SNAP CODE: **1103**
110301
110302

SOURCE ACTIVITY TITLE: **OTHER SOURCES AND SINKS**
Forest and Other Vegetation Fires
Man-induced
Other

NOSE CODE: **301.03.01**
301.03.02

NFR CODE: **N/A**

1 ACTIVITIES INCLUDED

Burning (naturally or man-induced) of non-managed and managed forests and other vegetation, excluding agricultural burning of stubble, etc.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

On a global scale biomass burning in all its forms is estimated to make very significant contributions to greenhouse gases (Andreae et al., 1988, Andreae, 1991). However, most of this burning is human-initiated, and takes place in the tropics. Of an estimated 3550 Tg CO_2 (as C) formed yearly from biomass burning, only 117 Tg C is ascribed to fires in the temperate and boreal regions, and only a small fraction of these take place in Europe (Levine, 1994).

Considering the European continent as a whole, the vast majority of these fires occur in the Eurasian part of Russia, where recent estimate suggest annual areas burnt of between 2-7 million ha (Conard and Davidenko, 1997, and references contained therein).

However, we here deal with the European part of the Russian Federation, along with the other European countries, where the area burnt is estimated at 0.5-1 million ha (range is from several years, Stannars and Bourdeau, 1995).

According to the CORINAIR-1990 inventory, forest fires account for 0.2% of European NO_x emissions, 0.5% of NMVOC emission, 0.2% of CH_4 emissions, 1.9% of CO emissions, 1.2% of N_2O emissions and 0.1% of NH_3 emissions. On the whole forest fires appear to contribute only a small percentage of emissions. However, uncertainties are very large and in some areas emissions might make appreciable contributions to ground level concentration, especially as fires occur over short periods of the time.

On a global scale biomass burning is a very significant source of CO_2 and a number of other gases to the atmosphere. However, most burning takes place in the tropical and subtropical regions, so emissions from European fires have received very little attention.

3 GENERAL

3.1 Description

Forest fires have always been a feature of forest ecosystems. However, although 'natural' forest fires may be initiated by lightning, recent estimates indicate that on a global scale almost all biomass burning is human-initiated and is increasing with time (Andreae, 1991, Levine, 1994). Much of the global emission results from so-called slash-and-burn agriculture in the tropics, but such practices are much less common in Europe. Prescribed burning, a management practice common in North America, and upon which most emission-factor measurements are based, is also not common in Europe. However, fires in Europe are still heavily associated with human influence, although often by accident rather than design.

The frequency and extent of fires in Europe is very variable from year to year, reflecting year-to-year climatological variability.

3.2 Definitions

Biomass - for forest fires the biomass of interest is the mass of all living and dead vegetation per unit area, in units of kg/m^2. Both above-ground and below-ground biomass are significant and must be distinguished. This use of the term biomass should be distinguished from the 'foliar biomass' of importance for VOC emission estimates from foliar activity (e.g. SNAP 1101,1102).

3.3 Techniques

3.4 Emissions

The major products of biomass burning are CO_2 and water vapour. However a large number of particulates and trace gases are produced, including the products of incomplete combustion (CO, NMHCs) and nitrogen and sulphur species. These arise partly from nitrogen and sulphur contained in the vegetation and organic matter in the surface soils. Additionally, emissions can arise from the re-volatilisation of substances which have been deposited (Hegg et al., 1987, 1990).

Some emissions are not considered further here as they have little relevance for tropospheric chemistry, but they are worth mentioning for their stratospheric impacts. These include H_2, COS and to a lesser extent CH_3Cl (Crutzen et al., 1979, Andreae, 1991).

Many other trace emissions have been measured, but which seem to contribute little to total emissions, e.g. methanesulphonate (MSA), aldehydes, organic acids (Andreae et al., 1988).

A secondary effect of fires is that emissions from the land-area after burning can be significantly enhanced relative to unburned areas. Such effects are not considered here.

3.5 Controls

Many forest fires are set deliberately or accidentally as a result of human activities. For example, data from Russia suggests that 68% of fires occur within 5 km of a road (Korovin, 1996). The main control options then consist of improved fire-prevention and fire-extinction.

Little information appears to be available on methodologies to reduce emissions during controlled forest burns. However, in the Agricultural sector it is known that time of burning and meteorological conditions have important effects on both emissions and ground level concentrations.

4 SIMPLER METHODOLOGY

From annual statistics of forest burnt one may simply multiply the area burnt by the emission factors given in Table 8.1. These emission factors are in fact identical to those given in the detailed methodology if default biome characteristics are used.

5 DETAILED METHODOLOGY

Emissions are obtained in a two-step process:

(i) Estimate the emissions of carbon from the burned land.
(ii) Estimate the emissions of other trace gases using emission ratios with respect to carbon.

The basic calculation of the mass of carbon emitted, M(C), follows the methodology of Seiler and Crutzen (1980):

$$M(C) = 0.45 \times A \times B \times \alpha \times \beta$$

Where

0.45 is the average fraction of carbon in fuel wood
"A" is the area burnt (m^2)
"B" is the average total biomass of fuel material per unit area (kg/m^2),
"α" is the fraction of the above average above-ground biomass
relative to the total average biomass B,
"β" is the burning efficiency (fraction burnt) of the above-ground biomass.

Values of B, "α" and "β" are given for relevant biomes in Table 5.1. These data are taken from Seiler and Crutzen (1980), although we have added a new forest category, "Mediterranean forest" to account for the low biomass density of this region. The "α" and "β" fractions assumed for this biome are derived from the Spanish CORINAIR 1990-93 inventories, see also Rodriguez Murrilo (1994).

Table 5.1: Biome characteristics for forest-fire emission estimates

Biome	Biomass (kg/m^2)	Above ground biomass fraction	Burning efficiency
	B	"α"	"β"
Boreal forest	25	0.75	0.2
Temperate forest	35	0.75	0.2
Mediterranean forest (1)	15	0.75	0.25
Scrubland (2)	7.5	0.64	0.5
Grassland (Steppe)(2)	2	0.36	0.5

Notes: all data from Seiler+Crutzen (1980), except:
(1) new forest category, assuming lower biomass density
(2) which is a subjective estimate, assuming burning efficiency of European grass/shrublands is less than the data on tropical biomes for which Seiler+Crutzen suggest 0.8

The emission of any particular species can then be obtained by multiplying the mass of carbon formed by the emission ratios (in g/kg C) from section 8.

As an example, if we use the factors presented above for Boreal forests, we can evaluate the mass of carbon generated in one hectare of burned boreal forest:

$$M(C) = 0.45 \times A \times B \times a \times b$$

$$= 0.45 \times 10000\ m^2 \times 25\ kg/m^2 \times 0.75 \times 0.2 = 16875\ kg$$

The emission ratio for NO_x is given in section 8 (Table 8.1) as 8 g/kg C emitted, therefore the emission factor to be applied is 135 kg NO_x/ha.

This factor is somewhat higher than the factor recommended for CORINAIR-90, namely 75 kg/ha for oceanic climate type forest, but as the background to the previous recommendation is not known we cannot discuss this further.

6 RELEVANT ACTIVITY STATISTICS

The area of forest burnt (A) must be known. The ecosystem-dependent biomass and burning "B", "α" and "β" should ideally be estimated from local data, otherwise the values given in Table 5.1 provide a default.

7 POINT SOURCE CRITERIA

No point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Emission factors of trace gases relative to CO_2 formed in burning are given in Table 8.1, based upon the recommendations of Andreae, 1991.

Table 8.1: Emission ratios for biomass fires, relative to carbon emitted as CO_2.

	moles X per 100 moles CO_2 emitted			g X/kg C emitted as CO_2
	Field Measurements	Laboratory Studies	"Best Guess"	"Best Guess"
CO	6.5-140	59-105	100	230
CH_4	6.2-16	11-16	11	15
NMHCs	6.6-11	3.4-6.8	7	21
NO_x	2-8	0.7-1.6	2.1	8
NH_3	0.9-1.9	0.08-2.5	1.3	1.8
N_2O	0.18-2.2	0.01-0.05	0.1	0.4
SO_x	0.1-0.34	-	0.3	1.6

Notes: average mass of NMHC assumed to be 37, derived from speciation obtained by Radke et al., 1991. NO_x as NO_2, SO_x as SO_2.
Source: Andreae (1991)

For the simplified methodology we can use the data given in Tables 5.1 and 8.1 to calculate default emission factors per hectare of land. These default emission factors are given in Table 8.2.

Table 8.2: Default emission factors (kg/ha) for forest and vegetation fires.

	CO	CH_4	NMVOC	NO_x	NH_3	N_2O	SO_x
Boreal forest	3881	253	354	135	30	8	30
Temperate forest	5434	354	496	189	43	6	43
Mediterranean forest	1456	95	133	51	11	3	11
Shrubland	828	54	76	29	7	1.6	7
Grass/Steppe	373	24	30	13	3	0.7	3

Notes: NO_x as NO_2, SO_x as SO_2.

Quality codes for all forest fire emissions should probably be "D".

9 SPECIES PROFILES

For NMHC emissions from a number of forest fires, Radke et al. (1991) obtained an average species profile of 35% C_3H_6, 30% C_2H_6, 16% C_2H_2, 14% C_3H_8, 5% n-C_4H_{10} (by mass).

10 UNCERTAINTY ESTIMATES

Andreae (1991) suggests that the emissions of CO_2 are uncertain by about 50% and a factor of 2 for the other trace gases. The fact that emission ratios so far determined seem to be consistent from Brazil to Canada (see Andreae, 1991, and references therein) lends some confidence to extrapolating results into Europe. However, one possible cause for concern lies in results reported by Hegg et al. (1987) which suggested that areas which had experienced substantial N-deposition emission ratios for NO_x could be an order of magnitude greater than those obtained in rural areas. Indeed, emissions of purely man-made species such as F12 are also observed from forest fires, again the result of resuspension of previously deposited pollutants (Hegg et al., 1990). Such re-suspension is very likely in many areas of Europe,

Overall, a factor of 3 uncertainty would seem a reasonable first guess for emissions of gases such as NO_x from Europe.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Very few measurements are available of emissions from natural forest fires, and all emission rates and biome-factors reported here are based upon studies in North America or the Amazon. Evaluation of these data against European conditions
should be a priority.

Despite all the complex interactions involved in forest fire emissions, the emission ratios as given in Table 2 do seem quite consistent between various workers.

The burning efficiency is here set to 0.2 for forest fires, following Seiler and Crutzen (1980). However, efficiencies of 0.76 have been reported from wild fires in Australia (Hurst et al., 1996), or 0.1 for fires in Siberia (Dixon and Krankino, 1993).

Additionally, the uncertainty in the area burned can be one of the limiting factors in establishing emissions. Estimates for Russia for example have varied by a factor of ten, partly due to the fact that official statistics do not include fires in areas not receiving fire-protection (Conard and Davidenko, 1996).

12 SPATIAL DISSAGGREGATION CRITERIA FOR AREA SOURCES

From statistics, satellite observation, etc.

13 TEMPORAL DISSAGGREGATION CRITERIA

14 ADDITIONAL COMMENTS

Some estimates of emissions from biomass burning distinguish between different phases of burning. In the 'smouldering' phase emissions tend to be higher than in the burning phase (Cofer et al., 1991), as it is the most easily combustible material which burns in the early phases. During the smouldering phase the less oxidised products (CO, HCs, etc.)are produced in higher proportions (Cofer et al., 1989, 1991). However, all phases of burning display a mixture of complete and incomplete combustion. Given the lack of data on typical European fires, and the lack of significant emissions from this source sector, such distinctions are not recommended for inventory development at this stage.

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

17 REFERENCES

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19 RELEASE VERSION, DATE AND SOURCE

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