to support the CMB calculation. The residues after burning will be estimate the mass, carbon content and chemical composition in the laboratory.

8.3 Recommendations

From this study, the following actions are recommended for future research

8.3.1 Total Particulate Matter (TPM) Sampling Method

To overcome the failure to sample TPM on filter for elemental and water-soluble analysis, the field experiment should set up in a small plot or low flow rate of air pump connecting with the open-face filter holder. The TPM collected on filters should be set up for characterization of total carbon (TC) by optical technique and thermal method. However, the layer of TPM on filter plays an important rule and also difficult to sample for measurement by optical transmittance analyzer. The options proposed in the conclusion should be implemented.

8.3.2 Ash and Charred Leaves Sampling Method

Ash and charred leaves are an important parameter in the CMB calculations. The method consists in sampling of the residues from field experiments by using use the aluminum foil to cover the soil surface. First the biomass fuel should be taken out from the position selected in the field, then use the aluminum foil cover on soil surface in this area and replace the biomass fuel or leaf litter on foil prior the ignition start. The biomass fuels in this position need to replace the original structure before taking it out. This method will prevent the contamination by soil and easy to sample ash and charred leaf from field after burning.

8.3.3 Fireline Intensity

The fireline intensity is a significant parameter influencing the emission of BC and OC, and should be measured with higher accuracy and precision in order to support a development of numerical model aiming to predict the emissions of gaseous and particulate from forest fires in Thailand.