Technical Report No. 3

Air Emissions Inventory for the Greater Metropolitan Region in New South Wales

Biogenic Emissions Module: Results

Prepared jointly by

Department of Environment and Climate Change NSW
Environment Protection Authority of Victoria

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EXECUTIVE SUMMARY

The Department of Environment and Climate Change NSW (DECC), in collaboration with Environment Protection Authority of Victoria (Ng, 2006), has completed a three year air emissions inventory project for biogenic sources. The base year of the biogenic inventory represents activities that took place during the 2003 calendar year. The area included in the study covers greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR), and is shown in Figure E1. The coordinates of the south-west and north-east corners of each region are listed in Table E1.

Figure E1. Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong Regions

Table E1. Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong Regions

Region	South-west corner MGA coordinates [a]		North-east corner MGA coordinates [a]	
	Easting (km)	Northing (km)	Easting (km)	Northing (km)
Greater Metropolitan	210	6159	420	6432
Sydney	261	6201	360	6300
Newcastle	360	6348	408	6372
Wollongong	279	6174	318	6201

[a] MGA = Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2002).

The sources included in the biogenic module are as follows:

- burning (emissions from agricultural burning, bushfires and prescribed burning);
- fugitive/windborne (windblown dust from agricultural lands and unpaved roads due to wind erosion);
- soil (emissions of oxides of nitrogen from soil due to microbial and chemical processes of nitrification and denitrification); and
- vegetation (emissions of volatile organic compounds from trees and grass).

The pollutants inventoried include criteria pollutants specified in the Ambient Air Quality National Environment Protection Measure (NEPM) (NEPC, 2003), air toxics associated with the National Pollutant Inventory (NPI) NEPM (NEPC, 2000) and the Air Toxics NEPM (NEPC, 2004) and any other pollutants associated with state specific programs, i.e. Load Based Licensing (Protection of the Environment Operations (General) Regulation 1998 (PCO, 1998)) and Protection of the Environment Operations (Clean Air) Regulation 2002 (PCO, 2005).

Tables E2 and E3 show total estimated emissions and source contributions to total estimated emissions (for selected substances) respectively from biogenic sources in the GMR, Sydney, Newcastle and Wollongong regions. These substances were selected since they are: the most common air pollutants founds in airsheds according to the NPI NEPM (NEPC 2000); referred to in NEPMS for Ambient Air Quality (NEPC 2003) and Air Toxics (NEPC 2004); and they have been classified as priority air pollutants (NEPC 2005). Total estimated emissions and source contributions to total estimated emissions are also presented for the region defined as Non-Urban. This region is the area of the GMR minus the combined areas of Sydney, Newcastle and Wollongong regions.

Figures E2 to E7 show the percentage contributions to total estimated emissions (for selected substances) in the five regions. Most biogenic emissions occur in Non-Urban region. Bushfires and prescribed burning are the most dominant sources of most pollutants in the GMR, except for total volatile organic compounds and acetaldehyde, which originate mostly from vegetation, and oxides of nitrogen, which originate mostly from soil. Agricultural burning and fugitive/windborne are minor sources of emissions, as agricultural lands and unpaved road areas are relatively small in the GMR.

Table E2. Emissions (t/yr) from all biogenic sources in 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	10.6	5,190		8,144		13,344
sulfur dioxide	0.962	519				520
lead & compounds	7.90×10^{-04}	2.35	2.68			5.03
particulate matter < 10 µm	57.9	15,680	1,699			17,436
particulate matter < 2.5 µm	33.6	14,373	662			15,069
polycyclic aromatic hydrocarbons		1.88				1.88
total VOCs	38.5	27,398			165,157	192,594
total suspended particulates (TSP)	65.8	23,519	3,411			26,996
carbon monoxide	299	188,105				188,405
Acetaldehyde					1,009	1,009
1,3-butadiene		158				158
Sydney						
oxides of nitrogen	0.923	693		891		1,585
sulfur dioxide	0.0835	69.3				69.4
lead & compounds	6.86×10^{-05}	0.364	0.449			0.813
particulate matter < 10 µm	5.03	2,425	268			2,699
particulate matter < 2.5 µm	2.92	2,223	104			2,331
polycyclic aromatic hydrocarbons		0.291				0.291
total VOCs	3.34	3,428			30,557	33,989
total suspended particulates (TSP)	5.71	3,638	539			4,182
carbon monoxide	26.0	27,320				27,346
Acetaldehyde					136	136
1,3-butadiene		19.8				19.8
Newcastle						
oxides of nitrogen	0.200	4.56		98.4		103

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
sulfur dioxide	0.0181	0.456				0.474
lead & compounds	1.49×10^{-05}	0.00218	0.111			0.113
particulate matter < 10 µm	1.09	14.6	77.6			93.3
particulate matter < 2.5 µm	0.633	13.3	30.3			44.2
polycyclic aromatic hydrocarbons		0.00175				0.00175
total VOCs	0.726	23.5			3,260	3,285
total suspended particulates (TSP)	1.24	21.8	156			179
carbon monoxide	5.64	170				176
Acetaldehyde					10.7	10.7
1,3-butadiene		0.136				0.136
Wollongong						
oxides of nitrogen		3.22		48.8		52.0
sulfur dioxide		0.322				0.322
lead & compounds		0.00210	0.00317			0.00527
particulate matter < 10 µm		14.0	1.75			15.8
particulate matter < 2.5 µm		12.8	0.681			13.5
polycyclic aromatic hydrocarbons		0.00168				0.00168
total VOCs		14.0			3,357	3,371
total suspended particulates (TSP)		21.0	3.51			24.5
carbon monoxide		145				145
Acetaldehyde					10.2	10.2
1,3-butadiene		0.0808				0.0808
Non-Urban						
oxides of nitrogen	9.51	4,489		7,106		11,604
sulfur dioxide	0.861	449				450
lead & compounds	7.06×10^{-04}	1.98	2.11			4.10
particulate matter < 10 µm	51.8	13,226	1,351			14,629
particulate matter < 2.5 µm	30.1	12,123	527			12,680
polycyclic aromatic hydrocarbons		1.59				1.59
total VOCs	34.5	23,933			127,982	151,949
total suspended particulates (TSP)	58.9	19,838	2,713			22,610
carbon monoxide	268	160,470				160,737
Acetaldehyde					852	852
1,3-butadiene		138				138

Table E3. Contributions (%) to emissions from all biogenic sources in 2003

Substance	agricultural burning	bushfire and prescribed burning	fugitive/ windborne	soil	vegetation
Greater Metropolitan					
oxides of nitrogen	0.080	39		61	
sulfur dioxide	0.19	100			
lead & compounds	0.016	47	53		
particulate matter < 10 µm	0.33	90	9.7		
particulate matter < 2.5 µm	0.22	95	4.4		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.020	14			86
total suspended particulates (TSP)	0.24	87	13		
carbon monoxide	0.16	100			
Acetaldehyde					100
1,3-butadiene		100			
Sydney					
oxides of nitrogen	0.058	44		56	
sulfur dioxide	0.12	100			
lead & compounds	0.0084	45	55		
particulate matter < 10 µm	0.19	90	9.9		
particulate matter < 2.5 µm	0.13	95	4.5		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.0098	10			90
total suspended particulates (TSP)	0.14	87	13		
carbon monoxide	0.095	100			
Acetaldehyde					100
1,3-butadiene		100			
Newcastle					
oxides of nitrogen	0.19	4.4		95	
sulfur dioxide	3.8	96			
lead & compounds	0.013	1.9	98		
particulate matter < 10 µm	1.2	16	83		
particulate matter < 2.5 µm	1.4	30	68		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.022	0.72			99
total suspended particulates (TSP)	0.69	12	87		
carbon monoxide	3.2	97			

Substance	agricultural burning	bushfire and prescribed burning	fugitive/ windborne	soil	vegetation
Acetaldehyde					100
1,3-butadiene		100			
Wollongong					
oxides of nitrogen		6.2		94	
sulfur dioxide		100			
lead & compounds		40	60		
particulate matter < 10 µm		89	11		
particulate matter < 2.5 µm		95	5.0		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.42			100
total suspended particulates (TSP)		86	14		
carbon monoxide		100			
Acetaldehyde					100
1,3-butadiene		100			
Non-Urban					
oxides of nitrogen	0.082	39		61	
sulfur dioxide	0.19	100			
lead & compounds	0.017	48	52		
particulate matter < 10 µm	0.35	90	9.2		
particulate matter < 2.5 µm	0.24	96	4.2		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.023	16			84
total suspended particulates (TSP)	0.26	88	12		
carbon monoxide	0.17	100			
Acetaldehyde					100
1,3-butadiene		100			

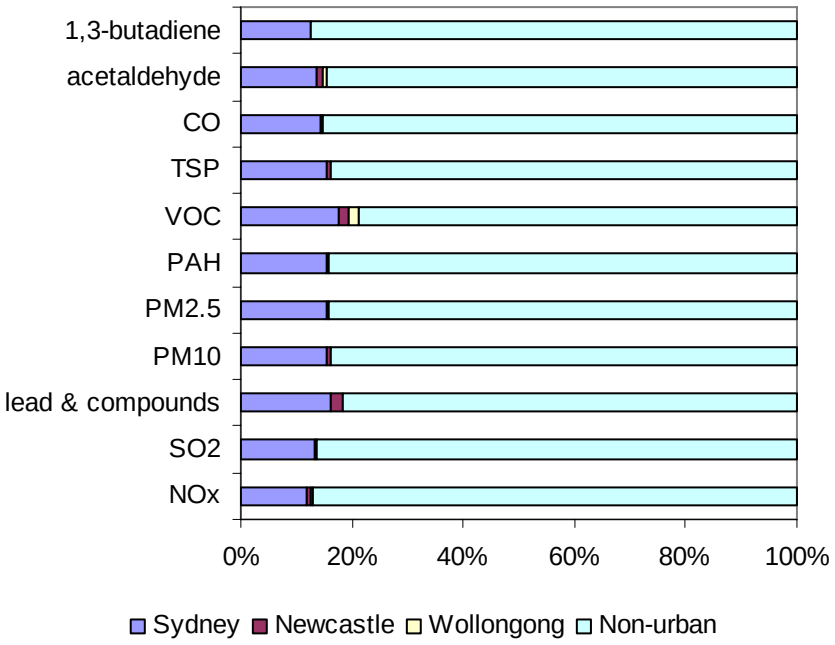

Figure E2. Contributions to emissions from all biogenic sources by region in 2003

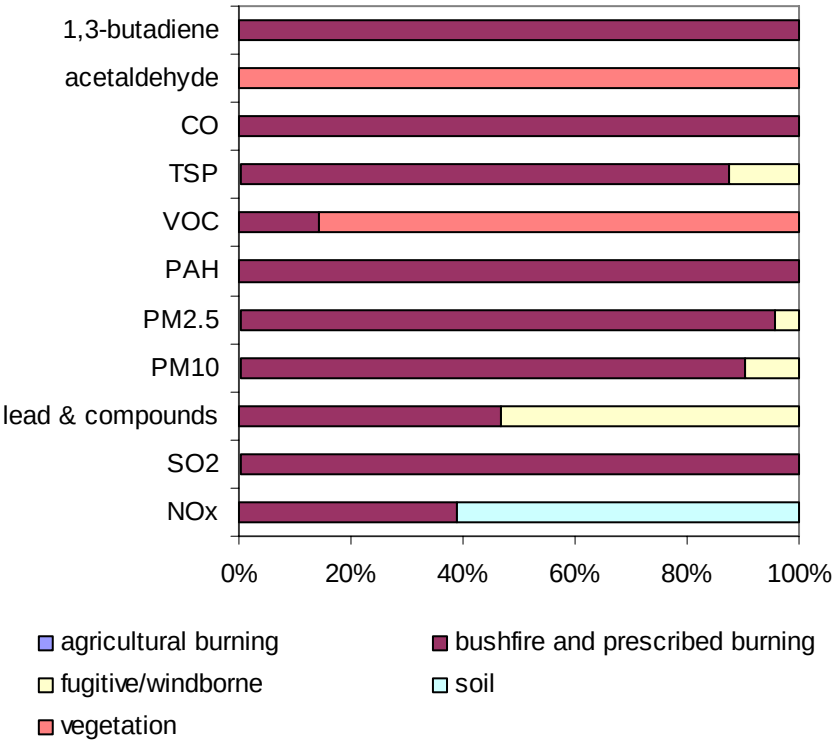

Figure E3. Contributions to emissions from all biogenic sources, GMR 2003

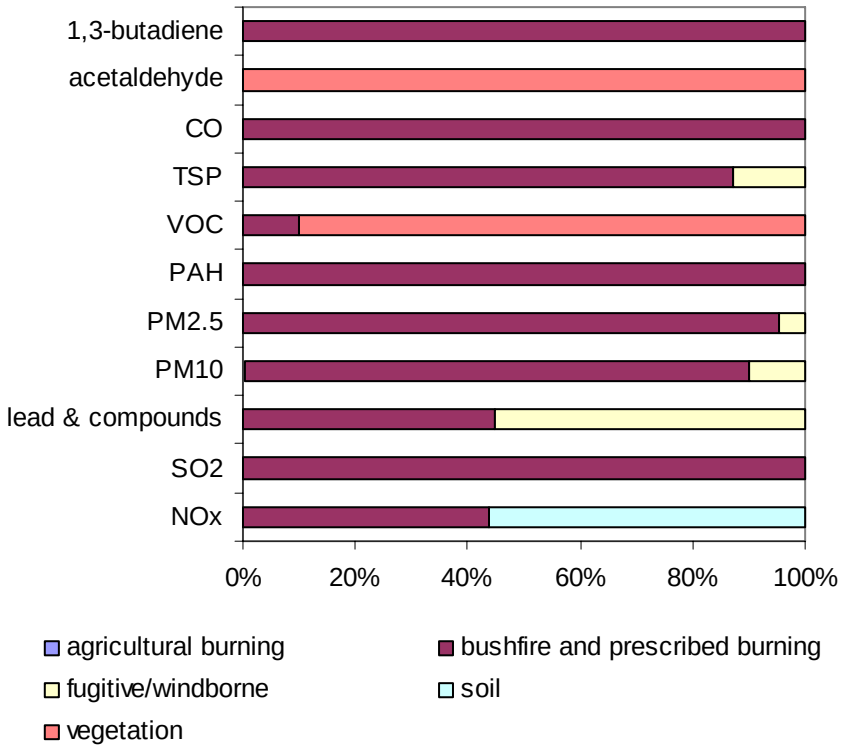

Figure E4. Contributions to emissions from all biogenic sources, Sydney region 2003

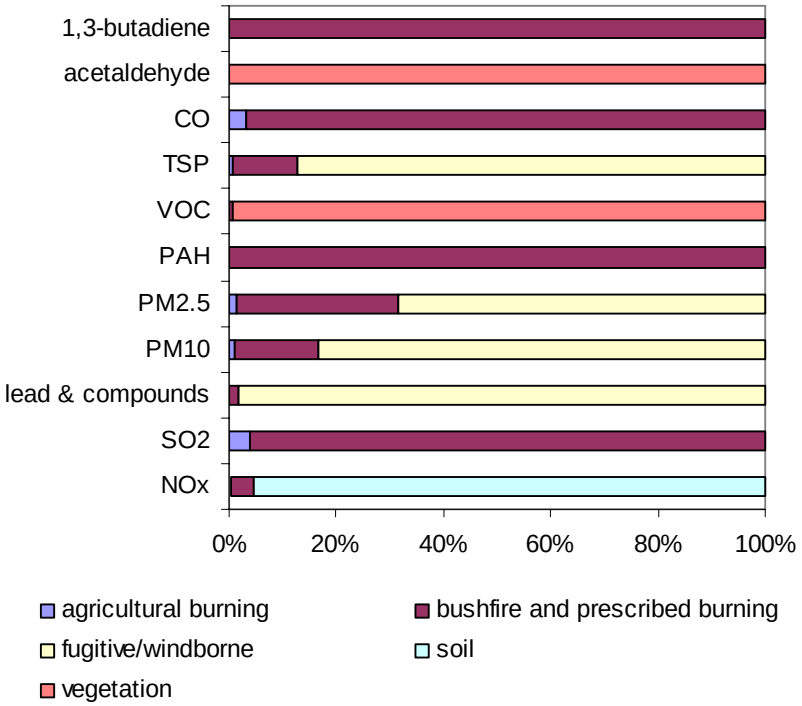

Figure E5. Contributions to emissions from all biogenic sources, Newcastle region 2003

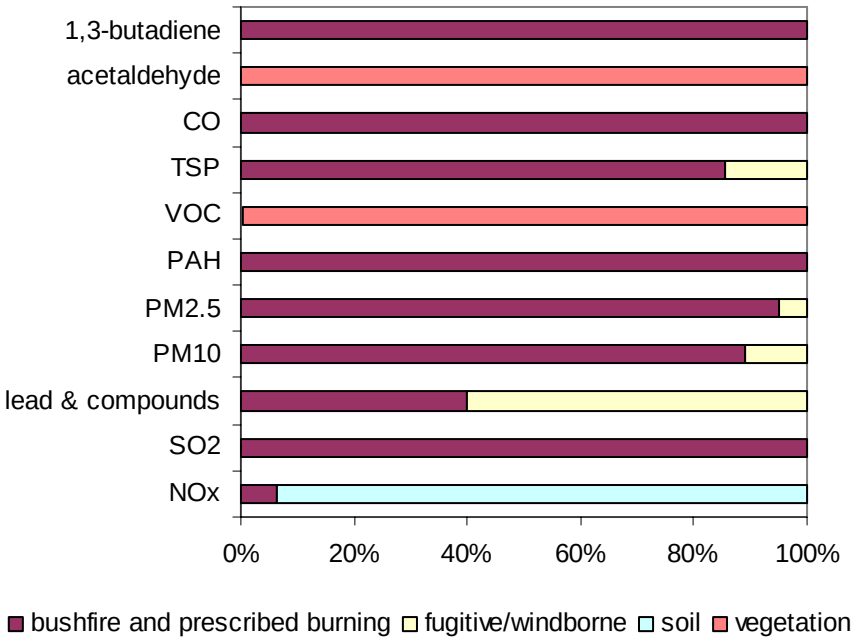

Figure E6. Contributions to emissions from all biogenic sources, Wollongong region 2003

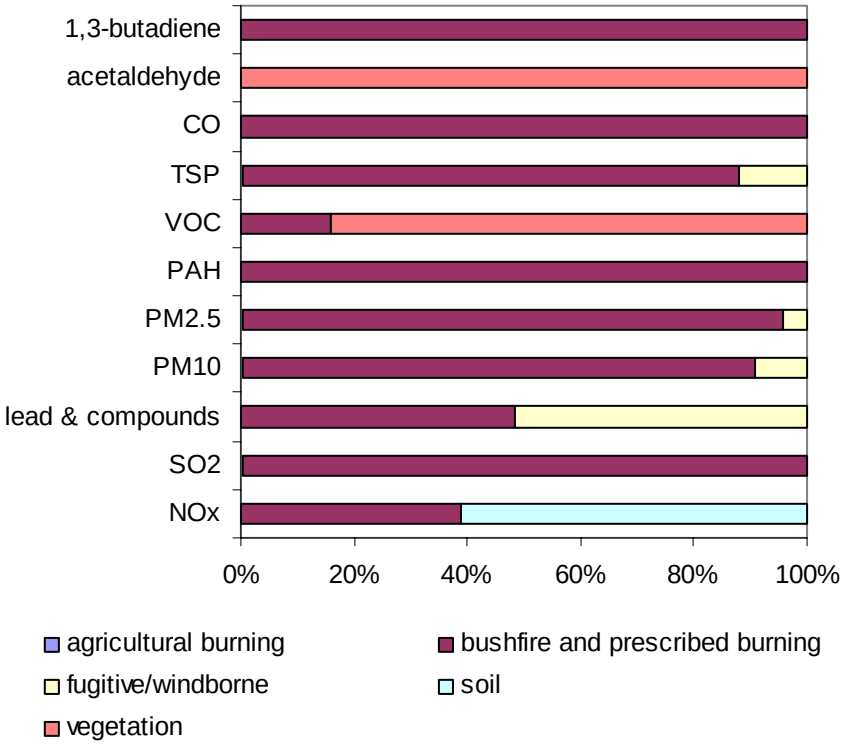

Figure E7. Contributions to emissions from all biogenic sources, Non-Urban region 2003

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ABBREVIATIONS

BEI-GIS	Biogenic Emission Inventory Geographical Information System
BEIS	Biogenic Emission Inventory System
CO	Carbon monoxide
DEC	Department of Environment and Conservation NSW
DECC	Department of Environment and Climate Change NSW
EDMS	Emissions Data Management System
EMS-95	Emission Modelling System 1995 version
EPA Victoria	Environment Protection Authority of Victoria
GIS	Geographic information system
GMR	Greater Metropolitan Region
MAQS	Metropolitan Air Quality Study
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NPI	National Pollutant Inventory
LGA	Local government area
PAH	Polycyclic aromatic hydrocarbons
PDF	Polychlorinated dioxins and furans
PE	Thornthwaite's precipitation-evaporation index
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than 2.5 µm
PM_{10}	Particulate matter with an aerodynamic diameter less than 10 µm
RFS	Rural Fire Service
SO_2	Sulfur dioxide
TAPM	The Air Pollution Model
TSP	Total suspended particulates
VOC	Volatile organic compounds

1 INTRODUCTION

The Department of Environment and Climate Change NSW (DECC), in collaboration with Environment Protection Authority of Victoria (Ng, 2006), has completed a three year air emissions inventory project for biogenic sources. The base year of the biogenic inventory represents activities that took place during the 2003 calendar year. The area included in the study covers greater Sydney, Newcastle and Wollongong regions, known collectively as the Greater Metropolitan Region (GMR). This report presents the emission estimation methodologies, activity data, emission factors and estimated emissions from biogenic sources. CSIRO (2004) has developed software to estimate emissions from vegetation, and the results obtained using this model have been presented in this report.

The purpose of this document is to focus on the results of the biogenic emissions inventory. The information is structured as follows:

- A description of the study region (Section 1.1);
- A description of emission sources considered (Section 1.2);
- A description of the pollutants evaluated (Section 1.3);
- A broad discussion of the methodology (Section 1.4);
- A description of: each source type considered; emission estimation methodologies; source activity data; emission factors; and total emissions estimated from each source type (Sections 2 to 5);
- An emissions summary, summarising emissions for the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions for all source types (Section 6);
- A description of the databases and spreadsheets used to calculate emissions (Section 7); and
- Total biogenic emissions of all substances emitted in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions and the percentage contribution from each region to total emissions in the GMR (Appendices 1, 2 and 3).

1.1 The study region

Emissions have been estimated for the GMR, which includes the metropolitan regions of Sydney, Newcastle and Wollongong as shown in Figure 1. The coordinates of the south-west and north-east corners of each region are listed in Table 1.

Figure 1. Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong Regions

Table 1. Definition of Greater Metropolitan, Sydney, Newcastle and Wollongong Regions

Region	South-west corner MGA coordinates [a]		North-east corner MGA coordinates [a]	
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[a] MGA = Map Grid of Australia based on the Geocentric Datum of Australia 1994 (GDA94) (ICSM, 2002).

Emission estimates have been provided on a 1 km x 1 km grid basis. The definition of the grids is common between all inventory modules.

Emissions have been estimated for the four regions and each local government area (LGA) within the GMR. Each grid cell in the GMR is assigned to a LGA. If a grid cell contains two or more LGAs or a sea area, the following methods have been used to assign the LGA:

1. majority area method – the LGA or sea area with the largest area; and
2. centroid method – the LGA or sea area at which the centroid of the grid cell is located.

Emission estimates from both methods have been included in the biogenic module. However, the emissions presented in this report have been based on the majority area method. Figure 2 shows the LGAs that are covered in the GMR.

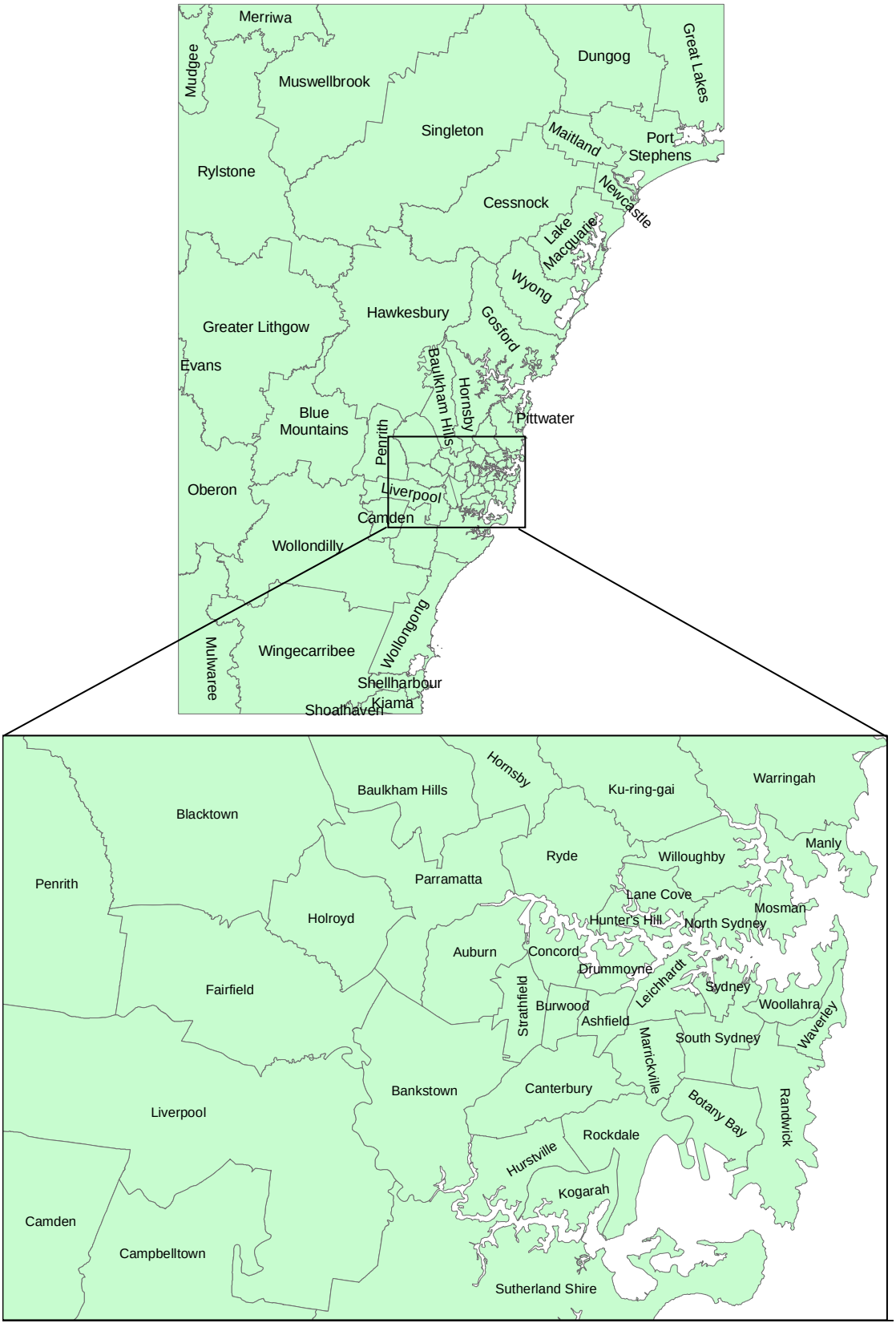


Figure 2. Local government areas in the GMR

1.2 Emission sources considered

The sources included in the biogenic module are as follows:

- burning (emissions from agricultural burning, bushfires and prescribed burning);
- fugitive/windborne (windblown dust from agricultural lands and unpaved roads due to wind erosion);
- soil (emissions of oxides of nitrogen from soil due to microbial and chemical processes of nitrification and denitrification); and
- vegetation (emissions of volatile organic compounds from trees and grass).

Grassland fires have not been included because they are uncommon in the GMR and are not recorded as a separate type of fire from bushfires or prescribed burning. Hence, a grassland fire, if any, is included as a bushfire or prescribed burning in the emissions inventory.

Note that windblown dust does not include unpaved road dust generated from vehicle movement, and grass emissions do not include those arising from cut grass. Emissions of wheel generated dust from unpaved roads have been estimated by Optimised Operations and included in the Off-Road Mobile emissions module.

1.3 Pollutants evaluated

The following substances have been included in the biogenic inventory:

- primary pollutants - oxides of nitrogen (NO_x), sulfur dioxide (SO_2), particulate matter < 10 µm (PM_{10}), particulate matter < 2.5 µm ($PM_{2.5}$), total volatile organic compounds (VOC), nitrogen dioxide (NO_2), nitric oxide (NO), total suspended particulates (TSP), and carbon monoxide (CO);
- metals - lead & compounds, antimony & compounds, arsenic & compounds, cadmium & compounds, chromium (III) compounds, chromium (VI) compounds, cobalt & compounds, copper & compounds, manganese & compounds, mercury & compounds, nickel & compounds, selenium & compounds, and zinc & compounds; and
- organic pollutants - polychlorinated dioxins and furans (PDF), total polycyclic aromatic hydrocarbons (PAH), methyl alcohol, acetylene, ethylene, ethane, acetaldehyde, ethyl alcohol, 1-propyne, propylene, propane, acetone, 1,3-butadiene, 1-butene, n-butane, 2-methylpropane; isobutane, isoprene, 1-pentene, 3-methyl-1-butene, n-pentane, n-hexane, n-heptane, n-octane, 4-ethylphenanthrene, anthracene, fluoranthene,

benzo(c)phenanthrene, chrysene, benzo(a)pyrene, benzo(e)pyrene, benzo(g,h,i)perylene, isomers of butene, isomers of pentane, monoterpenes, and isomers of pentene.

1.4 Methodology overview

Generally, emissions have been estimated by combining activity data with emission factors. Emissions of NO and NO_2 have been estimated by speciating the emissions of NO_x. PM_{10}, $PM_{2.5}$, PAH and metals have been speciated from TSP. Organic pollutants, except PDF and PAH, have been speciated from VOC. The emissions have been allocated spatially to each grid cell, and temporally to months, weekdays/weekend days and hours. Details of the methodology are described in the following sections for each source.

2 BURNING EMISSIONS

2.1 Agricultural burning emissions

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated from agricultural burning. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

Agricultural burning involves firing the standing stalks of a crop after harvesting. This practice is becoming less common and is being replaced by other forms of land management, which reduce erosion and conserve nutrients. The fraction of harvest subject to burn management is considered in the methodology described in the next section.

The amount of crop residue at the time of burning is in most cases less than that at the time of harvest. Vegetation decay and grazing by animals can reduce the amount of residue by one half. This loss is allowed for in the methodology.

Emissions have been estimated for the following pollutants:

- primary pollutants – CO, NO_x, PM_{10}, $PM_{2.5}$, TSP and VOC;
- organic air toxics – n-hexane, and polychlorinated dioxins and furans;
- metals – antimony & compounds, arsenic & compounds, cobalt & compounds, cadmium & compounds, chromium (III) compounds, chromium (VI) compounds, copper & compounds, lead & compounds, manganese & compounds, mercury & compounds, nickel & compounds, selenium & compounds, and zinc & compounds;
- speciated NO_x; and
- speciated VOC.

2.1.1 Emissions estimation

The method used to estimate emissions from agricultural burning has been based on that of the NPI manual (EA 1999) using the following equation:

$$E_{cj} = EF_{cj} \times M_c \times 10^{-3} \qquad (1a)$$

where E is emission from crop burning (kg/yr),
EF is emission factor for crop burning (g/kg),
M is fuel consumed by crop burning (kg/yr),
c is index for crop type, and
j is index for pollutant.

The fuel consumed by crop burning has been estimated using the following equation:

$$M_c = H_c \times R_c \times F_c \quad (1b)$$

where M is fuel consumed by crop burning (kg/yr),
H is regional harvest (kg/yr),
R is residue fraction,
F is fraction of harvest subject to burn management, and
c is index for crop.

2.1.2 Source activity

The annual harvest (production) of various crops in NSW is available from DPI (2004). DPI reports the crop harvest for the following regions: North West, Central West, South West, Tablelands and Coastal. However, only the Tablelands region intersects with the GMR. It has been assumed that half of the harvest in the Tablelands region is in the GMR. Also the 2004 harvest has been assumed for 2003 as the 2003 figures are not readily available. Table 2 shows the estimated 2003 annual crop harvest in the GMR. The dominant crops in the GMR are oats and wheat.

The NPI manual provides the values for residue fraction and fraction of harvest subject to burn management. The residue fraction is 0.648 for wheat and 0.576 for all other crops. A default factor of 0.23 has been used for the fraction of harvest subject to burn management.

Table 2. Estimated crop harvest, GMR 2003

Summer crop	Harvest (t/yr)	Winter crop	Harvest (t/yr)
Grain Sorghum	70	Wheat	9,505
Maize	3,965	Barley	645
Soybean	1,449	Oats	14,600
		Triticale	3,925
		Lupin albus	37.5
		Lupin angust	100
		Canola	835

2.1.3 Emission factors

Emission factors have been based on those from the NPI manual (EA 1999) and USEPA (2003). However, the emission factor for polychlorinated dioxins and furans (PDF) has been based on that from Bawden (2004). Emission factors for TSP have been derived from PM_{10} emission factors using the size fraction data from EMS-95 (Emigh & Wilkinson 1997). An emission factor for SO_2 is not available so one for fireplaces (USEPA 2003) has been used. Table 3 shows the emission factors for agricultural burning.

Table 3. Emission factors (g/kg) for agricultural burning

Crop	CO	NO_x	PDF	SO_2	TSP	VOC
Grain sorghum	38	2.21	8.2×10^{-10}	0.2	10.2	3.5
Maize	54	2.21	8.2×10^{-10}	0.2	7.96	6
Wheat	59	2.21	8.2×10^{-10}	0.2	9.66	5.5
Barley	78	2.21	8.2×10^{-10}	0.2	12.5	7.5
Oats	68	2.21	8.2×10^{-10}	0.2	18.8	10
Other crops	58	2.21	8.2×10^{-10}	0.2	12.5	9

2.1.4 Annual emissions

Table 4 shows the contributions to agricultural burning emissions by different crops in the GMR. Most emissions originate from burning oats and wheat, which are the dominant crops in the region.

Table 4. Contributions (%) to agricultural burning emissions by crop, GMR 2003

Crop	CO	NO_x	PDF	SO_2	TSP	VOC
Grain sorghum	0.12	0.19	0.19	0.19	0.14	0.084
Maize	9.5	11	11	11	6.4	8.2
Soybean	3.7	4.0	4.0	4.0	3.6	4.5
Wheat	28	29	29	29	21	20
Barley	2.2	1.8	1.8	1.8	1.6	1.7
Oats	44	40	40	40	55	50
Other crops	13	13	13	13	12	15
Total (t/yr)	299	10.6	3.95×10^{-09}	0.962	65.8	38.5

2.1.5 Speciation

VOC speciation has been based on that for 'open burning dump - landscape/pruning' (profile 0121) from Speciate 3.2 (USEPA 2002). Table 5 shows the speciation profile.

Table 5. VOC speciation profile for agricultural burning

Substance	Percentage	Substance	Percentage
acetylene	1.9	1-pentene	11.8
ethylene	19.4	n-pentane	1.9
propane	1.9	n-hexane	13.9
1-butene	5.9	n-heptane	13.9
n-butane	1.9	n-octane	13.8
2-methylpropane; isobutane	1.9	isomers of pentene	11.8

PM_{10} and $PM_{2.5}$ have been speciated from TSP using the size fraction data for 'agricultural burning' from EMS-95 (Emigh & Wilkinson 1997). Metals have been speciated from TSP using the speciation profile for 'agricultural burning – field crops' (profile 430) in CARB (2003). Chromium has been split into chromium (III) and chromium (VI) using emission factors for wood waste from USEPA (2003). Table 6 shows the speciation profile.

NO_x emissions have been assumed to contain 5% NO_2 and 95% NO (USEPA, 2005).

Estimated annual emissions from agricultural burning within the GMR, Sydney, Newcastle, and Non-Urban regions are provided in Table 7. There are no emissions from agricultural burning in Wollongong region.

Table 6. TSP speciation profile for agricultural burning

Substance	Percentage	Substance	Percentage
particulate matter < 10 µm	88.0	cobalt & compounds	0.0003
particulate matter < 2.5 µm	51.1	copper & compounds	0.0013
Lead & compounds	0.0012	manganese & compounds	0.0471
antimony & compounds	0.0051	mercury & compounds	0.0013
arsenic & compounds	0.0007	nickel & compounds	0.0009
cadmium & compounds	0.005	selenium & compounds	0.0006
chromium (III) compounds	0.00148	Zinc & compounds	0.0169
chromium (VI) compounds	0.000615		

Table 7. Annual emissions (t/yr) of all substances from agricultural burning by region in 2003

Substance	GMR	Sydney	Newcastle	Non-Urban
oxides of nitrogen	10.6	0.923	0.200	9.51
sulfur dioxide	0.962	0.0835	0.0181	0.861
lead & compounds	7.90×10^{-04}	6.86×10^{-05}	1.49×10^{-05}	7.06×10^{-04}
particulate matter < 10 µm	57.9	5.03	1.09	51.8
particulate matter < 2.5 µm	33.6	2.92	0.633	30.1
total VOCs	38.5	3.34	0.726	34.5
total suspended particulates (TSP)	65.8	5.71	1.24	58.9
carbon monoxide	299	26.0	5.64	268
antimony & compounds	0.00336	2.91×10^{-04}	6.32×10^{-05}	0.00300
arsenic & compounds	4.61×10^{-04}	4.00×10^{-05}	8.68×10^{-06}	4.12×10^{-04}
cadmium & compounds	0.00329	2.86×10^{-04}	6.20×10^{-05}	0.00294
chromium (III) compounds	9.77×10^{-04}	8.48×10^{-05}	1.84×10^{-05}	8.74×10^{-04}
chromium (VI) compounds	4.05×10^{-04}	3.52×10^{-05}	7.63×10^{-06}	3.62×10^{-04}
cobalt & compounds	1.97×10^{-04}	1.71×10^{-05}	3.72×10^{-06}	1.77×10^{-04}
copper & compounds	8.56×10^{-04}	7.43×10^{-05}	1.61×10^{-05}	7.65×10^{-04}
manganese & compounds	0.0310	0.00269	5.84×10^{-04}	0.0277
mercury & compounds	8.56×10^{-04}	7.43×10^{-05}	1.61×10^{-05}	7.65×10^{-04}
nickel & compounds	5.92×10^{-04}	5.14×10^{-05}	1.12×10^{-05}	5.30×10^{-04}
polychlorinated dioxins and furans	3.95×10^{-09}	3.43×10^{-10}	7.43×10^{-11}	3.53×10^{-09}
selenium & compounds	3.95×10^{-04}	3.43×10^{-05}	7.44×10^{-06}	3.53×10^{-04}
zinc & compounds	0.0111	9.66×10^{-04}	2.10×10^{-04}	0.00995
nitrogen dioxide	0.532	0.0462	0.0100	0.476
nitric oxide	6.59	0.572	0.124	5.89
acetylene	0.732	0.0635	0.0138	0.655
ethylene	7.47	0.649	0.141	6.68
propane	0.732	0.0635	0.0138	0.655
1-butene	2.27	0.197	0.0428	2.03
n-butane	0.732	0.0635	0.0138	0.655
2-methylpropane; isobutane	0.732	0.0635	0.0138	0.655
1-pentene	4.55	0.395	0.0857	4.07
n-pentane	0.732	0.0635	0.0138	0.655
n-hexane	5.36	0.465	0.101	4.79

Substance	GMR	Sydney	Newcastle	Non-Urban
n-heptane	5.36	0.465	0.101	4.79
n-octane	5.32	0.462	0.100	4.75
isomers of pentene	4.55	0.395	0.0857	4.07

2.1.6 Spatial allocation

Emissions have been allocated evenly to cropping areas, which are based on the 1996/97 Land Use of Australia, Version 2 downloaded from the web site of the Australian Government Department of Agricultural, Fisheries and Forestry (http://www.affa.gov.au). Figure 3 shows the cropping areas in the GMR and Figure 4 shows the gridded emissions of TSP from agricultural burning.

Table 8 shows the agricultural burning emission contributions by LGA. Note that the percentage contributions are the same for all substances, which have been distributed evenly over cropping areas. Most of the emissions from agricultural burning have been estimated to occur in Rylstone, Muswellbrook and Upper Lachlan (Mulwaree) LGAs.

Table 8. Contributions to agricultural burning emissions by LGA, GMR 2003

LGA	Emission (%)	LGA	Emission (%)	LGA	Emission (%)
Blue Mountains	1.4	Kiama	0.34	Port Stephens	0.79
Camden	1.7	Lithgow	11	Rylstone	21
Cessnock	2.4	Maitland	1.4	Shellharbour	0.69
Dungog	1.8	Merriwa	4.1	Singleton	6.4
Gosford	0.093	Mudgee	0.35	Upper Lachlan	13
Greater Argyle	0.34	Muswellbrook	15	Wingecarribee	9.8
Hawkesbury	3.5	Newcastle	0.017	Wollondilly	2.3
Hornsby	0.26	Oberon	2.1	Wyong	0.35

In terms of regions, 89.4%, 8.7% and 1.9% of the emissions from agricultural burning occur in Non-Urban, Sydney and Newcastle regions respectively. There are no emissions from agricultural burning in Wollongong region.

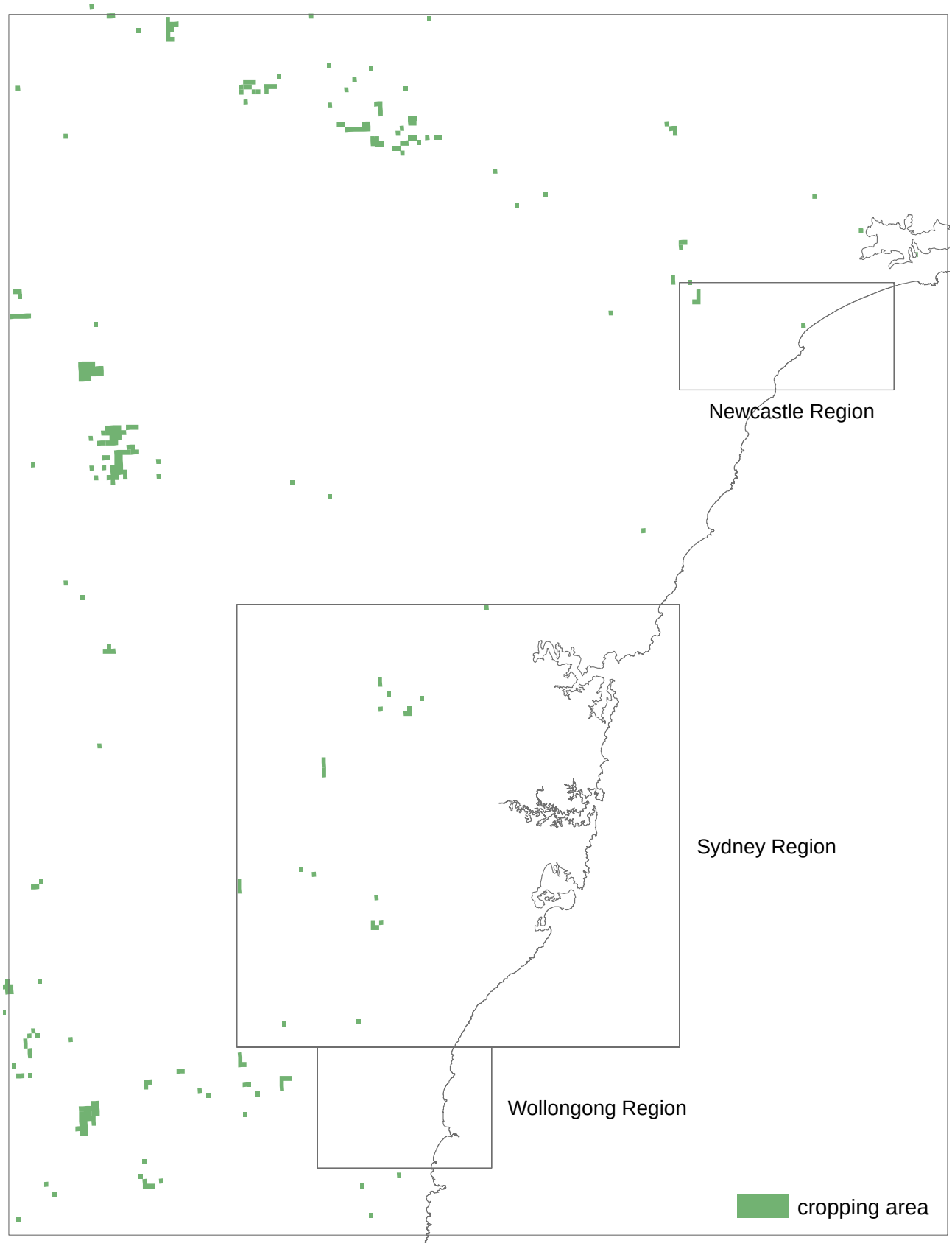


Figure 3. Cropping areas in the GMR

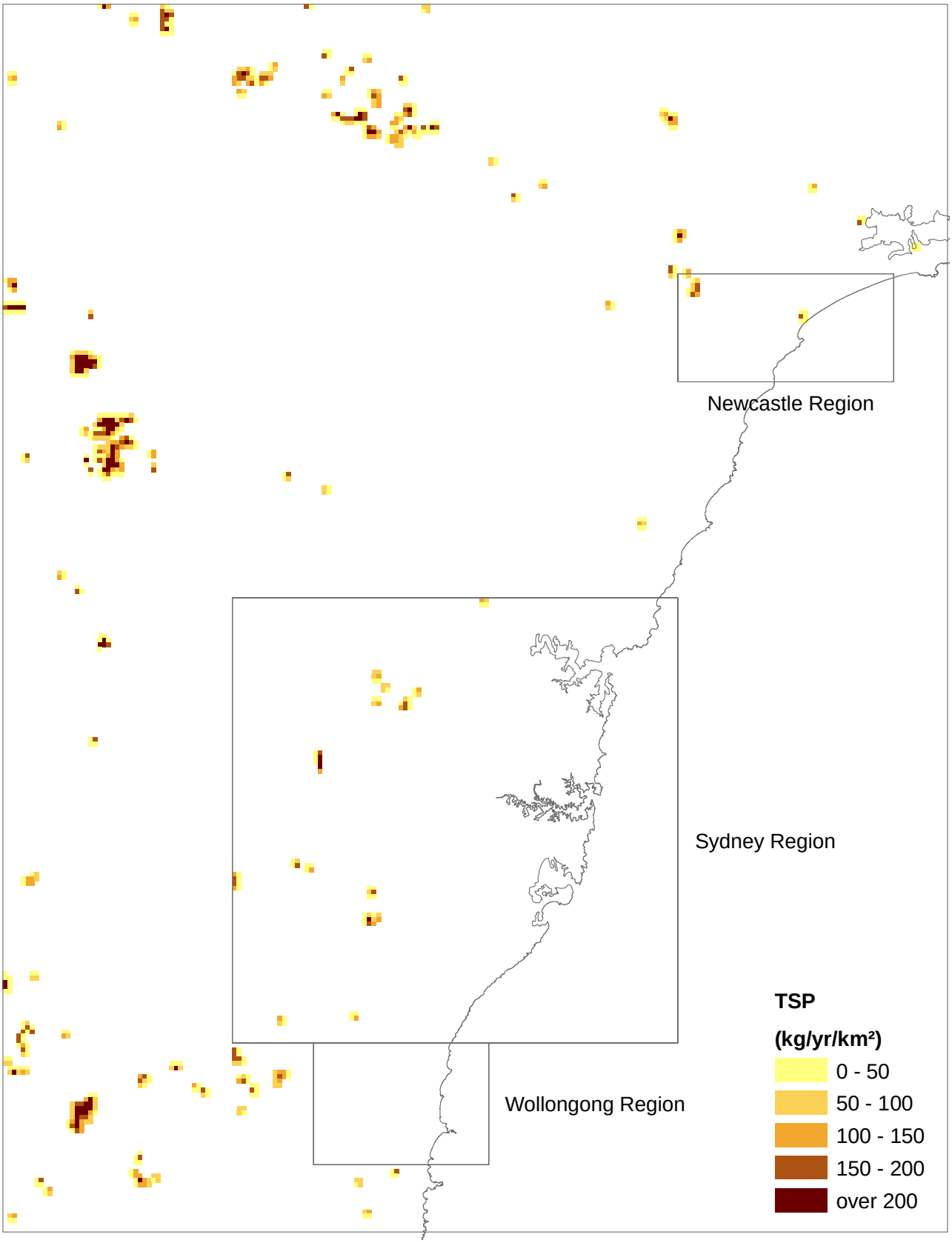


Figure 4. Gridded emissions of TSP from agricultural burning, GMR 2003

2.1.7 Temporal variation

Emissions have been allocated to months of harvesting when the crops are burnt after harvesting. For summer crops, which are planted in summer, the harvesting months are from May to June. For winter crops, which are planted in winter, the harvesting months are from November to January. Summer and winter crops are listed in Table 2. The harvesting periods have been based on the crop calendar published by the US Department of Agriculture and Department of Commerce (http://www.usda.gov/oce/waob/jawf/calendar). Emissions have been allocated evenly to May and June for summer crops, and November, December and January for winter crops. 80% of the emissions have been assumed to occur on weekdays (i.e. 16% of total emissions per weekday) and 20% on weekend days (i.e. 10% of total emissions per weekend day), with diurnal emissions being constant between 8 am and 8 pm. This assumption has been based on information obtained from Grains Council of Australia and Agforce Australia (Joynt & Ng 2002).

Figure 5 shows the average daily agricultural burning emissions of TSP on weekdays and weekend days in each month. Emissions of other substances show the same temporal variation.

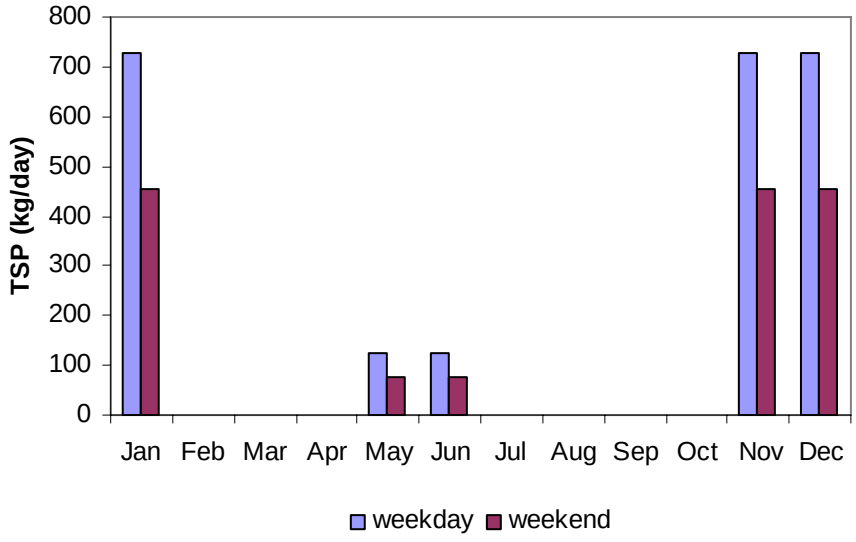


Figure 5. Average daily emissions of TSP from agricultural burning, GMR 2003

2.2 Bushfires, prescribed burning and grassland fires emissions

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated from bushfires, prescribed burning and grassland fires. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

Burning is carried out either anthropogenically (prescribed burning) or as a result of wildfires (bushfires). Prescribed burning occurs for a variety of reasons including fuel reduction, prevention of uncontrollable bushfires, and traditional Aboriginal burning. Prescribed burning and bushfires can occur in forests and grasslands. In this report, prescribed burning and bushfires refer to fires occurring in forests. Grassland fires refer to any fires on grasslands, whether they occur anthropogenically or naturally.

Emissions have been estimated for the following pollutants:

- primary pollutants – CO, NO_x, PM_{10}, $PM_{2.5}$, TSP and VOC;
- organic air toxics – 1,3-butadiene, polycyclic aromatic hydrocarbons, and polychlorinated dioxins and furans;
- metals – antimony & compounds, arsenic & compounds, cadmium & compounds, chromium (III) compounds, chromium (VI) compounds, cobalt & compounds, copper & compounds, lead & compounds, manganese & compounds, nickel & compounds, selenium & compounds, and zinc & compounds;
- speciated NO_x; and
- speciated VOC.

2.2.1 Emissions estimation

The method used to estimate emissions from bushfires, prescribed burning and grassland fires has been based on that of the NPI manual (EA 1999) using the following equation:

$$E_{ij} = A_i \times L_i \times EF_j \times 10^{-3} \quad (2)$$

where E is emission from a burn area (kg),
A is size of area burned (ha),
L is fuel loading of the burn area (kg/ha),
EF is emission factor (g/kg),
i is index for burn area, and
j is index for pollutant.

2.2.2 Source activity

Data on sizes and locations of burn areas and dates of the burns are collected by the DEC and Rural Fire Services (RFS). DEC has provided data for national parks and RFS has provided data for areas other than national parks.

Table 9 shows the total areas of bushfires and prescribed burning in the GMR. Although the RFS could not provide data for bushfires during the 2003 calendar year, the DEC has advised there is some overlap between DEC and RFS bushfires data (i.e. the DEC bushfire data for national parks also includes some bushfire data outside national parks (pers. com. Dr R. Bradstock). While the extent of this overlap is not precisely known, bushfires in national parks are the dominant source within the GMR. However, emissions from bushfires could have been underestimated by up to 50% due to the absence of data from the RFS.

There were 110 bushfires and 104 prescribed burns in national parks, and 281 prescribed burns in areas other than national parks in the GMR in 2003. Figure 6 shows the size distribution of bushfires and prescribed burns in national parks and Figure 7 shows that of prescribed burns in areas other than national parks. Most bushfires were between 0.1 and 100 ha, and prescribed burns between 10 and 100 ha. However, the largest fires were bushfires.

Table 9. Total areas (ha) of bushfires and prescribed burning, GMR 2003

Source	National parks	Areas other than national parks
Bushfires	93,127	no data [a]
Prescribed burning	9,252	10,906

a. While the DEC bushfire data for national parks also includes some bushfire data outside national parks (pers. com. Dr R. Bradstock), bushfire areas could have been underestimated by up to 50%.

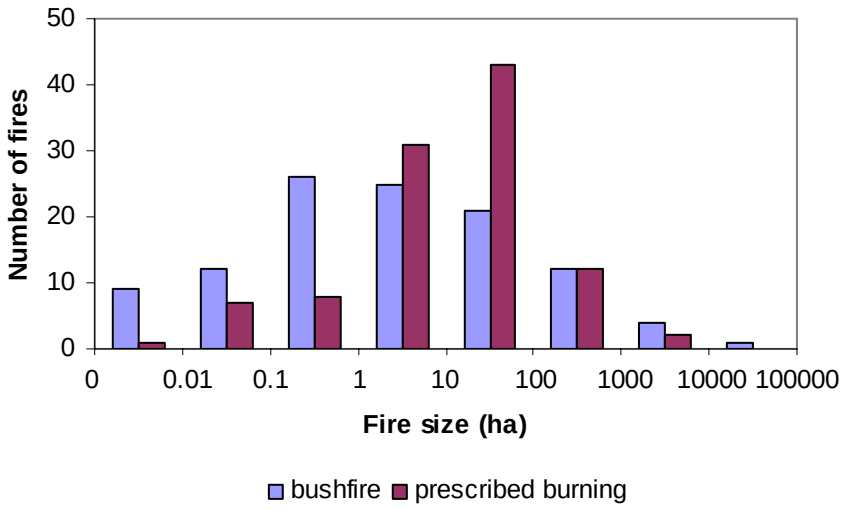


Figure 6. Size distribution of bushfires and prescribed burns in national parks, GMR 2003

The largest bushfires in national parks and prescribed burns in the GMR were 77,200 ha and 1,655 ha respectively.

The fuel loads for bushfires and prescribed burning have been assumed to be 26.2 and 7.64 t/ha respectively (AGO 2005).

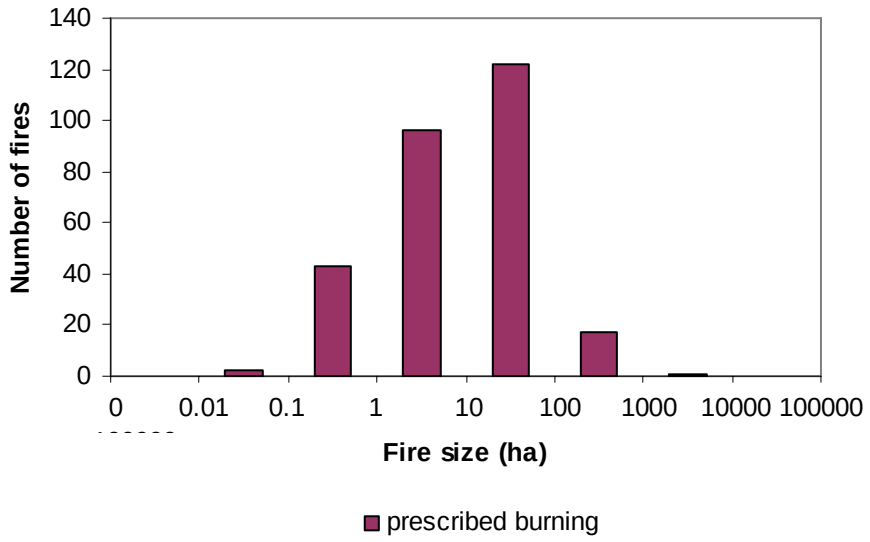


Figure 7. Size distribution of prescribed burns in areas other than national parks, GMR 2003

2.2.3 Emission factors

Emission factors have been based on those from the NPI manual (EA 1999) and USEPA (2003). However, the emission factor for PDF has been based on that from Bawden (2004). Emission factors for TSP have been derived from PM_{10} using the size fraction data from EMS-95 (Emigh & Wilkinson 1997). An emission factor for SO_2 is not available so one for fireplaces (USEPA 2003) has been used. Table 10 shows the emission factors for bushfires and prescribed burning.

Table 10. Emission factors (g/kg) for bushfires and prescribed burning

Source	CO	NO_x	PDF	SO_2	TSP	VOC
Bushfires	70	2	4.40×10^{-10}	0.2	8.5	10.8
Prescribed burning	112	2	8.50×10^{-10}	0.2	18	6.4

2.2.4 Annual emissions

Table 11 shows the contributions of emissions from bushfires and prescribed burning in the GMR. Most of the emissions originate from bushfires as they occupy larger areas and have higher fuel loads.

Table 11. Contributions (%) to bushfires and prescribed burning emissions by source, GMR 2003

Source	CO	NO_x	PDF	SO_2	TSP	VOC
Bushfires (national parks)	91	94	89	94	88	96
Prescribed burning (national parks)	4.2	2.7	5.0	2.7	5.4	1.7
Prescribed burning (areas other than national parks)	5.0	3.2	5.9	3.2	6.4	1.9
Total (t/yr)	188,105	5,190	1.20×10^{-06}	519	23,519	27,398

2.2.5 Speciation

VOC speciation has been based on that for 'miscellaneous burning - forest fires' (profile 0307) from Speciate 3.2 (USEPA 2002). Table 12 shows the speciation profile.

Table 12. VOC speciation profile for bushfires and prescribed burning

Substance	Percentage	Substance	Percentage
acetylene	9.31	1-butene	0.898
ethylene	21.2	n-butane	0.266
ethane	11.6	2-methylpropane; isobutane	0.122
1-propyne	0.455	3-methyl-1-butene	0.189
propylene	4.36	isomers of butene	1.02
propane	0.388	isomers of pentane	0.166
1,3-butadiene	0.577	Unidentified [a]	49.44

a. Includes one or more substances that have not been characterised.

PM_{10} and $PM_{2.5}$ have been speciated from TSP using the size fraction data for 'planned/unplanned forest fires' from EMS-95 (Emigh & Wilkinson 1997). Metals have been speciated from TSP using the speciation profile for 'forest prescribed burning – broadcast conifer' (profile 42321) in Speciate 3.2 (USEPA 2002). Chromium has been split into chromium (III) and chromium (VI) using emission factors for wood waste from USEPA (2003). Table 13 shows the speciation profile.

NO_x emissions have been assumed to contain 5% NO_2 and 95% NO (USEPA, 2005).

Estimated annual emissions from bushfires and prescribed burning within the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions are provided in Table 14.

Table 13. TSP speciation profile for bushfires and prescribed burning

Substance	Percentage	Substance	Percentage
particulate matter < 10 µm	66.7	polycyclic aromatic hydrocarbons	0.008
particulate matter < 2.5 µm	61.1	4-ethylphenanthrene	0.001
lead & compounds	0.01	anthracene	0.001
cadmium & compounds	0.031	fluoranthene	0.001
chromium (III) compounds	0.00141	benzo(c)phenanthrene	0.001
chromium (VI) compounds	0.000586	chrysene	0.001
copper & compounds	0.002	benzo(a)pyrene	0.001
manganese & compounds	0.011	benzo(e)pyrene	0.001
nickel & compounds	0.002	benzo(g,h,i)perylene	0.001
zinc & compounds	0.046		

Table 14. Annual emissions (t/yr) of all substances from bushfires and prescribed burning by region in 2003

Substance	GMR	Sydney	Newcastle	Wollongong	Non-Urban
oxides of nitrogen	5,190	693	4.56	3.22	4,489
sulfur dioxide	519	69.3	0.456	0.322	449
lead & compounds	2.35	0.364	0.00218	0.00210	1.98
particulate matter < 10 µm	15,680	2,425	14.6	14.0	13,226
particulate matter < 2.5 µm	14,373	2,223	13.3	12.8	12,123
polycyclic aromatic hydrocarbons	1.88	0.291	0.00175	0.00168	1.59
total VOCs	27,398	3,428	23.5	14.0	23,933
total suspended particulates (TSP)	23,519	3,638	21.8	21.0	19,838
carbon monoxide	188,105	27,320	170	145	160,470
1,3-butadiene	158	19.8	0.136	0.0808	138
cadmium & compounds	7.29	1.13	0.00677	0.00652	6.15
chromium (III) compounds	0.333	0.0514	3.09×10^{-04}	2.97×10^{-04}	0.281
chromium (VI) compounds	0.138	0.0213	1.28×10^{-04}	1.23×10^{-04}	0.116
copper & compounds	0.470	0.0728	4.37×10^{-04}	4.21×10^{-04}	0.397
manganese & compounds	2.59	0.400	0.00240	0.00231	2.18
nickel & compounds	0.470	0.0728	4.37×10^{-04}	4.21×10^{-04}	0.397
polychlorinated dioxins and furans	1.20×10^{-06}	1.82×10^{-07}	1.11×10^{-09}	1.03×10^{-09}	1.02×10^{-06}
zinc & compounds	10.8	1.67	0.0100	0.00967	9.13

Substance	GMR	Sydney	Newcastle	Wollongong	Non-Urban
nitrogen dioxide	259	34.7	0.228	0.161	224
nitric oxide	3,215	429	2.82	2.00	2,781
acetylene	2,552	319	2.19	1.31	2,229
ethylene	5,806	726	4.98	2.97	5,072
ethane	3,181	398	2.73	1.63	2,779
1-propyne	125	15.6	0.107	0.0637	109
propylene	1,194	149	1.02	0.611	1,043
propane	106	13.3	0.0912	0.0544	92.9
1-butene	246	30.8	0.211	0.126	215
n-butane	72.9	9.12	0.0625	0.0373	63.7
2-methylpropane; isobutane	33.4	4.18	0.0287	0.0171	29.2
3-methyl-1-butene	51.6	6.46	0.0443	0.0264	45.1
4-ethylphenanthrene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
anthracene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
fluoranthene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
benzo(c)phenanthrene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
chrysene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
benzo(a)pyrene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
benzo(e)pyrene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
benzo(g,h,i)perylene	0.235	0.0364	2.18×10^{-04}	2.10×10^{-04}	0.198
isomers of butene	280	35.0	0.240	0.143	244
isomers of pentane	45.6	5.70	0.0391	0.0233	39.8

2.2.6 Spatial allocation

Emissions have been allocated to grid cells where the fires start. However, RFS does not record the coordinates of rural fires, so the centroids of the suburbs where the fires occurred have been used to locate the fires. If a fire is larger than 100 ha (the size of a grid cell), emissions have been assigned to the grid cell where the fire is allocated, as no information regarding the spread of a fire is available.

Figure 8 shows the locations of bushfires and prescribed burning in national parks, and Figure 9 that of prescribed burning in areas other than national parks. Note that proportional symbols are used in Figure 9 to display the number of fires assigned to suburb centroids. Figure 10 shows the gridded emissions of TSP from bushfires and prescribed burning.

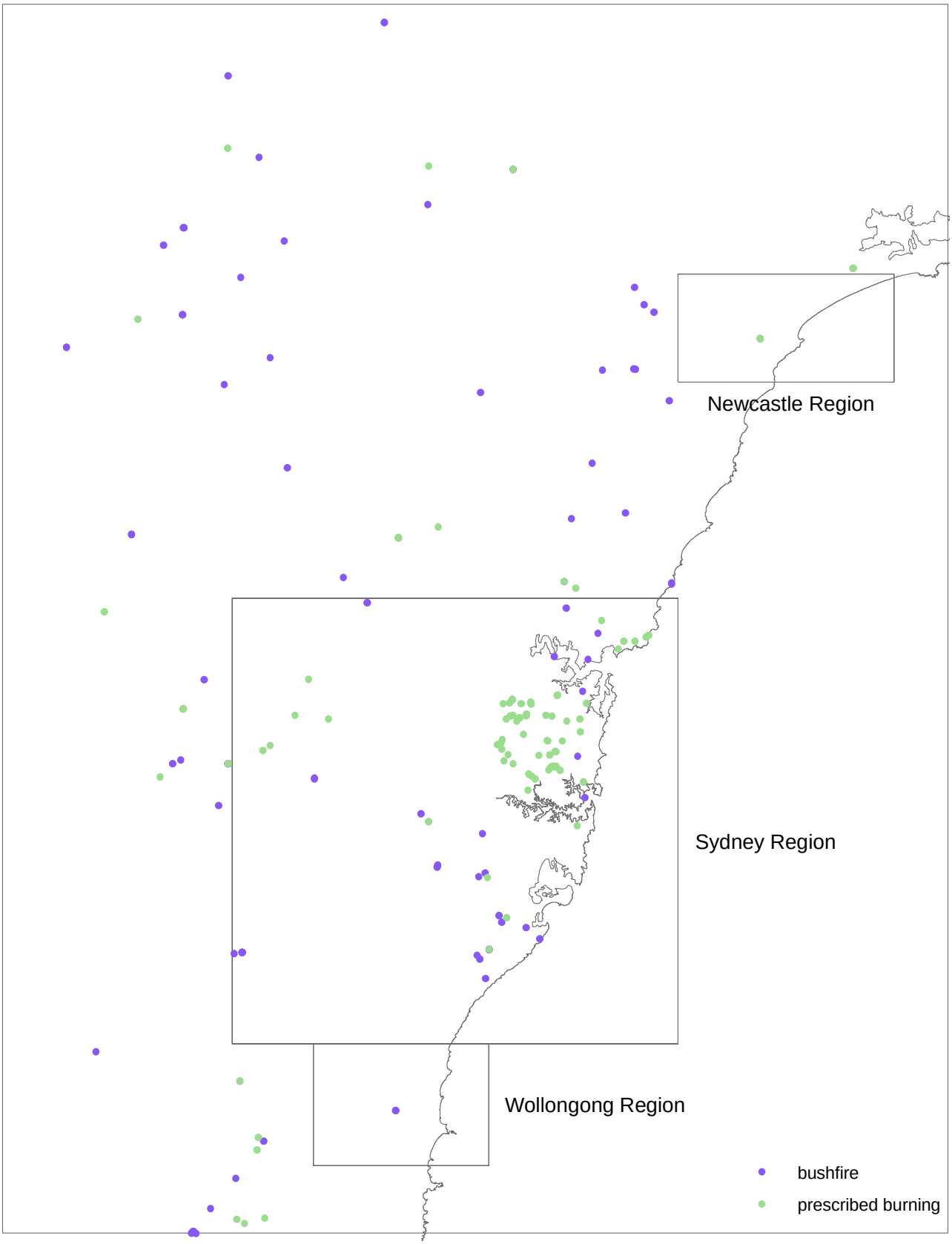


Figure 8. Locations of bushfires and prescribed burning in national parks, GMR 2003

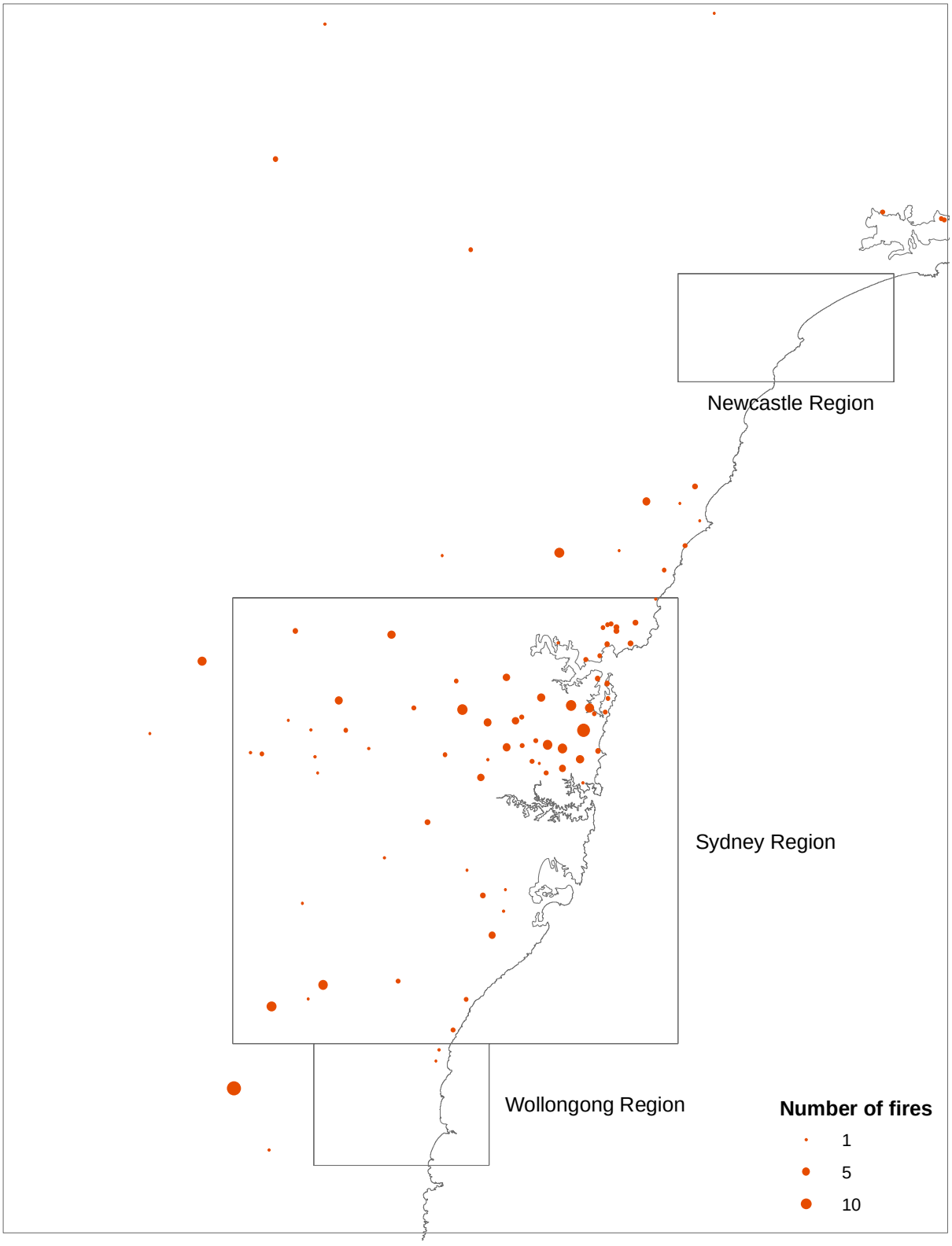


Figure 9. Locations of prescribed burning in areas other than national parks, GMR 2003

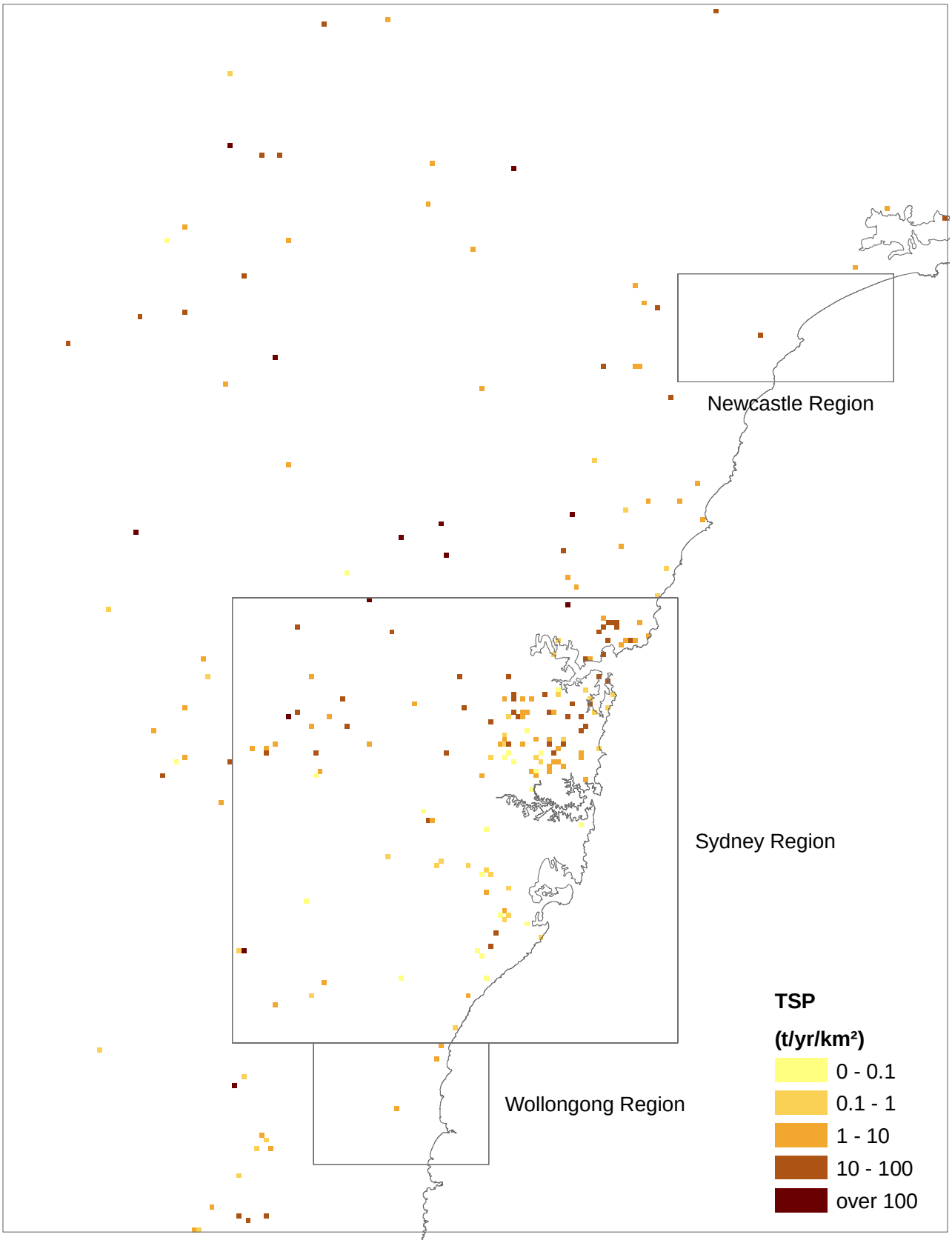


Figure 10. Emissions of TSP from bushfires and prescribed burning, GMR 2003

Table 15 shows the contributions of bushfires and prescribed burning emissions by LGA. The emissions are dominated from a single large bushfire in Lithgow LGA. Wollondilly and Gosford LGAs also have significant emissions due to large bushfires.

Table 15. Contributions (%) to bushfires and prescribed burning emissions by LGA, GMR 2003

LGA	Bushfires	Prescribed burning	LGA	Bushfires	Prescribed burning
Bankstown	0.0023	0.036	Muswellbrook	0.59	6.6
Baulkham Hills		2.0	Newcastle	0.083	0.17
Blacktown		0.37	Penrith		1.2
Blue Mountains	0.38	13	Pittwater	0.0011	6.3
Cessnock	0.53		Port Stephens		0.077
Dungog		0.99	Ryde		0.00050
Fairfield	0.00011	0.86	Rylstone	0.62	2.7
Gosford	4.4	6.9	Singleton	1.3	8.6
Great Lakes		1.0	Sutherland	0.030	1.3
Hawkesbury	1.8	19	Warringah	0.043	5.0
Hornsby	0.0048	7.4	Wingecarribee	0.055	13
Ku-ring-gai		1.6	Wollondilly	6.1	0.20
Lake Macquarie	0.19		Wollongong	0.034	0.58
Lithgow	83	0.025	Woollahra		0.0022
Liverpool	0.0054	0.036	Wyong	0.93	0.72
Manly		0.054	Total	100	100

Table 16 shows the contributions of bushfires and prescribed burning emissions by region. Most emissions occur in Non-Urban region, although significant emissions also occur in Sydney region. Emissions from Newcastle and Wollongong regions are relatively small. However, a large variation in spatial emissions is expected from year to year.

Table 16. Contributions (%) to bushfires and prescribed burning emissions by region, GMR 2003

Source	GMR	Sydney	Newcastle	Wollongong	Non-Urban
Bushfires	100	11	0.083	0.034	89
Prescribed burning	100	47	0.17	0.50	52

2.2.7 Temporal variation

Monthly and weekday/weekend day variation of emission have been based on the actual dates of burns. Figure 11 and Figure 12 show the number of fires by month and day for bushfires and prescribed burning respectively. Most bushfires occur in September and January, and prescribed burning in September and August. Figure 13 shows the average daily emissions for bushfires and prescribed burning by month and day. The emissions are dominated by the Lithgow bushfire, which occurred in January. However, a large variation in emissions is expected from year to year.

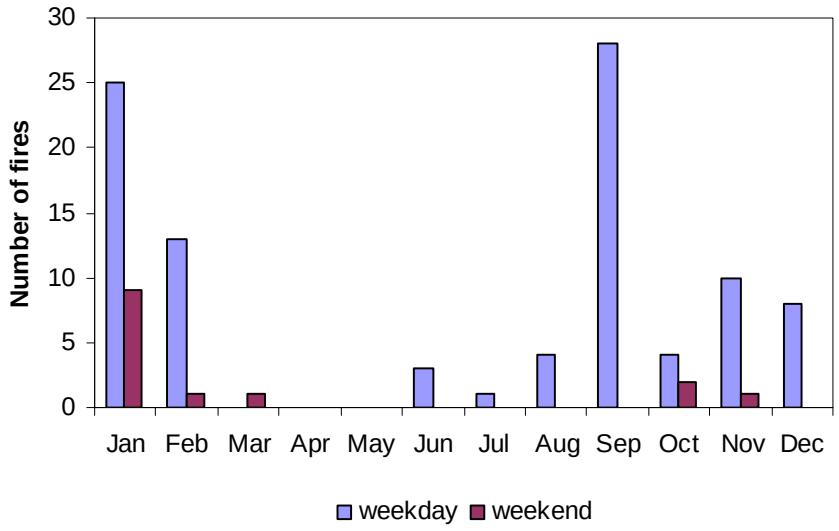


Figure 11. Number of bushfires by month and day, GMR 2003

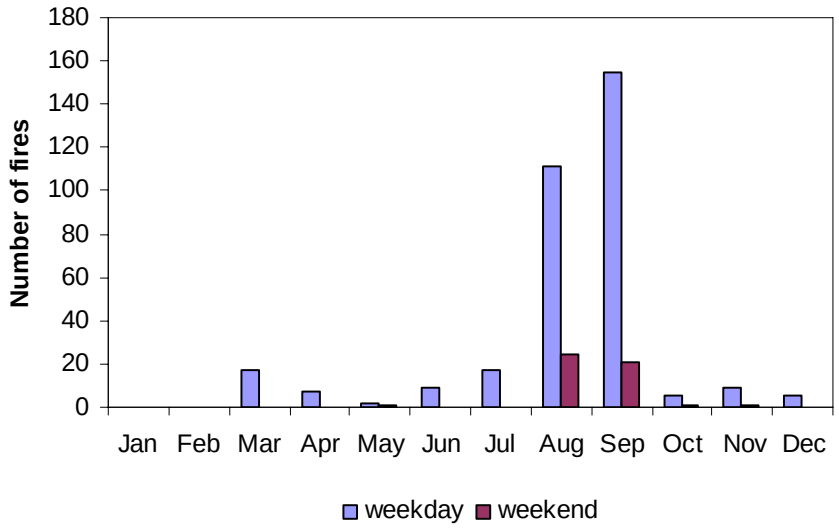


Figure 12. Number of prescribed burning by month and day, GMR 2003

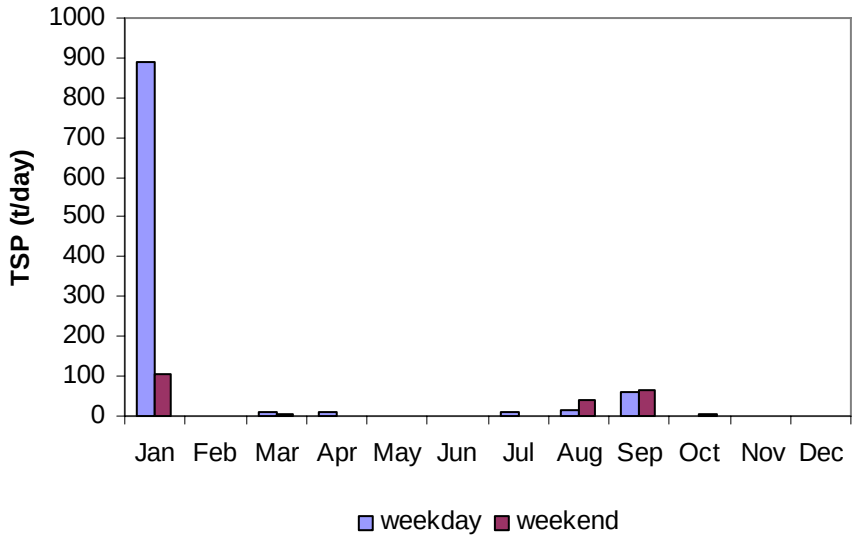


Figure 13. Average daily emissions of TSP from bushfires and prescribed burning, GMR 2003

Times of burns are not available from DEC or RFS, so the hourly profiles have been based on those experienced in Victoria in 2002. Figure 14 shows the hourly profiles for bushfires and prescribed burning. The profile for prescribed burning is more pronounced in early afternoon, as most prescribed burns are carried out during that time.

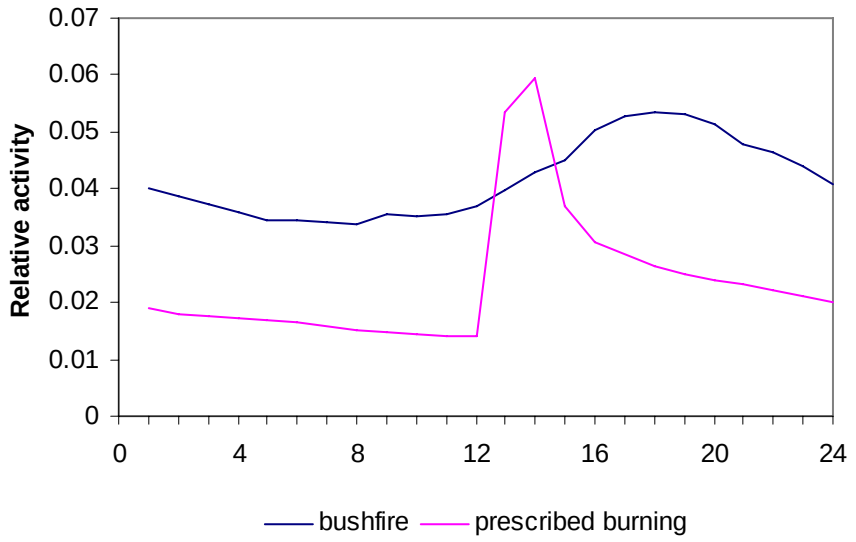


Figure 14. Hourly profiles for bushfires and prescribed burning

3 FUGITIVE/WINDBORNE EMISSIONS

3.1 Agricultural lands emissions

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated for windblown dust from agricultural lands. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

Wind blowing across exposed agricultural land results in particulate matter emissions. The particulate matter contains metal and compounds that either naturally occur in soil or are added from fertilisers. Emissions have been estimated for the following pollutants:

- primary pollutants – PM_{10}, $PM_{2.5}$ and TSP; and
- metals – antimony & compounds, arsenic & compounds, cadmium & compounds, chromium (III) compounds, chromium (VI) compounds, cobalt & compounds, copper & compounds, lead & compounds, manganese & compounds, mercury & compounds, nickel & compounds, selenium & compounds, and zinc & compounds.

3.1.1 Emissions estimation

The method used to estimate windblown dust emissions from agricultural lands has been based on a wind erosion equation adapted by CARB (1997a):

$$E_c = H_c \times A \times I_s \times K_c \times C \times L'_{cs} \times V'_c \qquad (3a)$$

where E is suspended particulate fraction of wind erosion losses of tilled fields (t/yr),
H is crop area (ha),
A is portion of total wind erosion losses that would be measured as suspended particulate (= 0.025),
I is soil erodibility (t/ha/yr),
K is surface roughness factor (dimensionless),
C is climatic factor (dimensionless),
L' is unsheltered field width factor (dimensionless),
V' is vegetative cover factor (dimensionless), and
c is index for crop type, and
s is index for soil type.

3.1.2 Crop area

The annual harvest (crop area) of various crops in NSW is available from DPI (2004). DPI reports the crop harvest for the following regions: North West, Central West, South West, Tablelands and Coastal. However, only the Tablelands region is within the GMR. It has been assumed that half of the harvest in the Tablelands region is in the GMR. Also the 2004 harvest has been assumed for 2003 as the 2003 figures are not readily available. Table 17 shows the estimated 2003 crop areas in the GMR. The dominant crops in the GMR are oats and wheat.

Table 17. Estimated crop areas, GMR 2003

Summer crop	Harvest (ha)	Winter crop	Harvest (ha)
Grain sorghum	25	Wheat	3,400
Maize	900	Barley	1,075
Soybean	790	Oats	7,800
		Triticale	1,600
		Cereal rye	25
		Lupin albus	25
		Lupin angust	50
		Canola	450

3.1.3 Soil erodibility

The soil erodibility (I) is a function of soil particle diameter, which has been estimated for various soil textural classes (USEPA 1988). A digital map of Australian soil type is available for download from the web site of the Australian Government Department of Agricultural, Fisheries and Forestry (BRS 1991). Figure 15 shows the distribution of soil types in the GMR. Table 18 lists the soil types, their percentage of land area and erodibility according to the textural classes from USEPA (1988). Note that the legend of Figure 15 is arranged in order of decreasing erodibility, as in Table 18. A darker shade of red indicates higher erodibility and a darker shade of green indicates lower erodibility. Table 18 and Figure 15 show that the GMR consists mostly of massive earths and yellow duplex, which are moderately conducive to wind erosion.

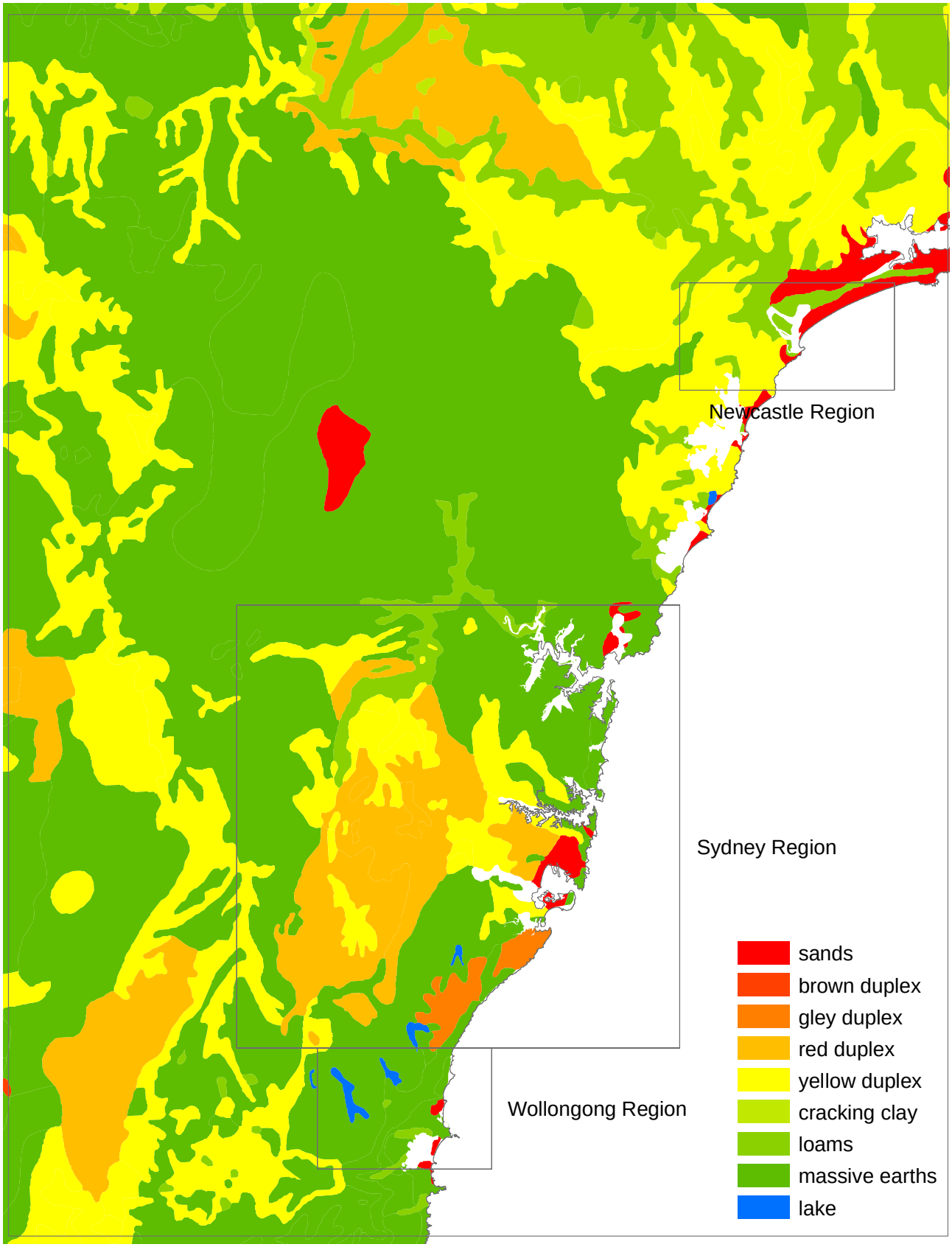


Figure 15. Soil types in the GMR

Table 18. Soil erodibility and areas in the GMR

Soil type	Area (%)	Erodibility (t/ha/yr)	Soil type	Area (%)	Erodibility (t/ha/yr)
Sands	1.9	544	Cracking clay	0.30	138
Brown duplex	0.0032	213	Loams	9.1	138
Gley duplex	0.54	213	Massive earths	53	94
Red duplex	9.9	213	Lake	0.16	0
Yellow duplex	26	213			

3.1.4 Surface roughness factor

The surface roughness factor (K) is crop specific. Table 19 shows the surface roughness factors that have been derived using the data from USEPA (1988). The dominant crops in the GMR are oats and wheat. Their surface roughness factors are moderately conducive to wind erosion. Common Australian crops have surface roughness factors between 0.5 and 1.

Table 19. Values of surface roughness factor, unsheltered field width and average unsheltered field width factor for crops in the GMR

Crop	Surface roughness factor	Unsheltered field width (m)	Average unsheltered field width factor
Grain sorghum	0.5	610	0.924
Oats	0.8	610	0.979
Beans (lupin albus, lupin angust, canola)	0.5	305	0.824
Other crops	0.6	610	0.951

3.1.5 Climatic factor

Research has indicated that the rate of soil movement by wind varies directly as the cube of wind velocity and inversely as the square of soil surface moisture. Surface moisture is difficult to measure directly, but precipitation-evaporation indices (PE) can be used to approximate the amount of moisture in soil surface particles. Generally, higher PE values result in higher soil moisture and hence lower emissions.

The climatic factor has been calculated according to:

$$C = 0.0828 \times WS^3 / PE^2 \qquad (3b)$$

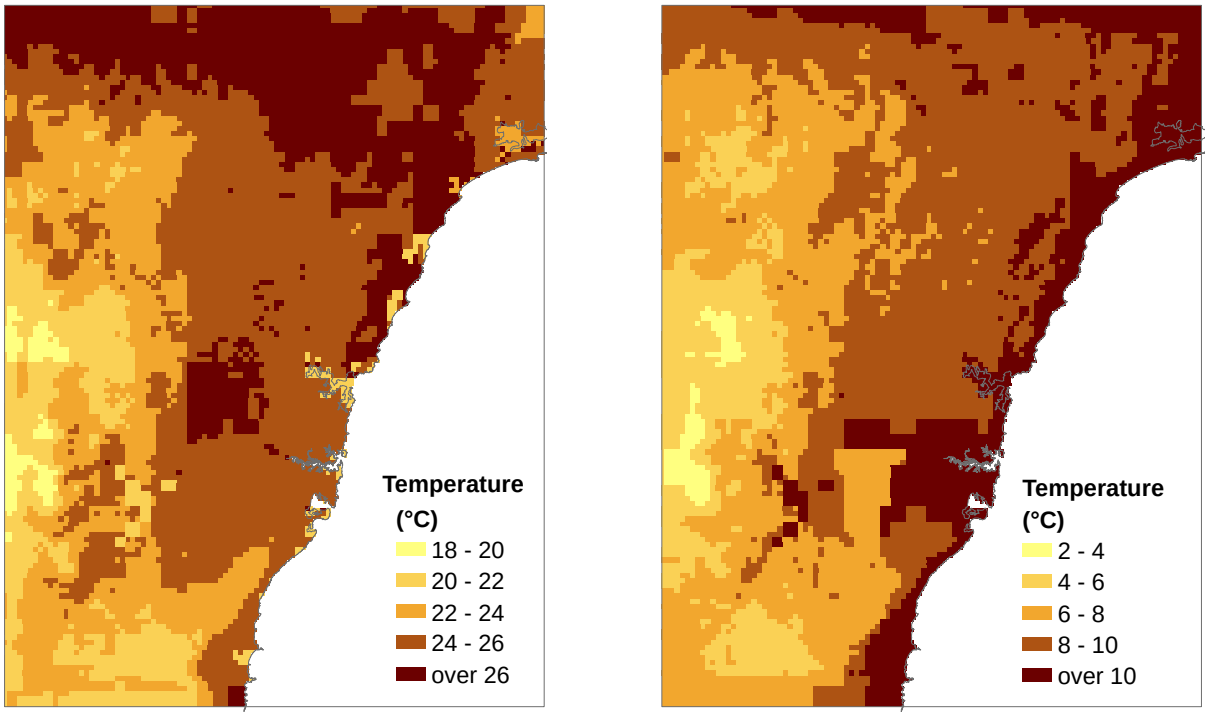
where WS is mean annual wind speed (km/hr) 10 metres above the ground,
PE is Thornthwaite's precipitation-evaporation index, and

$$PE = \sum_{i=1}^{12} PE_i = \sum_{i=1}^{12} 1.64 \times \left(\frac{P_i}{T_i + 12.2} \right)^{10/9} \quad (3c)$$

where P is average monthly precipitation (mm) where all values less than 12.5 mm have been assigned the value of 12.5 mm,
T is average monthly temperature (°C), and
i is index for month.

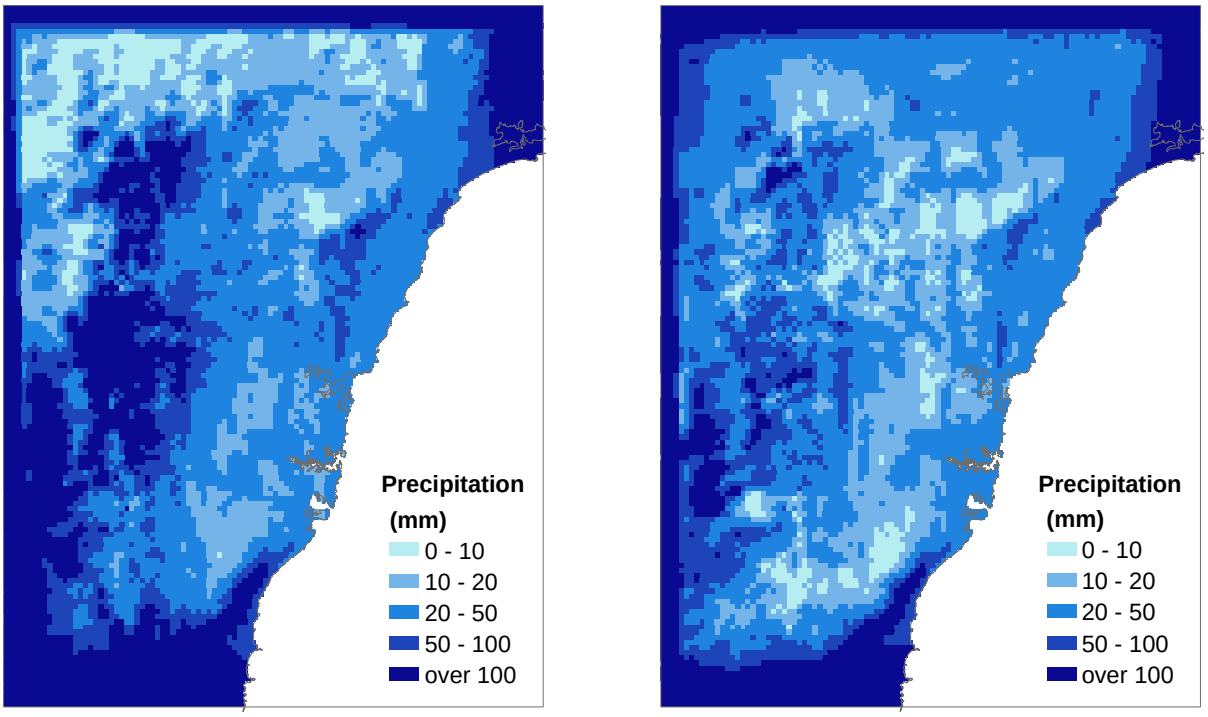
Gridded monthly temperature, precipitation and wind speed data have been based on those from TAPM (Hurley 2005). Figure 16, Figure 17 and Figure 18 show the meteorological data for January and July. The spatial distributions of the meteorological data are similar for the two months, with January being hotter, wetter and less windy.

Figure 19 shows the monthly precipitation and temperature averaged over the land area in the GMR, and Figure 20 Thornthwaite's precipitation-evaporation index and wind speed.



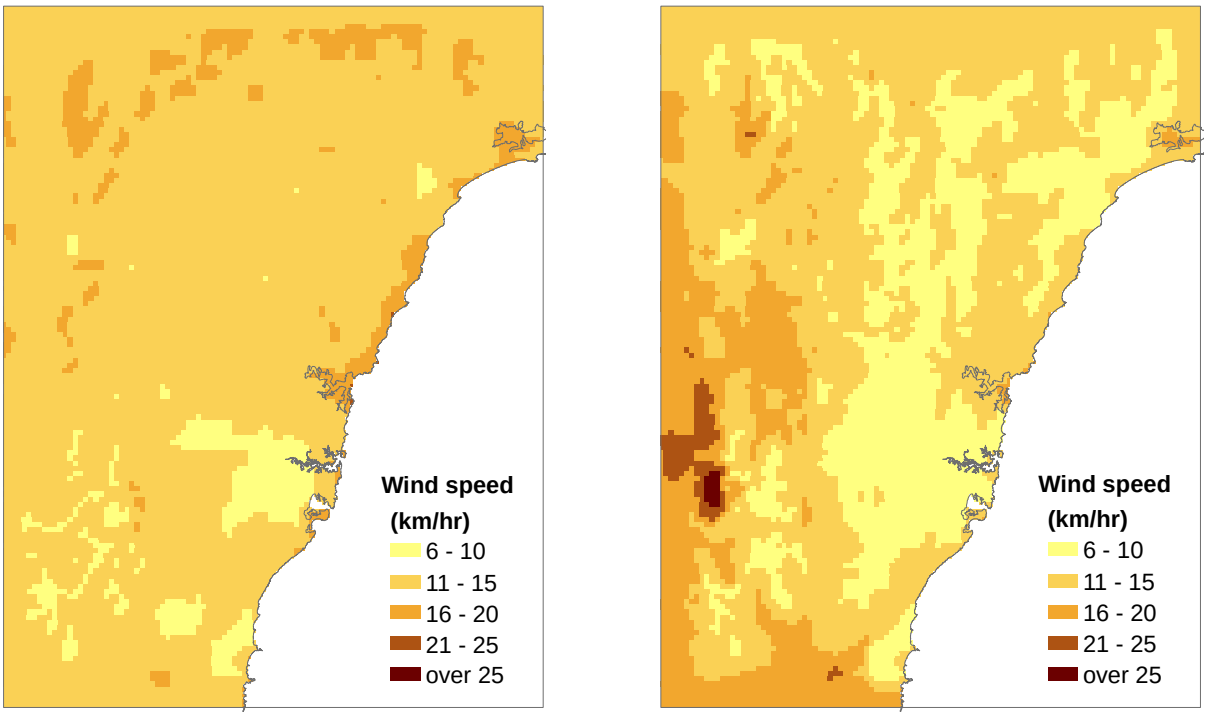
January July

Figure 16. Gridded monthly average temperature, GMR 2003



January July

Figure 17. Gridded monthly average precipitation, GMR 2003



January July

Figure 18. Gridded monthly average wind speed, GMR 2003

Note that the PE values strongly depend on precipitation, with September having the lowest value. Figure 20 also shows the monthly wind speed, indicating that September is particularly susceptible to wind erosion due to high wind speeds and low PE values. The monthly wind speed data for each grid cell have been used to derive the mean annual wind speed used in Equation 3b.

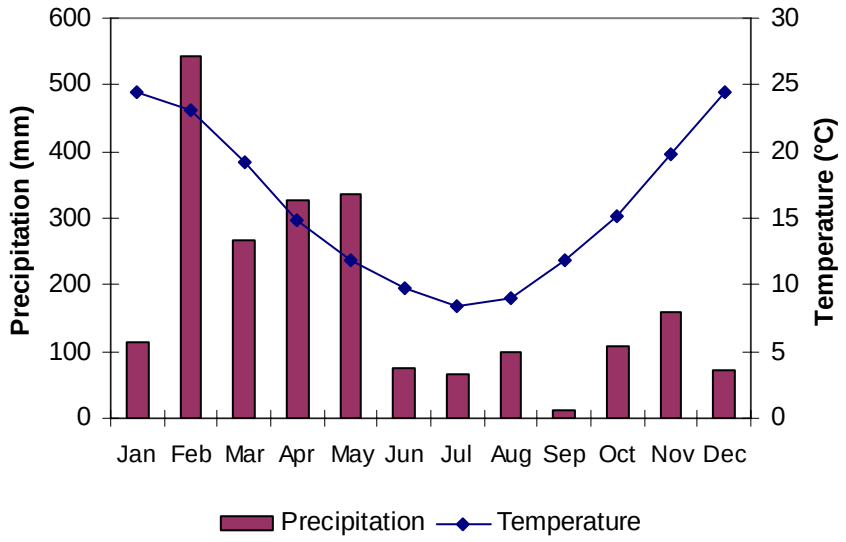


Figure 19. Average monthly precipitation and temperature, GMR 2003

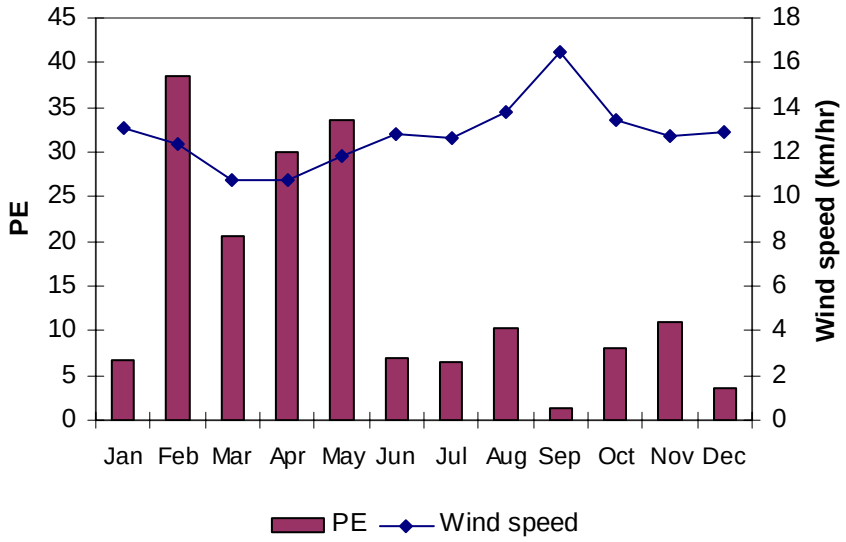


Figure 20. Average monthly Thornthwaite's precipitation-evaporation index and wind speed, GMR 2003

Figure 21 shows the gridded annual climatic factor in the GMR. The climatic factor is generally low in the GMR, indicating that the climate in the GMR is not conducive to wind erosion. In Bunbury of Western Australia, the climatic factor can be as high as 1.23 (SKM 2003). The climatic factor in the northern part of the GMR is higher due to lower precipitation and higher temperatures experienced in the area.

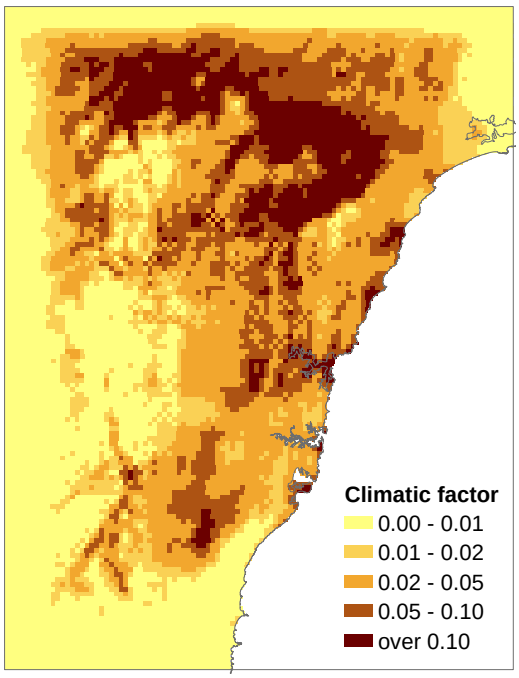


Figure 21. Gridded annual climatic factor, GMR 2003

3.1.6 Unsheltered field width factor

The unsheltered field width factor (L') has been calculated from the unsheltered width (L) and the product of erodibility (I) and surface roughness (K). The unsheltered width (L) has been derived using the data from USEPA (1988) and reproduced in Table 19 for crops in the GMR. The following relationship between L', L and IK developed by Ng (2004) has been used to derive the unsheltered field width.

$$-\log(1-L') = 1.8467\times10^{-7}(IK)^2L - 6.1213\times10^{-6}(IK)L + 6.876\times10^{-4}L + 3.3161\times10^{-3}(IK) + 0.0336 \qquad (3d)$$

where log is logarithm of base 10.

As the unsheltered field width factor depends on soil erodibility, it varies from grid cell to grid cell. Table 19 shows the average values of unsheltered field width factor weighted for soil erodibility on agricultural lands in the GMR. The dominant crops in the GMR are oats and wheat. Their unsheltered field width factors are highly conducive to wind erosion. An unsheltered field width factor can have a value between 0 and 1.

3.1.7 Vegetative cover factor

The vegetative cover factor (V') is estimated by the following equation during the growing season:

$$V' = \exp\left(-0.201 \times CP^{0.7366}\right) \quad (3e)$$

where CP is canopy cover (%).

For most crops a single crop canopy cover development profile has been used for each month. A cover of 25% to 100% has been assumed for the growing season.

During the post harvest period, the vegetative factor is estimated by:

$$V' = \exp\left(-0.0438 \times SP\right) \quad (3f)$$

where SP is soil cover (%).

For most crops the soil cover is of the order of 25% to 50% within a month or two after harvest. The second post-harvest period has been assigned a very low cover of approximately 5%. This 5% cover remains until planting. Table 20 shows the canopy covers and soil covers that have been assigned to crops in the GMR based on the crop calendar published by US Department of Agriculture and Department of Commerce (http://www.usda.gov/oce/waob/jawf/calendar).

Table 20. Canopy covers (%) during growing season and soil covers (%) during post-harvest period for crops in the GMR

Month	Summer crops [a]	Winter crops [a]
January	50 (vegetative)	100 (harvesting)
February	50 (reproductive)	25 [b]
March	75 (filling)	5 [b]
April	75 (maturing to harvesting)	5 [b]
May	100 (harvesting)	25 (planting)
June	100 (harvesting)	25 (planting)
July	25 [b]	50 (vegetative)
August	5 [b]	50 (vegetative)
September	5 [b]	50 (vegetative to heading)
October	25 (planting)	75 (heading to maturing)
November	25 (planting)	100 (harvesting)
December	25 (planting)	100 (harvesting)

a. Canopy cover unless otherwise specified
b. Soil cover

Figure 22 shows the vegetative cover factors that have been estimated from Equations 3e and 3f for crops in the GMR. As winter crops are mainly grown in the GMR, March and April are the months most susceptible for wind erosion in terms of the vegetative cover.

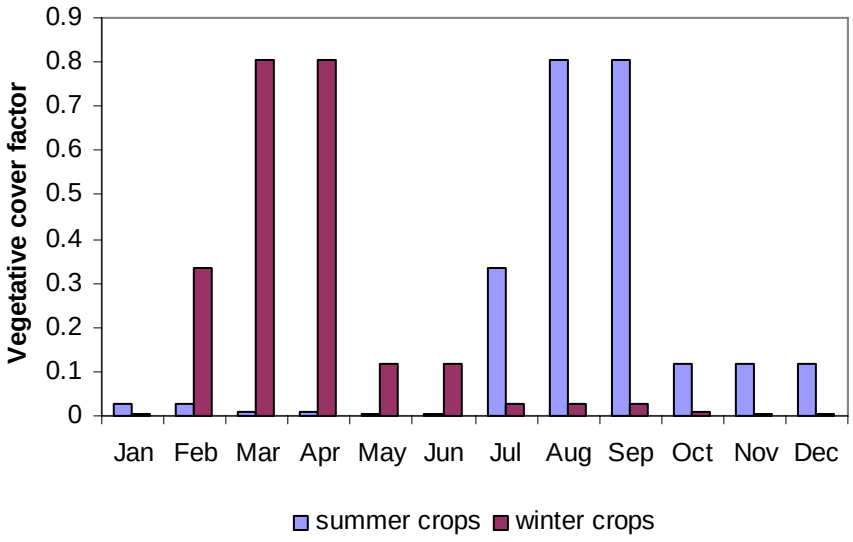


Figure 22. Estimated vegetative cover factors for crops in the GMR

3.1.8 Annual emissions

Table 21 shows the contribution of windblown dust emissions from agricultural lands by crop type. Oats constitute 48% of agricultural lands in the GMR but contribute 56% of the windblown dust emissions.

Table 21. Contributions (%) to windblown dust emissions from agricultural lands by crop type, GMR 2003

Crop	Grain sorghum	Other summer crops	Oats	Beans	Other winter crops	Total (t/yr)
TSP	0.11	9.3	56	2.0	32	471

3.1.9 Speciation

PM_{10} and $PM_{2.5}$ have been speciated from TSP using the size fraction data for 'windblown dust-agricultural' from EMS-95 (Emigh & Wilkinson 1997). Metals have been speciated from TSP using the speciation profile for 'windblown dust - agricultural lands' (profile 418) from CARB (2003). Chromium has been split into chromium (III) and chromium (VI) using emission factors for dust from CARB (2000). Table 22 shows the speciation profile.

Table 22. TSP speciation profile for agricultural land windblown dust

Substance	Percentage	Substance	Percentage
particulate matter < 10 µm	49.8	cobalt & compounds	0.0087
particulate matter < 2.5 µm	19.6	copper & compounds	0.0067
lead & compounds	0.0062	manganese & compounds	0.0953
antimony & compounds	0.0006	mercury & compounds	0.0011
arsenic & compounds	0.0016	nickel & compounds	0.005
cadmium & compounds	0.002	selenium & compounds	0.0002
chromium (III) compounds	0.0201	zinc & compounds	0.0164
chromium (VI) compounds	0.000832		

There are no VOC and NO_x emissions from windblown dust.

Estimated annual emissions from windblown dust from agricultural lands within the GMR, Sydney, Newcastle and Non-Urban regions are provided in Table 23. There are no emissions from windblown dust from agricultural lands in Wollongong region.

Table 23. Annual emissions (t/yr) of all substances from agricultural land windblown dust by region in 2003

Substance	GMR	Sydney	Newcastle	Non-Urban
lead & compounds	0.0292	0.00264	0.00219	0.0244
particulate matter < 10 µm	235	21.2	17.6	196
particulate matter < 2.5 µm	92.3	8.34	6.90	77.0
total suspended particulates (TSP)	471	42.6	35.3	394
antimony & compounds	0.00283	2.56×10^{-04}	2.12×10^{-04}	0.00236
arsenic & compounds	0.00754	6.82×10^{-04}	5.64×10^{-04}	0.00630
cadmium & compounds	0.00943	8.52×10^{-04}	7.05×10^{-04}	0.00787
chromium (III) compounds	0.0946	0.00855	0.00708	0.0790
chromium (VI) compounds	0.00392	3.55×10^{-04}	2.94×10^{-04}	0.00328
cobalt & compounds	0.0410	0.00371	0.00307	0.0342
copper & compounds	0.0316	0.00285	0.00236	0.0264
manganese & compounds	0.449	0.0406	0.0336	0.375
mercury & compounds	0.00519	4.69×10^{-04}	3.88×10^{-04}	0.00433
nickel & compounds	0.0236	0.00213	0.00176	0.0197
selenium & compounds	9.43×10^{-04}	8.52×10^{-05}	7.05×10^{-05}	7.87×10^{-04}

Substance	GMR	Sydney	Newcastle	Non-Urban
zinc & compounds	0.0773	0.00699	0.00578	0.0645

3.1.10 Spatial allocation

Emissions have been allocated to cropping areas, which are the same as those used for agricultural burning (see Figure 3). Emissions have been adjusted with climatic factors and soil factors applicable at particular grid cells. Figure 23 shows the gridded emissions of TSP for windblown dust from agricultural lands. Most of the windblown dust occurs in the northern part of the GMR, showing that the emissions are influenced geographically mainly by the climatic factor.

Table 24 shows the windblown dust from agricultural lands emission contributions by LGA. Most of the windblown dust emissions from agricultural lands have been estimated to occur in Muswellbrook and Singleton LGAs.

Table 24. Contributions to windblown dust emissions from agricultural lands by LGA, GMR 2003

Region	Emission (%)	Region	Emission (%)	Region	Emission (%)
Blue Mountains	0.20	Kiama	0.0021	Port Stephens	1.7
Camden	3.4	Lithgow	6.2	Rylstone	7.6
Cessnock	9.5	Maitland	3.7	Shellharbour	0.011
Dungog	2.5	Merriwa	0.24	Singleton	19
Gosford	0.092	Mudgee	0.063	Upper Lachlan	2.0
Greater Argyle	0.00046	Muswellbrook	35	Wingecarribee	1.7
Hawkesbury	3.7	Newcastle	0.077	Wollondilly	2.3
Hornsby	0.20	Oberon	0.013	Wyong	0.30

In terms of regions, 83% of the emissions occur in Non-Urban region, 9.0% from Sydney region and 7.5% from Newcastle region. There are no emissions from windblown dust from agricultural lands in Wollongong region.

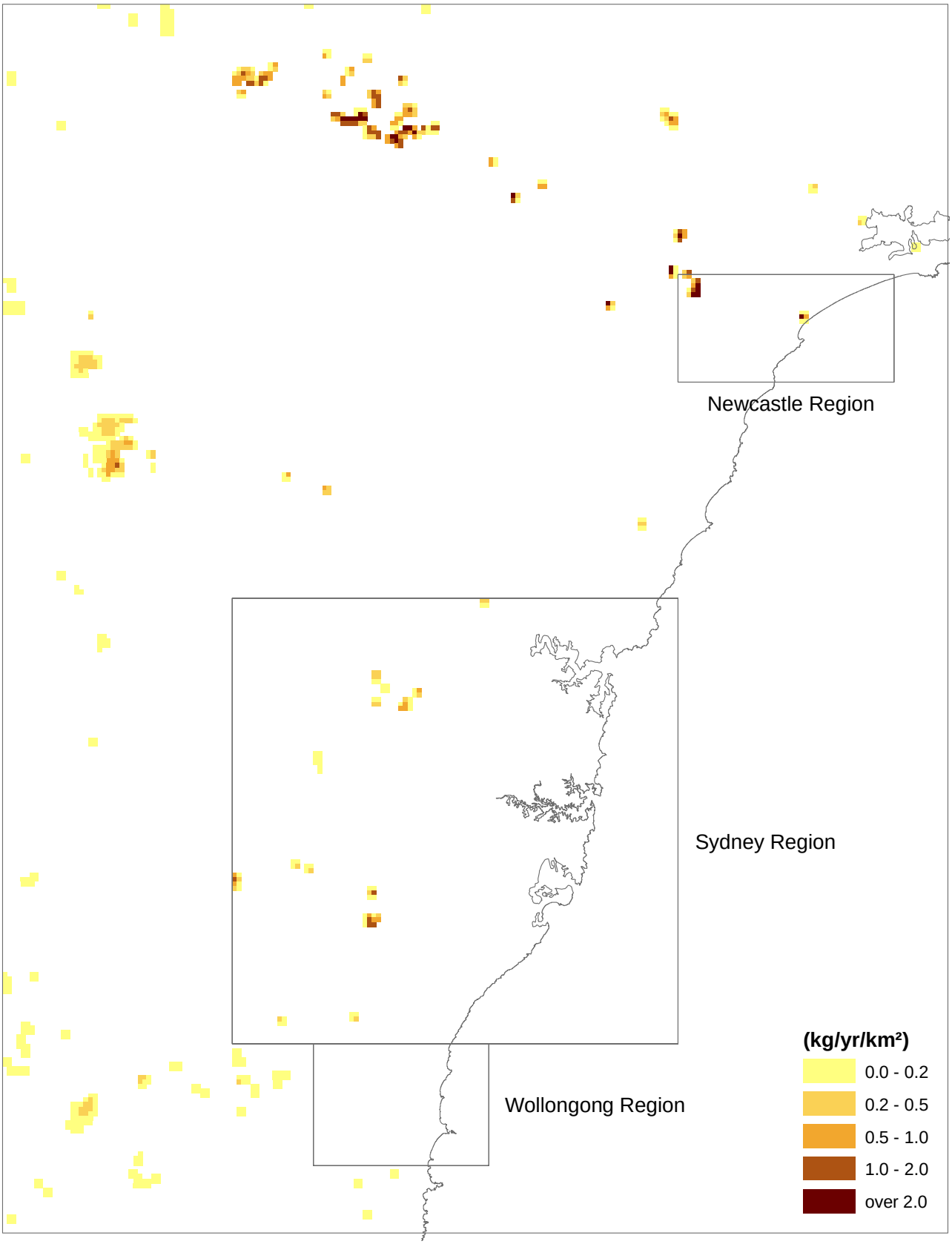


Figure 23. Emissions of TSP from agricultural land windblown dust, GMR 2003

3.1.11 Temporal variation

Emissions have been allocated to each month based on the following factors:

- areas of summer and winter crops,
- climatic factors of each month, and
- vegetative cover factors of each month.

The climatic factor that has been used to allocate annual emissions to a month is based on the month-as-a-year climatic factor developed by CARB (1997a). When calculating the annual C factor, the monthly PE values have been summed for all of the months in the year (see Equation 3c). However, to calculate the month-as-a-year C factor, each month's PE has been multiplied by 12. Then each month's PE×12 has been input into the C factor equation along with the mean monthly wind speed for that same month. The result is a C factor which would apply if the climate for that month were instead the year round climate. By then summing all of the monthly C factors for the year and then dividing each individual month by the sum, the month-as-a-year C factor has been normalised to 1. These normalised monthly numbers provide the climate based temporal profile. They have been multiplied by the annual results to produce monthly emissions. Figure 24 shows the month-as-a-year C factors averaged over the land area in the GMR. Most of the windblown dust emissions have been allocated to September, as anticipated in Section 3.1.5. Note that the month-as-a-year C factor varies from grid cell to grid cell, and a different factor has been used to adjust the emissions in each grid cell.

Figure 25 shows the monthly TSP emissions from windblown dust from agricultural lands. The emissions are strongly influenced by vegetative factor and climatic factor (compare Figure 22 and Figure 24).

An hourly profile has been used to allocate average daily emissions to an hour. The hourly profile is different for each month and grid cell. The method used to derive the hourly profile is similar to that to derive the month-as-a-year C factor, but each month's PE is multiplied by 12 × 24. Figure 26 shows the hourly TSP emissions by season. The hourly emission varies with season, although most windblown dust emissions from agricultural lands are expected to occur during day and evening time.

It is assumed that windblown dust emissions are constant 7 days per week.

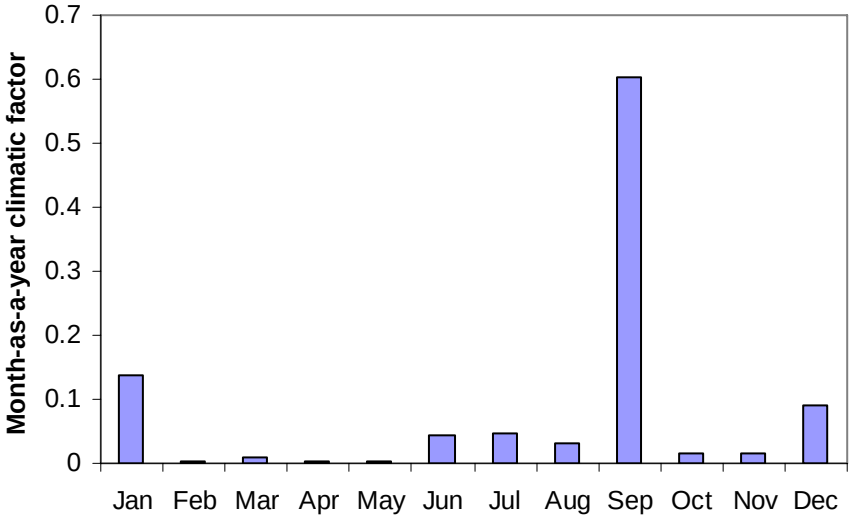


Figure 24. Month-as-a-year climatic factors, GMR 2003

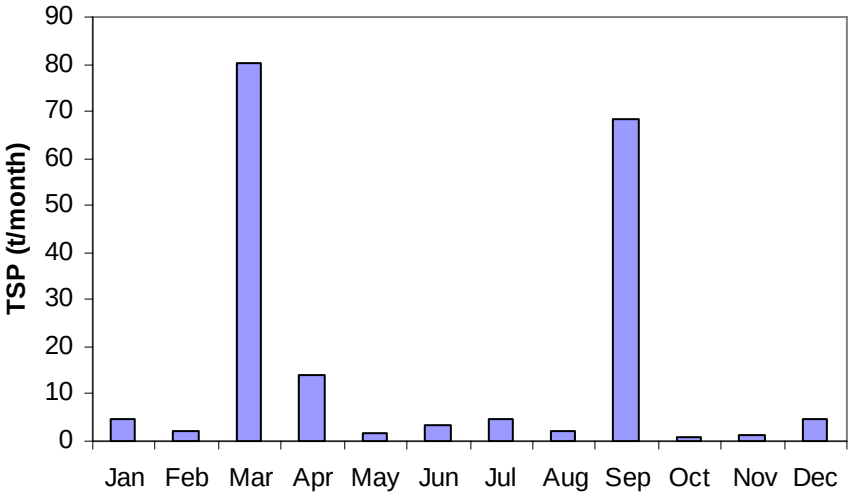


Figure 25. Monthly TSP emissions from agricultural land windblown dust, GMR 2003

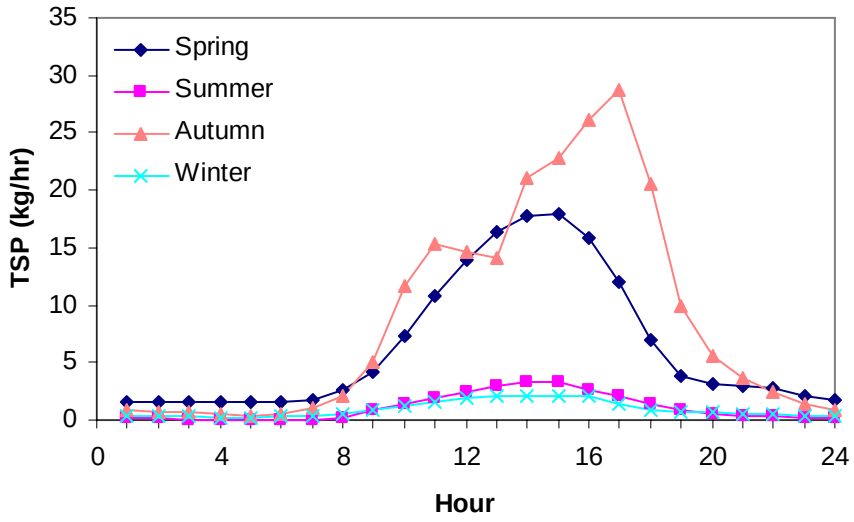


Figure 26. Average hourly TSP emissions by season for windblown dust from agricultural lands, GMR 2003

3.2 Unpaved roads emissions

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated for windblown dust from unpaved roads. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

This source category covers the fugitive dust emissions resulting from wind erosion of soil from unpaved roads. The fugitive dust contains metal and compounds that are naturally found in soil. Emissions have been estimated for the following pollutants:

- primary pollutants – PM_{10}, $PM_{2.5}$ and TSP; and
- metals – antimony & compounds, arsenic & compounds, cadmium & compounds, chromium (III) compounds, chromium (VI) compounds, cobalt & compounds, copper & compounds, lead & compounds, manganese & compounds, mercury & compounds, nickel & compounds, selenium & compounds, and zinc & compounds

3.2.1 Emissions estimation

Windblown dust emissions from unpaved roads have been estimated with the same wind erosion equation that has been used for agricultural lands (CARB 1997b). The equation, which is simplified for unpaved roads, is as follows:

$$E = H \times A \times I \times C \times L' \quad (4)$$

where E is quantity of unpaved road dust entrained to the air by wind erosion (t/yr),

H is area of unpaved roads (ha),

A is portion of the total roadway wind erosion losses that are assumed to be suspended into the air (=0.038),

I is soil erodibility (t/ha/yr),

C is climatic factor (dimensionless), and

L' is unsheltered field width factor (= 0.32).

3.2.2 Unpaved road area

GIS data for unpaved/unsealed roads has been obtained from DEC. The area of unpaved roads is determined from the total length of unpaved roads in the GMR, which is 37,700 km. Most of these roads are minor unsealed and their average width is 8 m (SKM 2003). The estimated unpaved road area in the GMR is approximately 30,200 ha, which is larger than the agricultural land area of approximately 16,100 ha.

3.2.3 Soil erodibility and climatic factor

The soil erodibility (I) has been determined from soil texture classes, and climatic factor (C) has been determined from monthly precipitation, temperature and wind speed as for agricultural lands (see Sections 3.1.3 and 3.1.5).

3.2.4 Annual emissions

The TSP emission from unpaved road windblown dust in the GMR in 2003 is estimated to be 2,940 t/yr, which is much larger than the 471 t/yr from agricultural lands. This is due to the larger area of unpaved roads in the GMR, and the absence of surface roughness and vegetative cover factors for unpaved roads.

3.2.5 Speciation

PM_{10} and $PM_{2.5}$ have been speciated from TSP using the size fraction data for 'windblown dust - unpaved areas' from EMS-95 (Emigh & Wilkinson 1997). Metals have been speciated from TSP using the speciation profile for 'windblown dust - unpaved road/area' (profile 416) from CARB (2003). Chromium has been split into chromium (III) and chromium (VI) using emission factors for dust from CARB (2000). Table 25 shows the speciation profile.

There are no VOC and NO_x emissions from windblown dust.

Estimated annual emissions from windblown dust from unpaved roads within the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions are provided in Table 26.

Table 25. TSP speciation profile for unpaved road windblown dust

Substance	Percentage	Substance	Percentage
particulate matter < 10 µm	49.8	cobalt & compounds	0.0149
particulate matter < 2.5 µm	19.4	copper & compounds	0.0087
lead & compounds	0.0901	manganese & compounds	0.1051
antimony & compounds	0.0007	mercury & compounds	0.0015
arsenic & compounds	0.0015	nickel & compounds	0.0063
cadmium & compounds	0.0025	selenium & compounds	0.0001
chromium (III) compounds	0.0235	zinc & compounds	0.0622
chromium (VI) compounds	0.000976		

Table 26. Annual emissions (t/yr) of all substances from unpaved road windblown dust by region in 2003

Substance	GMR	Sydney	Newcastle	Wollongong	Non-Urban
lead & compounds	2.65	0.447	0.109	0.00317	2.09
particulate matter < 10 µm	1,464	247	60.1	1.75	1155
particulate matter < 2.5 µm	570	96.1	23.4	0.681	450
total suspended particulates (TSP)	2,940	496	121	3.51	2319
antimony & compounds	0.0206	0.00347	8.44×10^{-04}	2.46×10^{-05}	0.0162
arsenic & compounds	0.0441	0.00744	0.00181	5.27×10^{-05}	0.0348
cadmium & compounds	0.0735	0.0124	0.00301	8.78×10^{-05}	0.0580
chromium (III) compounds	0.691	0.117	0.0284	8.27×10^{-04}	0.546
chromium (VI) compounds	0.0287	0.00484	0.00118	3.43×10^{-05}	0.0226
cobalt & compounds	0.438	0.0739	0.0180	5.24×10^{-04}	0.346
copper & compounds	0.256	0.0431	0.0105	3.06×10^{-04}	0.202
manganese & compounds	3.09	0.521	0.127	0.00369	2.44
mercury & compounds	0.0441	0.00744	0.00181	5.27×10^{-05}	0.0348
nickel & compounds	0.185	0.0312	0.00760	2.21×10^{-04}	0.146
selenium & compounds	0.00294	4.96×10^{-04}	1.21×10^{-04}	3.51×10^{-06}	0.00232
zinc & compounds	1.83	0.308	0.0750	0.00219	1.44

3.2.6 Spatial allocation

Emissions have been allocated to unpaved roads. Figure 27 shows the unpaved roads in the GMR. Emissions have been adjusted with climatic factors and soil factors applicable at particular grid cells. Figure 28 shows the gridded emissions of TSP for windblown dust from unpaved roads. Most of the emissions occur in the north-eastern part of the GMR, showing the strong influence of the climatic factor on windblown dust emissions.

Table 27 shows the windblown dust from unpaved roads emission contributions by LGA. Most of the windblown dust emissions from unpaved roads have been estimated to occur in Singleton LGA.

In terms of regions, 79% of the emissions occur in Non-Urban region, 17% from Sydney region, 4.1% from Newcastle region and only 0.12% from Wollongong region.

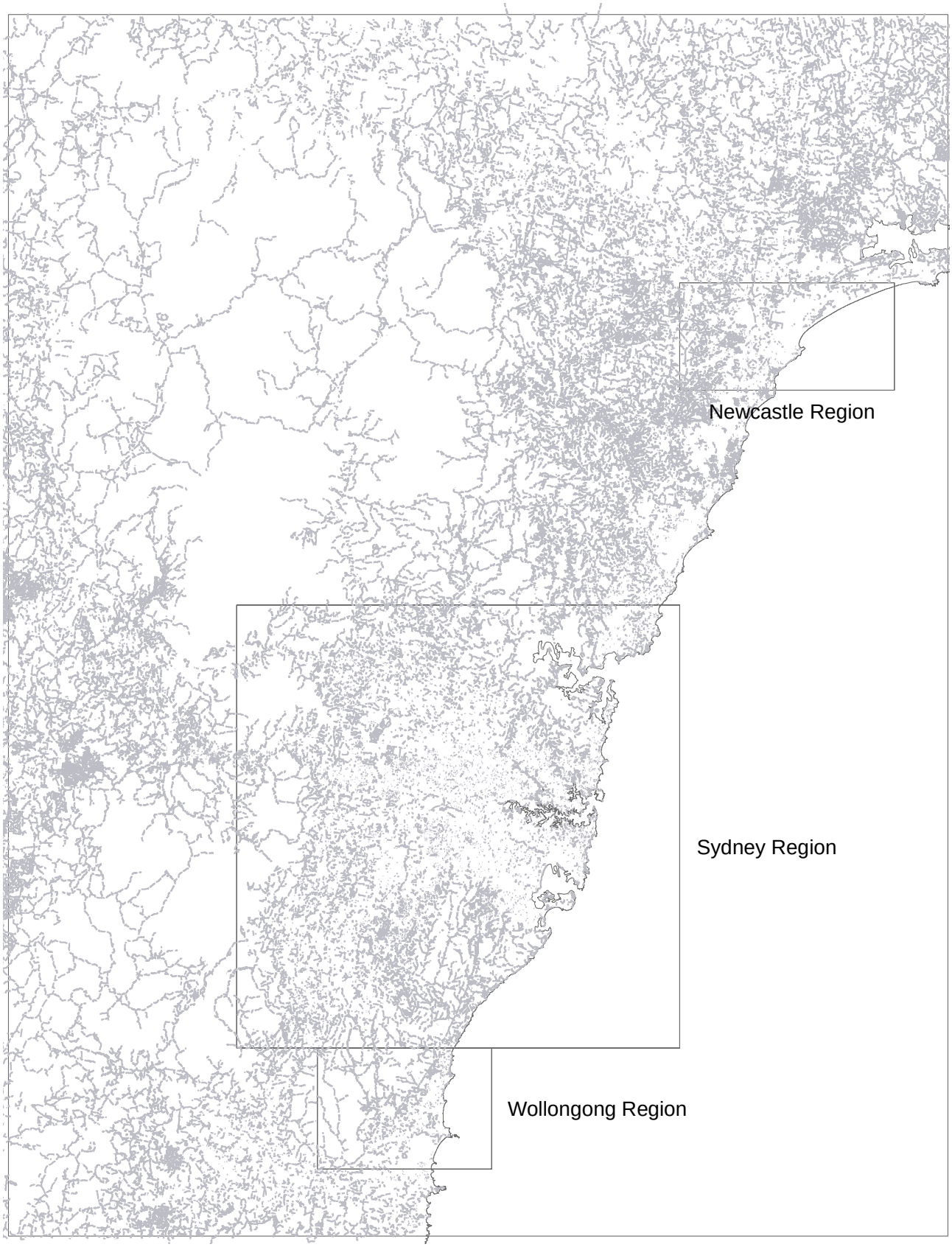


Figure 27. Unpaved roads in the GMR

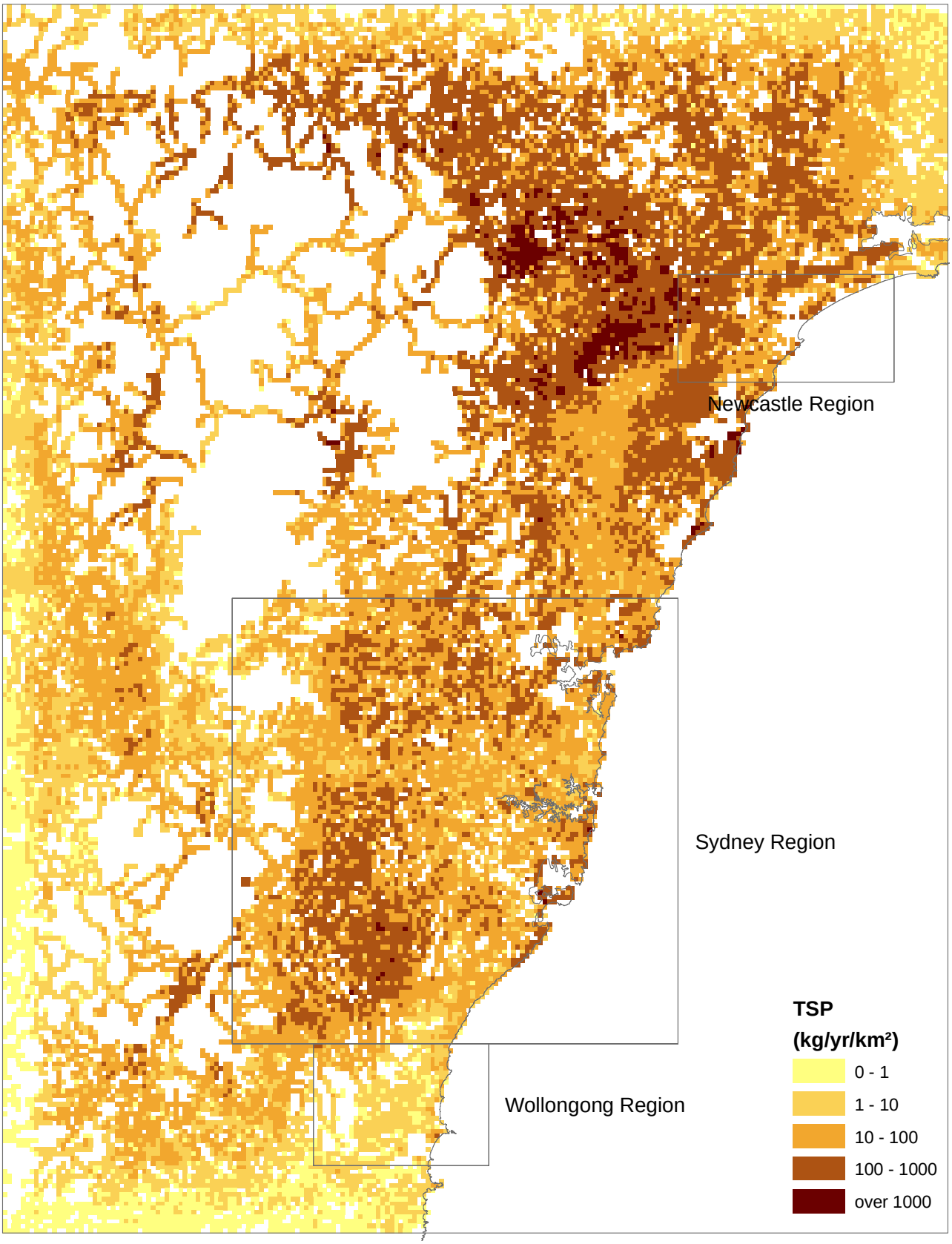


Figure 28. Emissions of TSP from unpaved road windblown dust, GMR 2003

Table 27. Contributions to windblown dust emissions from unpaved roads by LGA, GMR 2003

LGA	Emission (%)	LGA	Emission (%)	LGA	Emission (%)
Ashfield	0.012	Hunters Hill	0.0027	Pittwater	0.17
Auburn	0.038	Hurstville	0.0053	Port Stephens	3.0
Bankstown	0.043	Kiama	0.0043	Randwick	0.12
Baulkham Hills	1.0	Kogarah	0.013	Rockdale	0.059
Blacktown	0.47	Ku-ring-gai	0.14	Ryde	0.062
Blue Mountains	0.52	Lake Macquarie	4.7	Rylstone	1.8
Botany Bay	0.024	Lane Cove	0.018	Shellharbour	0.011
Burwood	0.0046	Leichhardt	0.0066	Shoalhaven	0.00046
Camden	1.2	Lithgow	1.5	Singleton	22
Campbelltown	1.8	Liverpool	0.94	Strathfield	0.0094
Canada Bay	0.035	Maitland	2.6	Sutherland	0.87
Canterbury	0.028	Manly	0.023	Sydney	0.063
Cessnock	27	Marrickville	0.019	Upper Lachlan	0.14
Dungog	4.8	Merriwa	0.11	Warringah	0.17
Evans	0.0016	Mosman	0.0034	Waverley	0.071
Fairfield	0.15	Mudgee	0.12	Willoughby	0.024
Gosford	2.7	Muswellbrook	5.1	Wingecarribee	0.95
Great Lakes	0.52	Newcastle	0.45	Wollondilly	4.6
Greater Argyle	0.0015	North Sydney	0.0071	Wollongong	0.16
Hawkesbury	4.2	Oberon	0.11	Woollahra	0.047
Holroyd	0.045	Parramatta	0.053	Wyong	2.9
Hornsby	1.2	Penrith	1.1		

3.2.7 Temporal variation

Emissions have been allocated temporally based solely on climatic factors. The methodology is the same as that used for windblown dust from agricultural lands. As the climatic factors have been calculated for grid cells with unpaved roads, their monthly and hourly profiles would be different from those for agricultural lands. Figure 29 shows the monthly TSP emissions from windblown dust from unpaved roads. The monthly emissions are reflective of the climatic factor (see Figure 24), with the highest emissions occurring in September.

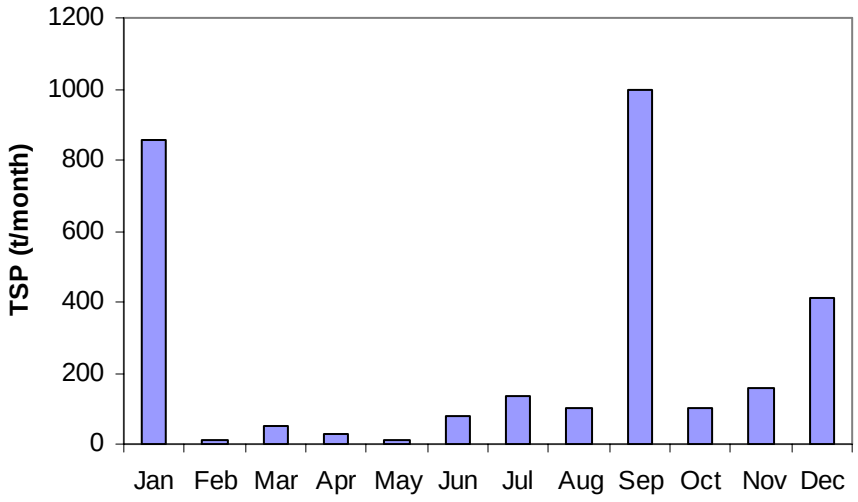


Figure 29. Monthly TSP emissions from unpaved road windblown dust, GMR 2003

Figure 30 shows the hourly TSP emissions by season. The hourly emission varies with season, although most windblown dust emissions from unpaved roads are expected to occur during day time.

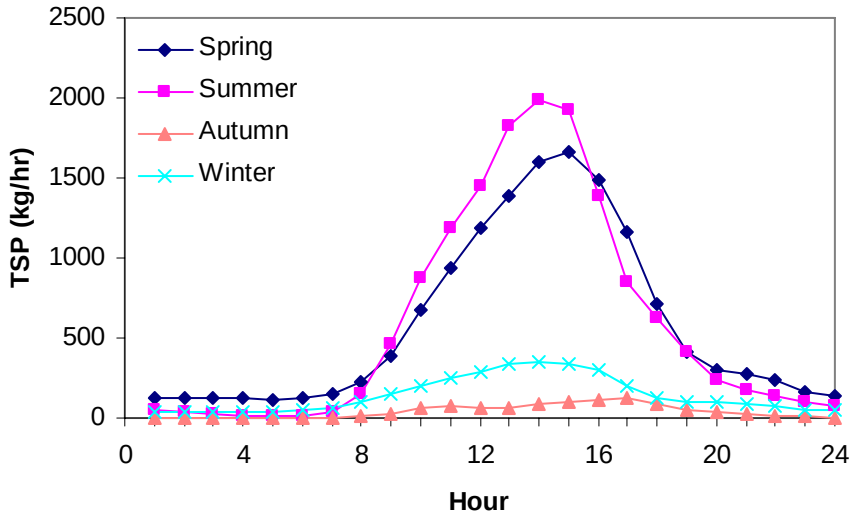


Figure 30. Average hourly TSP emissions from unpaved road windblown dust, GMR 2003

As for agricultural lands, windblown dust emissions from unpaved roads are assumed to be constant 7 days a week.

4 SOIL EMISSIONS

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated for soil. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

Emissions from soil arise from microbial and chemical processes of nitrification and denitrification. Oxides of nitrogen and nitric oxide are the only pollutants estimated for biogenic emissions from soil.

4.1 Emissions estimation

The method used to estimate biogenic NO_x emissions from soil has been based on that of BEIS-2 (Radian 1996) using the following equation:

$$ER = \sum_j A_j \times EF_j \times 10^{-6} \times C_T \qquad (5a)$$

where ER is NO_x emission rate (g/hr),
A is area of land use (m^2),
EF is land use emission factor ($\mu g/m^2/hr$),
C_T is temperature correction factor, and
j is index for land use type.

The temperature correction factor has been estimated as follows:

$$C_T = \exp\left[0.071 \times (T_j - 273)\right], \text{ for } T_j > 273$$
$$C_T = 0, \text{ for } T_j \le 273 \qquad (5b)$$

where T is soil temperature (K), and
j is index for land use type.

The soil temperature, depending on land use type, has been estimated from the following equations:

$$T_{j=grassland} = 0.66 \times T_A + 101.67$$
$$T_{j=forest} = 0.84 \times T_A + 47.31$$
$$T_{j=agricultural} = 1.03 \times T_A - 5.29 \qquad (5c)$$
$$T_{j=wetland} = 0.92 \times T_A + 26.25$$

where T_A is ambient temperature (K).

Williams et. al. (1992) has developed two equations for estimating soil temperature for agricultural areas, one is for corn, which is used in BEIS-2, and the other is for cotton, wheat and soybeans. The equation for cotton, wheat and soybeans has been used since these crop types are more common in Australia.

4.2 Source activity

Land use data have been based on the 1996/97 Land Use of Australia, Version 2 downloaded from the web site of the Australian Government Department of Agricultural, Fisheries and Forestry (http://www.affa.gov.au). Table 28 shows the land use areas in the GMR.

Table 28. Land use areas in the GMR

Land use category	Land use	Area (km²)
Conservation and natural environment (Forest)	managed resource protection	5,796
	nature conservation	7,059
	other minimal use	4,040
Production from relatively natural environments	plantation forestry	64
(Forest)	production forestry	1,366
Production from dry land agriculture and	grazing modified pastures	1,775
plantations (Grassland)	irrigated modified pastures	413
	livestock grazing	14,878
Production from irrigated agriculture and	cropping	269
Plantations (Agricultural)	irrigated cropping	27
	irrigated perennial horticulture	87
	irrigated seasonal horticulture	119
	perennial horticulture	155
	seasonal horticulture	4
Intensive uses (Urban)	intensive use	2,691
	residential	744
	transport and communication	134
Water (Wetland)	marsh/wetland	39
Water (Water)	estuary/coastal waters	40
	lake	68
	reservoir	149
	river	81

The land use categories used in BEIS-2 are shown in brackets (see Section 4.3). The dominant land use categories in the GMR are grassland and forest.

Gridded hourly temperature data for each month have been based on those from TAPM (See Section 3.1.5).

4.3 Emission factors

The emission factors have been based on those from BEIS-2. Table 29 shows the emission factors. In BEIS-2, the emission factors are expressed as NO. In Table 29, the emission factors are expressed as NO_x, i.e. NO_2 equivalent.

Table 29. Emission factors (µg/m²/hr) for soil

Land use category	Forest	Grassland	Agricultural	Urban	Wetland	Water
NO_x (µg/m²/hr)	6.9	88.9	53.7	19.2	0.307	0

4.4 Annual emissions

The annual emission of NO_x from soil is 8,140 t. Table 30 shows the contributions by land use category. Most NO_x are emitted from grassland, which has the largest area and highest emission factor.

Table 30. Contributions (%) to emissions from soil by land use category, GMR 2003

Land use category	Forest	Grassland	Agricultural	Urban	Wetland	Water	Total (t/yr)
NO_x (%)	6.3	87	2.5	0.00080	0	4.0	8,140

4.5 Speciation

All biogenic NO_x emitted from soil is assumed to be NO (Carnovale et. al. 1996). Estimated annual emissions from soil within the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions are provided in Table 31.

Table 31. Annual emissions (t/yr) of all substances from soil by region in 2003

Substance name	GMR	Sydney	Newcastle	Wollongong	Non-Urban
nitric oxide	5,294	579	64.0	31.7	4,619
oxides of nitrogen	8,144	891	98.4	48.8	7,106

4.6 Spatial allocation

Biogenic NO_x emissions have been allocated according to land use categories and adjusted with temperature correction factors at particular grid cells. Figure 31 shows the land use in the GMR. Note the forest around Sydney is classified as managed resource protection area, meaning a protected area managed mainly for the sustainable use of natural ecosystems. Some of the area may be urban but the available data do not have further breakdown of the land use category. Figure 32 shows the gridded emissions of NO_x from soil. The spatial distribution of emissions is mainly influenced by land use category.

Table 32 shows the contributions to soil emissions by LGA. Singleton and Muswellbrook LGAs have the highest soil emissions in the GMR.

In terms of regions, 87% of the emissions occur in Non-Urban region, 11% from Sydney region, 1.2% from Newcastle region and 0.60% from Wollongong region.

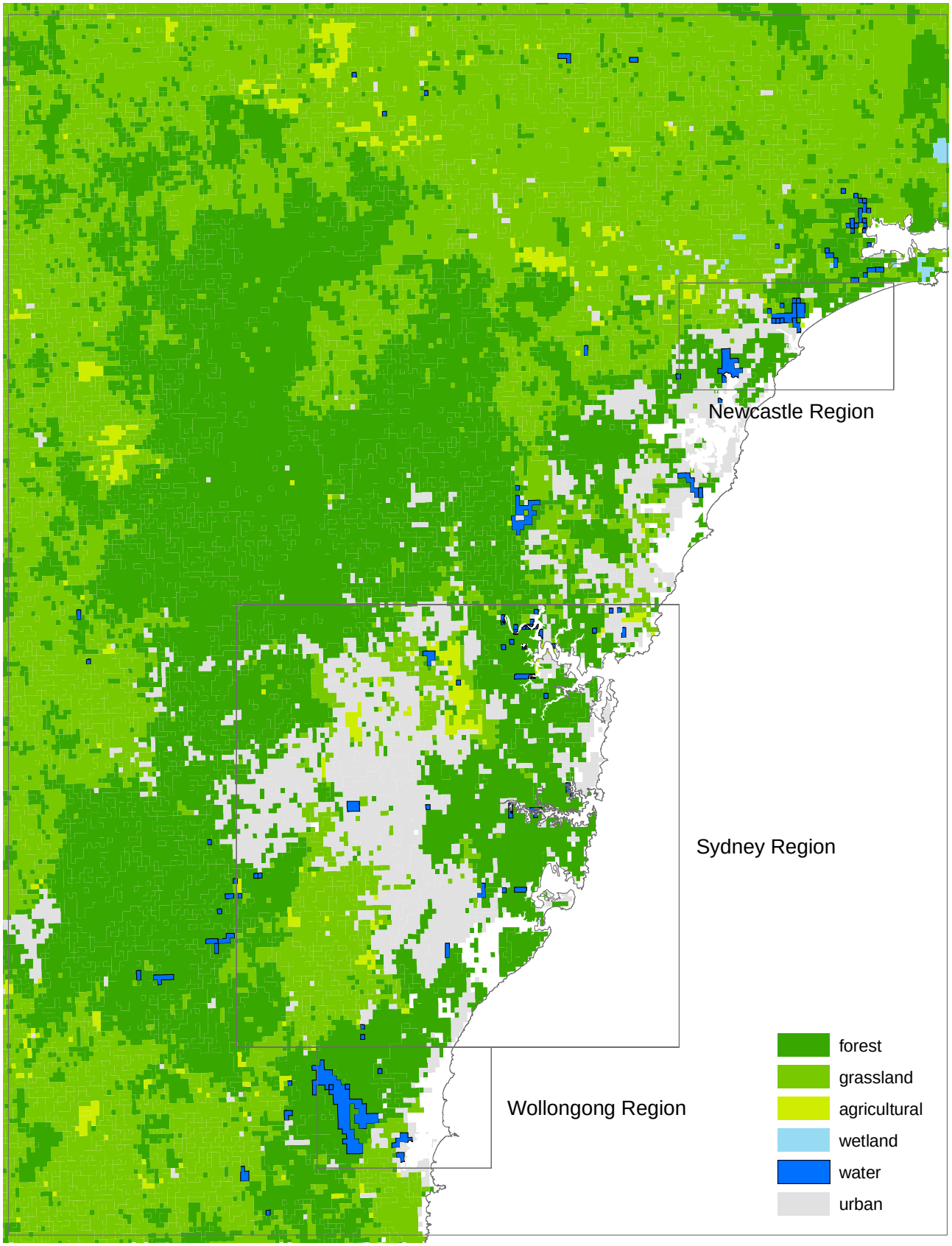


Figure 31. Land use in the GMR

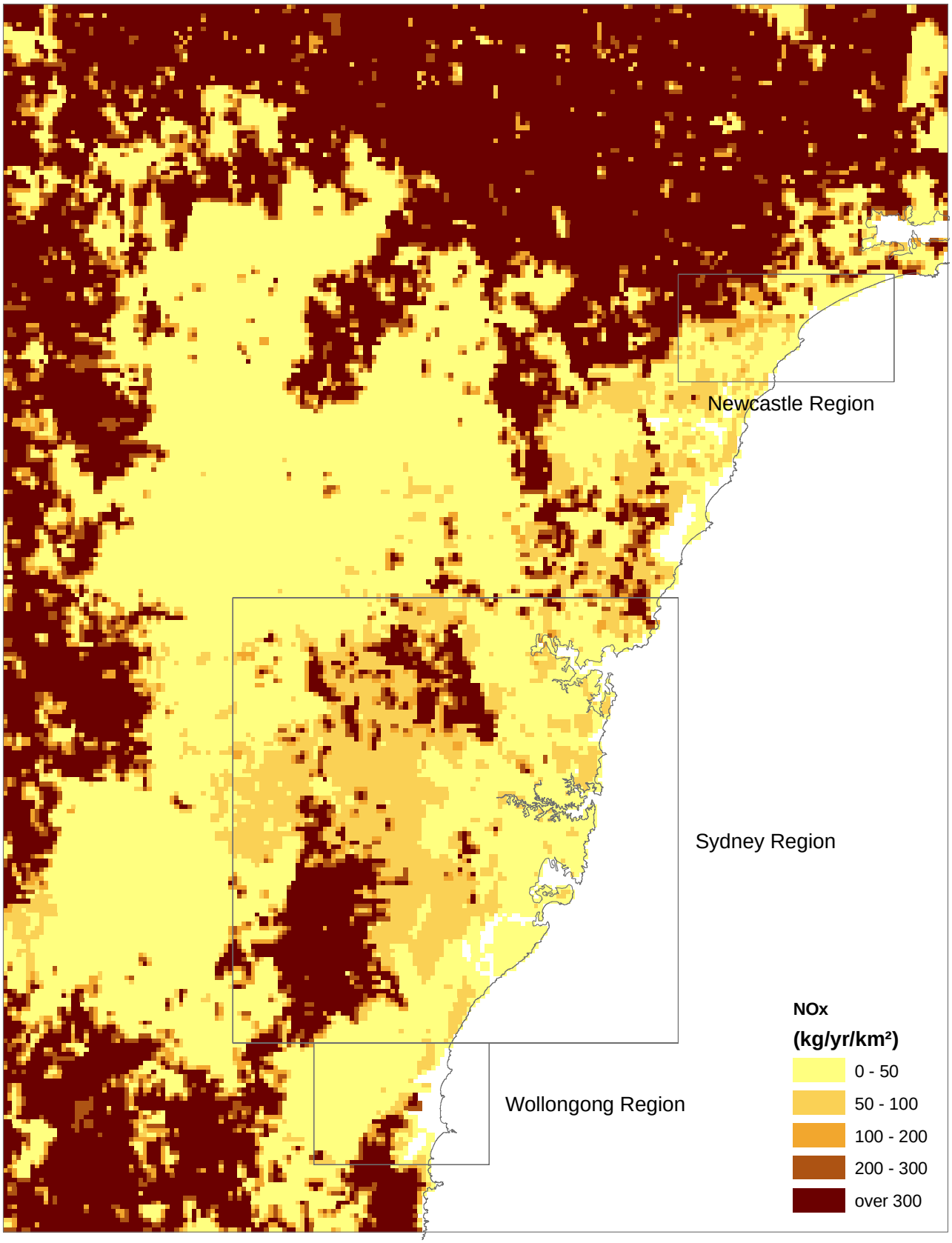


Figure 32. Gridded emissions of NO_x from soil, GMR 2003

Table 32. Contributions to soil emissions by LGA, GMR 2003

LGA	Emission (%)	LGA	Emission (%)	LGA	Emission (%)
Ashfield	0.0040	Hunters Hill	0.00096	Pittwater	0.043
Auburn	0.019	Hurstville	0.013	Port Stephens	2.1
Bankstown	0.079	Kiama	0.55	Randwick	0.012
Baulkham Hills	0.92	Kogarah	0.0071	Rockdale	0.0097
Blacktown	0.28	Ku-ring-gai	0.053	Ryde	0.030
Blue Mountains	1.0	Lake Macquarie	0.54	Rylstone	8.6
Botany Bay	0.0073	Lane Cove	0.0040	Shellharbour	0.57
Burwood	0.0028	Leichhardt	0.0045	Shoalhaven	0.055
Camden	0.78	Lithgow	6.4	Singleton	17
Campbelltown	0.33	Liverpool	0.44	Strathfield	0.0052
Canada Bay	0.0082	Maitland	2.0	Sutherland	0.16
Canterbury	0.014	Manly	0.0088	Sydney	0.012
Cessnock	5.7	Marrickville	0.0080	Upper Lachlan	3.3
Dungog	8.0	Merriwa	3.4	Warringah	0.093
Evans	0.17	Mosman	0.0021	Waverley	0.0025
Fairfield	0.077	Mudgee	1.3	Willoughby	0.0080
Gosford	1.6	Muswellbrook	10.5	Wingecarribee	6.1
Great Lakes	4.8	Newcastle	0.28	Wollondilly	4.5
Greater Argyle	0.61	North Sydney	0.0048	Wollongong	0.56
Hawkesbury	2.5	Oberon	2.2	Woollahra	0.0028
Holroyd	0.019	Parramatta	0.026	Wyong	0.94
Hornsby	0.36	Penrith	0.66		

4.7 Temporal variation

Biogenic NO_x emissions have been temporally allocated to particular hours and months through the use of the temperature correction factor. Figure 33 shows the monthly emissions from soil, which vary according to monthly temperature (see Figure 19). Figure 34 shows the average hourly temperature by season and Figure 35 the hourly emissions. The hourly emissions closely follow the shape of hourly temperature, which peaks at 1 pm. The emissions are more pronounced around afternoon, as emissions vary exponentially with temperature. It is assumed that soil emissions on weekdays and weekend days are the same.

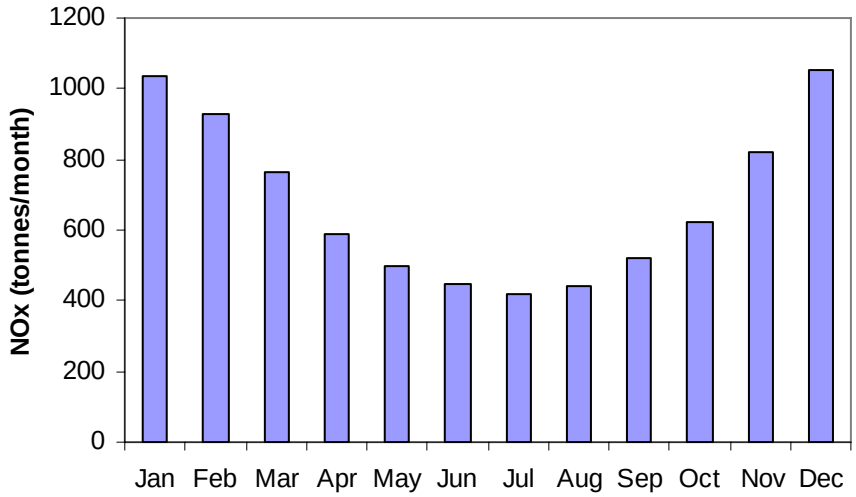


Figure 33. Monthly NO_x emissions from soil, GMR 2003

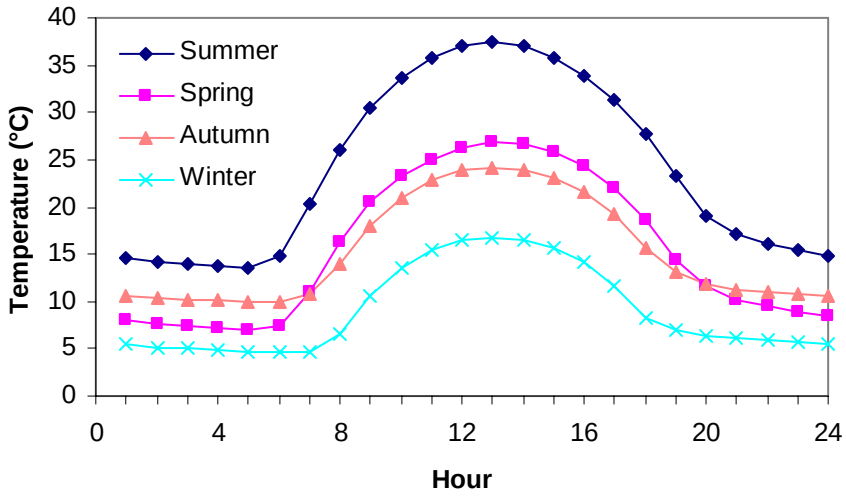


Figure 34. Average hourly temperature by season, GMR 2003

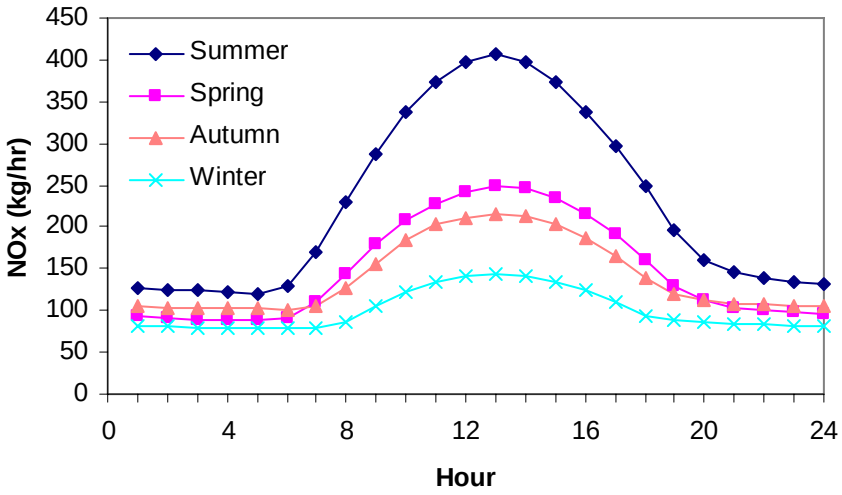


Figure 35. Hourly NO_x emissions from soil by season, GMR 2003

5 VEGETATION EMISSIONS

This section describes the emission estimation methodology; source activity data; emission factors; and total emissions estimated for vegetation. Speciation, spatial allocation and temporal variation of the emissions are also discussed.

Emissions from vegetation occur naturally due to emissions of volatile organic compounds from trees and grass.

Emissions have been estimated for the following pollutants: acetaldehyde, acetone, ethyl alcohol, isoprene, methyl alcohol, monoterpenes and total VOCs.

5.1 Emissions estimation

Average gridded hourly emissions from trees and grass for each month in the GMR have been generated from the Biogenic Emissions Inventory Geographical Information System (BEI-GIS) developed by CSIRO (2004). Gridded hourly temperature data for each month from TAPM, genus-specific emission factors and biomass data have been used in BEI-GIS to calculate emissions from trees and grass using a canopy model and pasture model respectively (CSIRO 2004).

5.2 Annual emissions

Table 33 shows the contributions to emissions from vegetation by source type. Trees emit most of the total VOC emissions in the GMR, although acetaldehyde, acetone, ethyl alcohol and methyl alcohol originate only from grass.

Table 33. Contributions (%) to emissions from vegetation by source type, GMR 2003

Source	Acetaldehyde	Acetone	Ethyl alcohol	Isoprene	Methyl alcohol	Monoterpenes	Total VOCs
Tree				99.84		99.1	97
Grass	100	100	100	0.16	100	0.9	3.0
Total (t/yr)	1,009	969	1,298	135,897	1,304	24,680	165,157

For the MAQS region, CSIRO (2004) reported total VOCs of 120,000 t/yr from trees and 2,900 t/yr from grass. For the same region in this inventory, the estimated total VOCs are 66,700 t/yr from trees and 2,010 t/yr from grass. The emission estimated by CSIRO for trees and

grass could have been overestimated, as they were extrapolated from an estimate for a summer day.

5.3 Speciation

Emissions for individual species and total VOCs have been estimated using BEI-GIS as detailed above. Estimated annual emissions from vegetation within the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions are provided in Table 34.

Table 34. Annual emissions (t/yr) of all substances from vegetation by region in 2003

Pollutant	GMR	Sydney	Newcastle	Wollongong	Non-Urban
acetaldehyde	1,009	136	10.7	10.2	852
acetone	969	131	10.3	9.84	818
ethyl alcohol	1,298	175	13.8	13.2	1,095
isoprene	135,897	25,755	2,694	2,795	104,653
methyl alcohol	1,304	176	13.9	13.2	1,100
monoterpenes	24,680	4,184	517	516	19,463
total VOCs	165,157	30,557	3,260	3,357	127,982

5.4 Spatial allocation

Emissions from vegetation have been spatially allocated as in BEI-GIS, and adjusted using TAPM temperature data. Figure 36 and Figure 37 show the gridded total VOC emissions from trees and grass respectively.

The spatial distribution of emissions is mainly influenced by spatial distribution of biomass and temperature. However, emissions from trees are more strongly influenced by biomass.

Table 32 shows the contributions to vegetation emissions by LGA. Singleton LGA has the highest emissions from both trees and grass in the GMR.

Table 35. Contributions (%) to emissions from vegetation by LGA, GMR 2003

LGA	Tree	Grass	LGA	Tree	Grass
Baulkham Hills	0.48	1.2	Merriwa	0.77	2.4
Blacktown	0.61	0.25	Mudgee		1.5
Blue Mountains	5.3	3.0	Muswellbrook	4.0	9.0

LGA	Tree	Grass	LGA	Tree	Grass
Camden	0.80	0.35	Newcastle	0.19	0.088
Campbelltown	0.87	0.45	Oberon	1.8	2.1
Cessnock	8.4	6.0	Penrith	1.5	0.63
Dungog	7.1	5.7	Pittwater		0.18
Fairfield	0.12	0.051	Port Stephens	2.9	2.0
Gosford	0.34	3.1	Rylstone	5.4	8.9
Great Lakes	4.3	5.9	Shellharbour	0.66	0.24
Greater Argyle	0.42	0.19	Shoalhaven	0.062	0.026
Hawkesbury	8.8	8.4	Singleton	16	14
Hornsby	0.049	1.5	Sutherland	0.88	0.46
Kiama	0.81	0.30	Upper Lachlan	2.1	2.0
Ku-ring-gai		0.024	Warringah		0.28
Lake Macquarie	1.7	1.7	Wingecarribee	7.7	4.3
Lithgow	4.0	4.9	Wollondilly	6.7	5.1
Liverpool	0.87	0.40	Wollongong	1.9	0.93
Maitland	0.57	0.32	Wyong	1.7	2.3
			Total	100	100

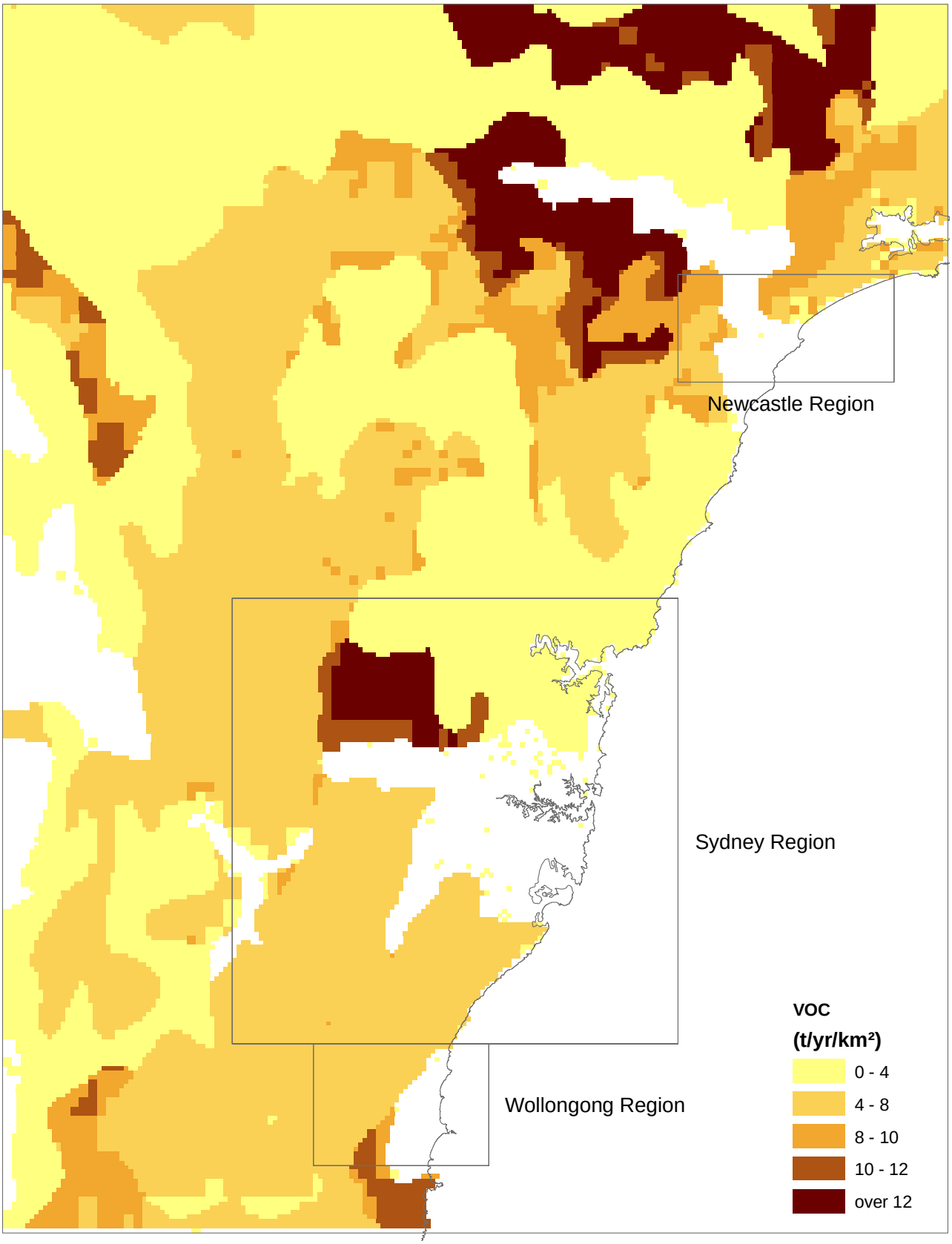


Figure 36. Gridded emissions of total VOC from trees, GMR 2003

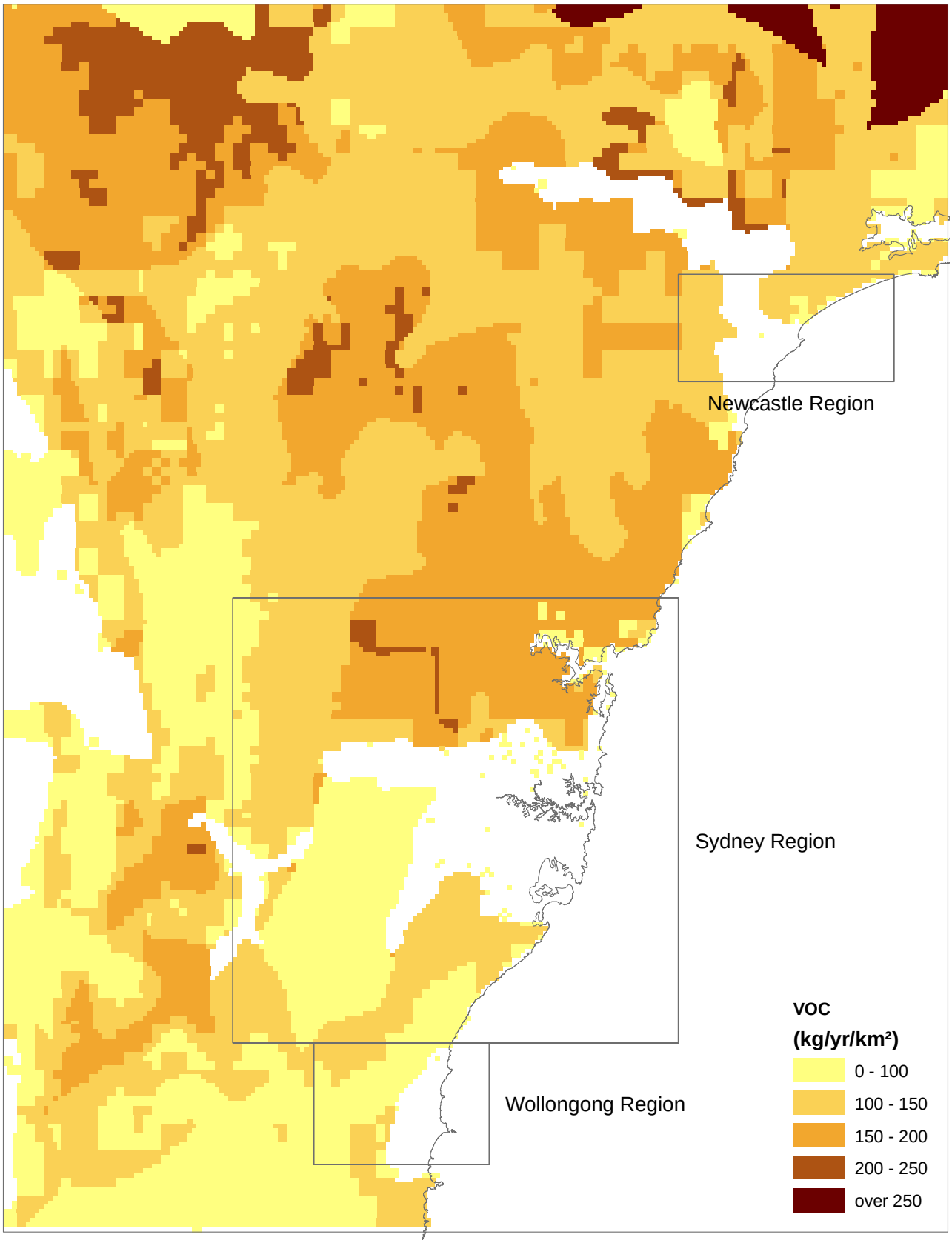


Figure 37. Gridded emissions of total VOC from grass, GMR 2003

Table 36 shows the contributions to vegetation emissions by region. Most emissions from vegetation occur in Non-Urban region, although emissions in Sydney region are also significant. Emissions from Newcastle and Wollongong regions are small.

Table 36. Contributions (%) to emissions from vegetation by region in 2003

Source	GMR	Sydney	Newcastle	Wollongong	Non-Urban
Tree	100	19	2.0	2.1	77
Grass	100	14	1.1	1.0	84

5.5 Temporal variation

Average hourly emissions have been estimated for each month from BEI-GIS. Figure 38 and Figure 39 show the monthly emissions from trees and grass respectively. January has the highest total VOC emissions from trees, most of which are isoprene. The high isoprene emissions are due to the strong solar radiation in January predicted by BEI-GIS. For grass, most of the total VOC emissions occur in January and December. Emissions from May to August are negligible.

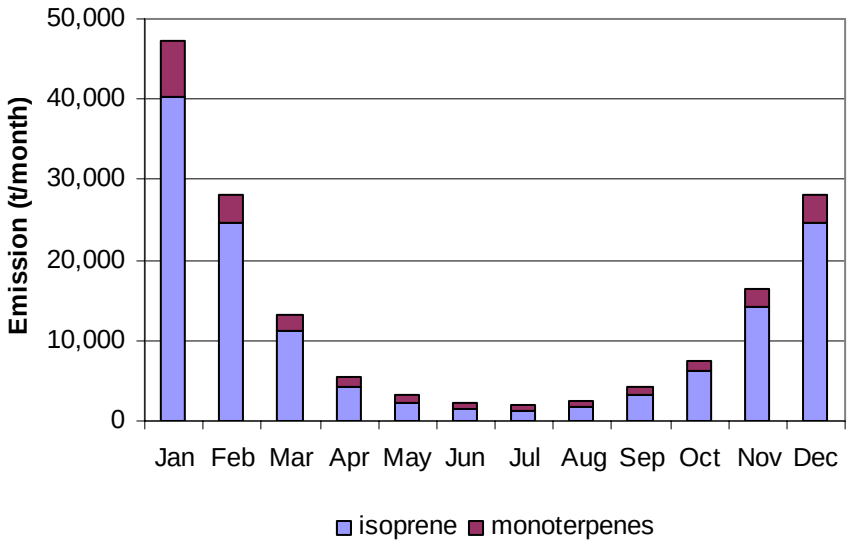


Figure 38. Monthly emissions of total VOC from trees, GMR 2003

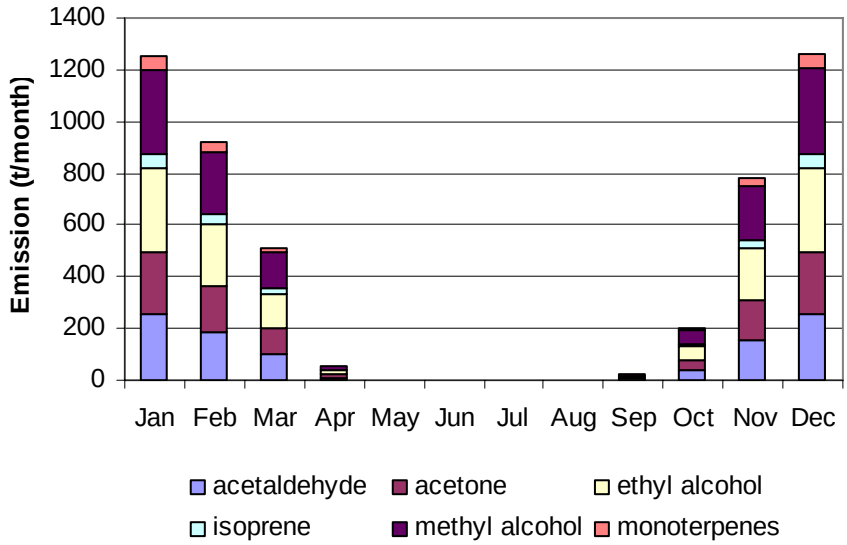


Figure 39. Monthly emissions of total VOC from grass, GMR 2003

Figure 40 and Figure 41 show the hourly emissions by season for trees and grass respectively. Isoprene emissions from trees and all emissions from grass are strongly influenced by solar radiation and temperature, and the emissions are zero at night without solar radiation. Monoterpenes emissions from trees depend only on temperature and are present at night. Emissions from grass are negligible in winter and there are no emissions between 9 pm and 5 am in any season.

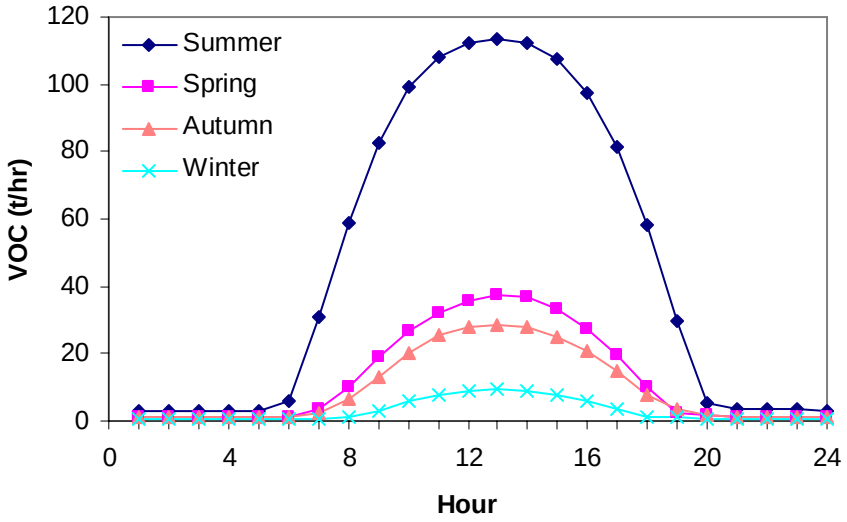


Figure 40. Hourly emissions of total VOC from trees by season, GMR 2003

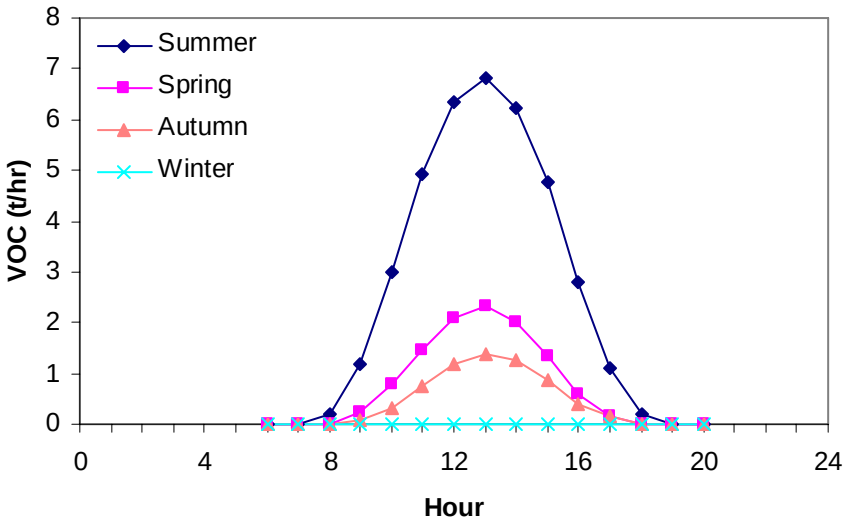


Figure 41. Hourly emissions of total VOC from grass by season, GMR 2003

It is assumed that vegetation emissions on weekdays and weekend days are the same.

6 SUMMARY OF EMISSIONS

6.1 Annual emissions

The pollutants inventoried include criteria pollutants specified in the Air NEPM (NEPC, 2003), air toxics associated with the National Pollutant Inventory NEPM (NEPC, 2000) and the Air Toxics NEPM (NEPC, 2004) and any other pollutants associated with state specific programs, i.e. Load Based Licensing (Protection of the Environment Operations (General) Regulation 1998 (PCO, 1998)) and Protection of the Environment Operations (Clean Air) Regulation 2002 (PCO, 2005).

This section presents total estimated emissions and source contributions to total estimated emissions (for selected substances) respectively from biogenic sources in the GMR, Sydney, Newcastle and Wollongong regions. These substances were selected since they are: the most common air pollutants founds in airsheds according to the National Pollutant Inventory NEPM (NEPC 2000); referred to in National Environment Protection Measures (NEPMs) for criteria pollutants (NEPC 2003) and air toxics (NEPC 2004); and they have been classified as priority air pollutants (NEPC 2005). Total estimated emissions and source contributions to total estimated emissions are also presented for the region defined as Non-Urban. This region is the area of the GMR minus the combined areas of Sydney, Newcastle and Wollongong regions.

Total estimated emissions of all substances emitted in the GMR, Sydney, Newcastle, Wollongong and Non-Urban regions and the percentage contribution from each region to total emissions in the GMR are presented in Appendices 1, 2 and 3.

Table 37 lists the emission estimates of primary pollutants and air toxics from all biogenic sources. Figure 43 to Figure 47 show the percentage contributions in the five regions. The emission estimates and percentage contributions for the full list of substances are contained in Appendix 1. Most biogenic emissions occur in Non-Urban region. Bushfires and prescribed burning are the most dominant sources of most pollutants in the GMR, except for total VOCs and acetaldehyde, which originate mostly from vegetation, and oxides of nitrogen, which originate mostly from soil. The contributions to emissions of lead and compounds are about the same from bushfires and prescribed burning, and fugitive/windborne. Agricultural burning is a minor source of emissions, as agricultural lands are relatively small in the GMR. It is assumed that no agricultural burning is carried out in Wollongong region.

Table 37. Emissions (t/yr) from all biogenic sources in 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	10.6	5,190		8,144		13,344
sulfur dioxide	0.962	519				520
lead & compounds	7.90×10^{-04}	2.35	2.68			5.03
particulate matter < 10 µm	57.9	15,680	1,699			17,436
particulate matter < 2.5 µm	33.6	14,373	662			15,069
polycyclic aromatic hydrocarbons		1.88				1.88
total VOCs	38.5	27,398			165,157	192,594
total suspended particulates (TSP)	65.8	23,519	3,411			26,996
carbon monoxide	299	188,105				188,405
acetaldehyde					1,009	1,009
1,3-butadiene		158				158
Sydney						
oxides of nitrogen	0.923	693		891		1,585
sulfur dioxide	0.0835	69.3				69.4
lead & compounds	6.86×10^{-05}	0.364	0.449			0.813
particulate matter < 10 µm	5.03	2,425	268			2,699
particulate matter < 2.5 µm	2.92	2,223	104			2,331
polycyclic aromatic hydrocarbons		0.291				0.291
total VOCs	3.34	3,428			30,557	33,989
total suspended particulates (TSP)	5.71	3,638	539			4,182
carbon monoxide	26.0	27,320				27,346
acetaldehyde					136	136
1,3-butadiene		19.8				19.8
Newcastle						
oxides of nitrogen	0.200	4.56		98.4		103
sulfur dioxide	0.0181	0.456				0.474
lead & compounds	1.49×10^{-05}	0.00218	0.111			0.113
particulate matter < 10 µm	1.09	14.6	77.6			93.3
particulate matter < 2.5 µm	0.633	13.3	30.3			44.2
polycyclic aromatic hydrocarbons		0.00175				0.00175
total VOCs	0.726	23.5			3,260	3,285
total suspended particulates (TSP)	1.24	21.8	156			179

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
carbon monoxide	5.64	170				176
acetaldehyde					10.7	10.7
1,3-butadiene		0.136				0.136
Wollongong						
oxides of nitrogen		3.22		48.8		52.0
sulfur dioxide		0.322				0.322
lead & compounds		0.00210	0.00317			0.00527
particulate matter < 10 µm		14.0	1.75			15.8
particulate matter < 2.5 µm		12.8	0.681			13.5
polycyclic aromatic hydrocarbons		0.00168				0.00168
total VOCs		14.0			3,357	3,371
total suspended particulates (TSP)		21.0	3.51			24.5
carbon monoxide		145				145
acetaldehyde					10.2	10.2
1,3-butadiene		0.0808				0.0808
Non-Urban						
oxides of nitrogen	9.51	4,489		7,106		11,604
sulfur dioxide	0.861	449				450
lead & compounds	7.06×10^{-04}	1.98	2.11			4.10
particulate matter < 10 µm	51.8	13,226	1,351			14,629
particulate matter < 2.5 µm	30.1	12,123	527			12,680
polycyclic aromatic hydrocarbons		1.59				1.59
total VOCs	34.5	23,933			127,982	151,949
total suspended particulates (TSP)	58.9	19,838	2,713			22,610
carbon monoxide	268	160,470				160,737
acetaldehyde					852	852
1,3-butadiene		138				138

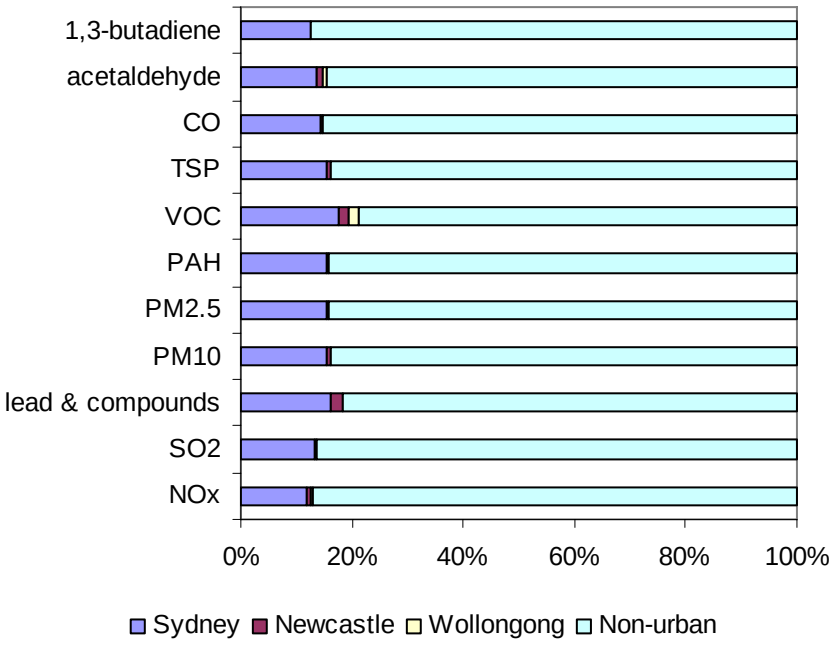


Figure 42. Contributions to emissions from all biogenic sources by region in 2003

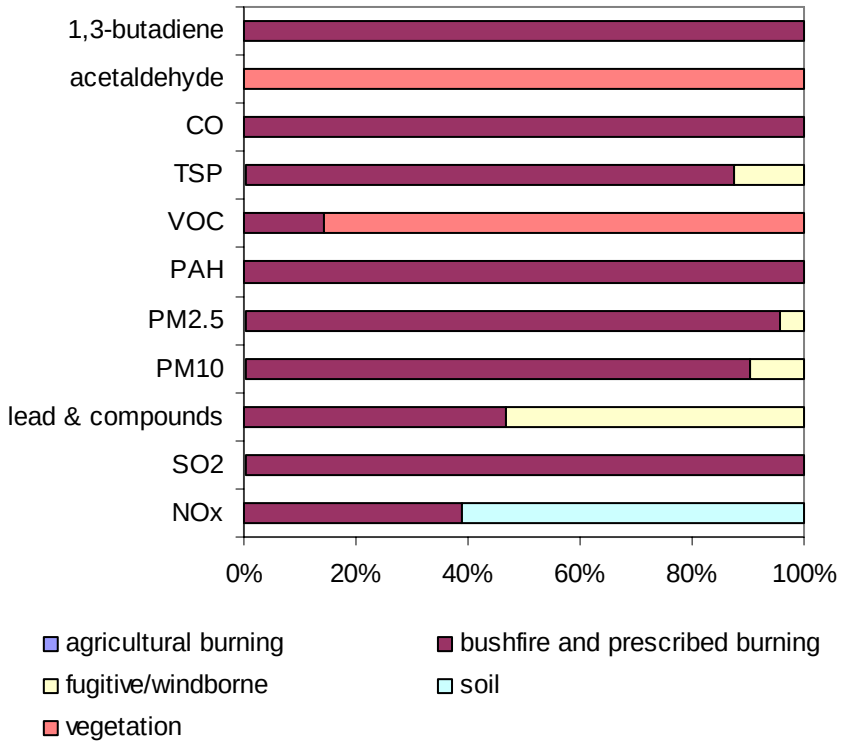


Figure 43. Contributions to emissions from all biogenic sources, GMR 2003

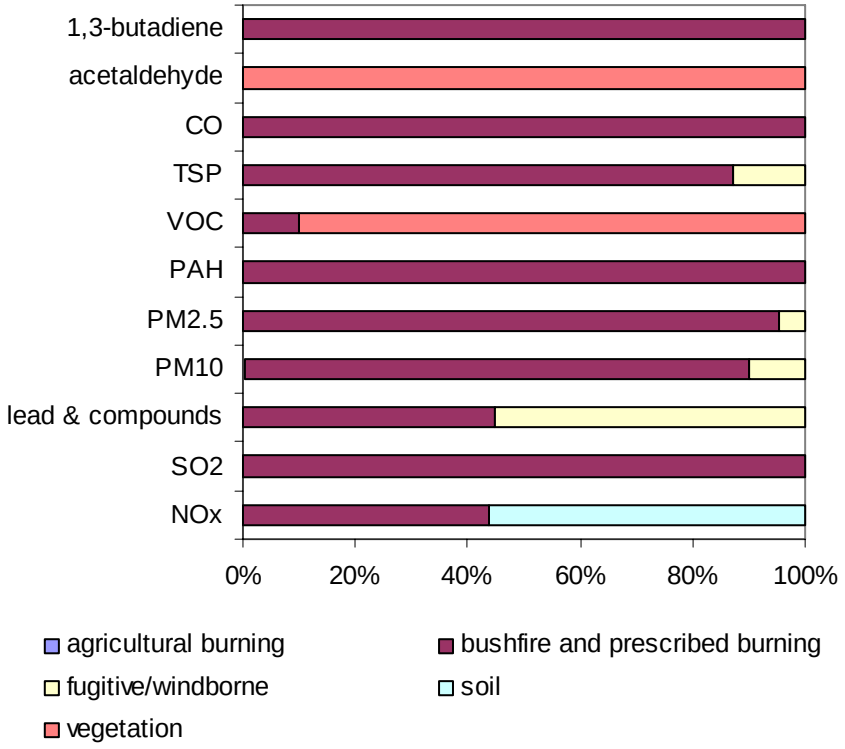


Figure 44. Contributions to emissions from all biogenic sources, Sydney region 2003

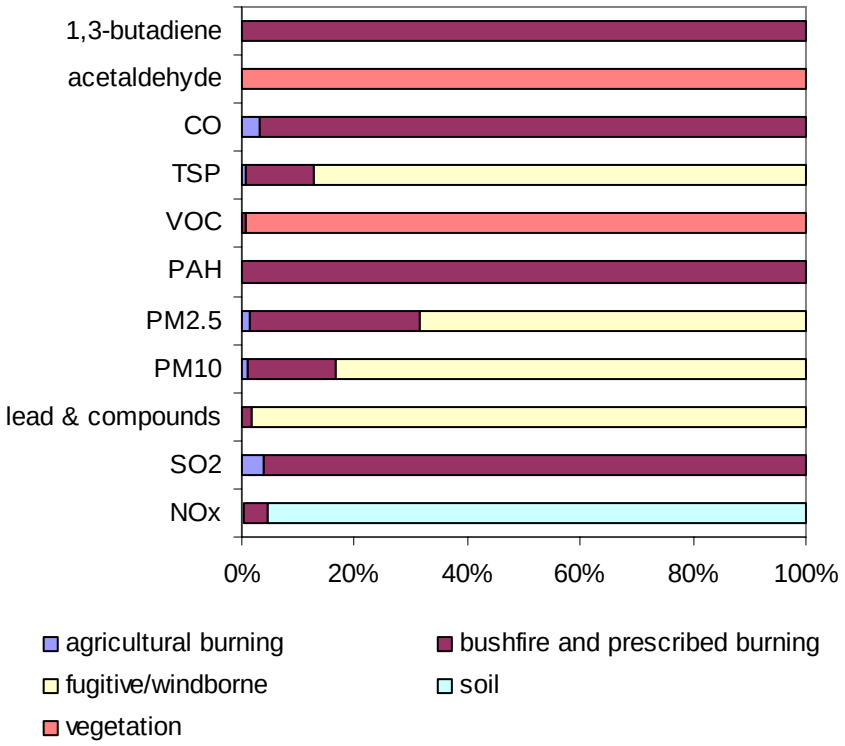


Figure 45. Contributions to emissions from all biogenic sources, Newcastle region 2003

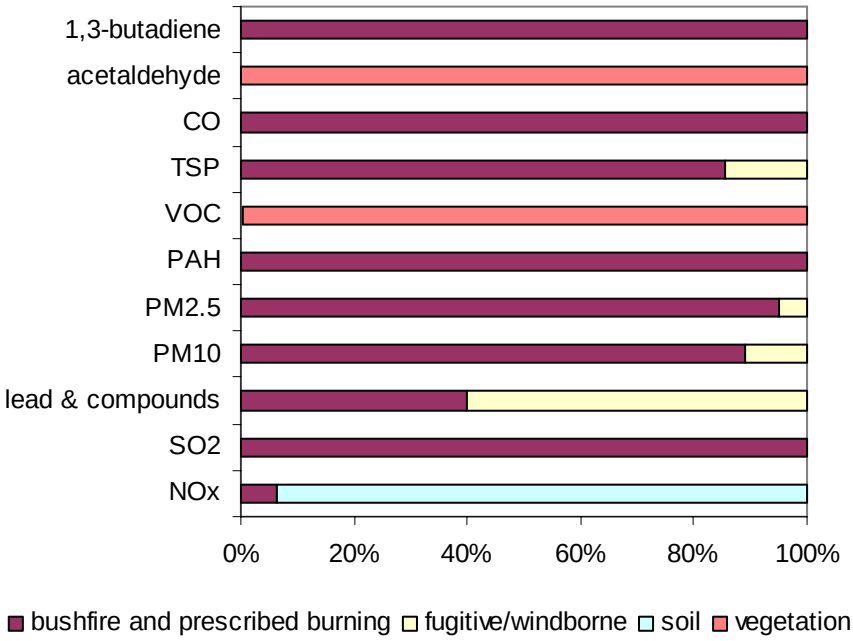


Figure 46. Contributions to emissions from all biogenic sources, Wollongong region 2003

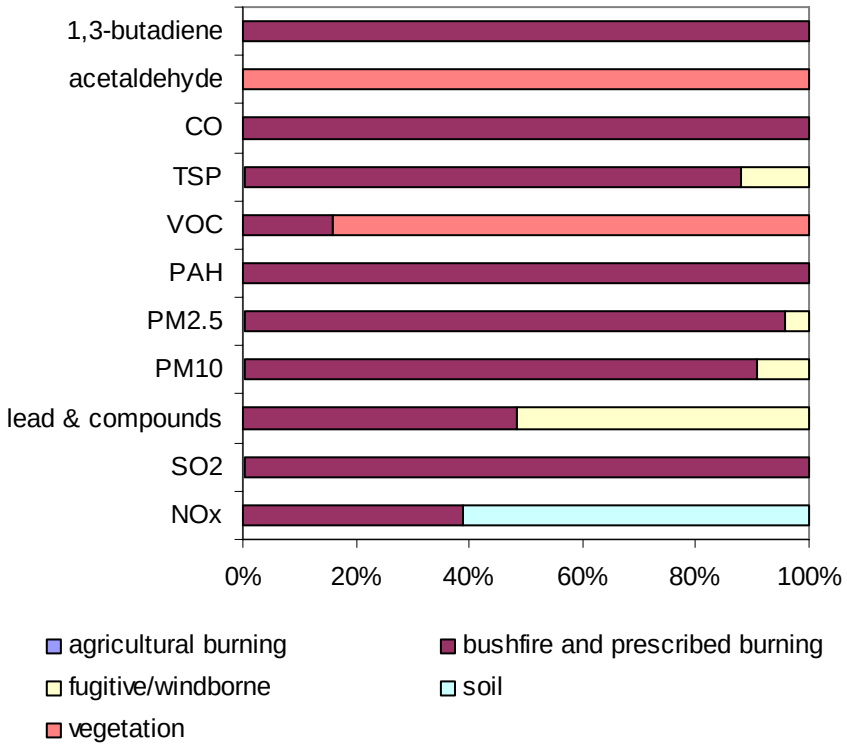


Figure 47. Contributions to emissions from all biogenic sources, Non-Urban region 2003

6.2 Spatial distribution

Figure 48 shows the gridded emission of CO from all biogenic sources. The emissions are dominated by bushfires and prescribed burning, with low levels of emissions from agricultural burning on cropping areas.

Figure 49 shows the gridded emissions of NO_x from all biogenic sources. The spatial distribution of emissions broadly reflects those from soil, with hot spots of burning scattered around various places, which have more localised emissions than soil (see Section 2.2.6).

Figure 50 shows the gridded emissions of PM_{10} from all biogenic sources. The spatial distribution of emissions broadly reflects those from windblown dust from unpaved roads, with hot spots of burning and windblown dust from agricultural lands scattered around various places.

As SO_2 originates mostly from bushfires and prescribed burning, and a small amount from agricultural burning, the spatial distribution of SO_2 is similar to that of CO (see Figure 51).

Figure 52 shows the gridded emissions of total VOC from all biogenic sources. The spatial distribution of emissions broadly follows those from trees, with hot spots of burning scattered around various places.

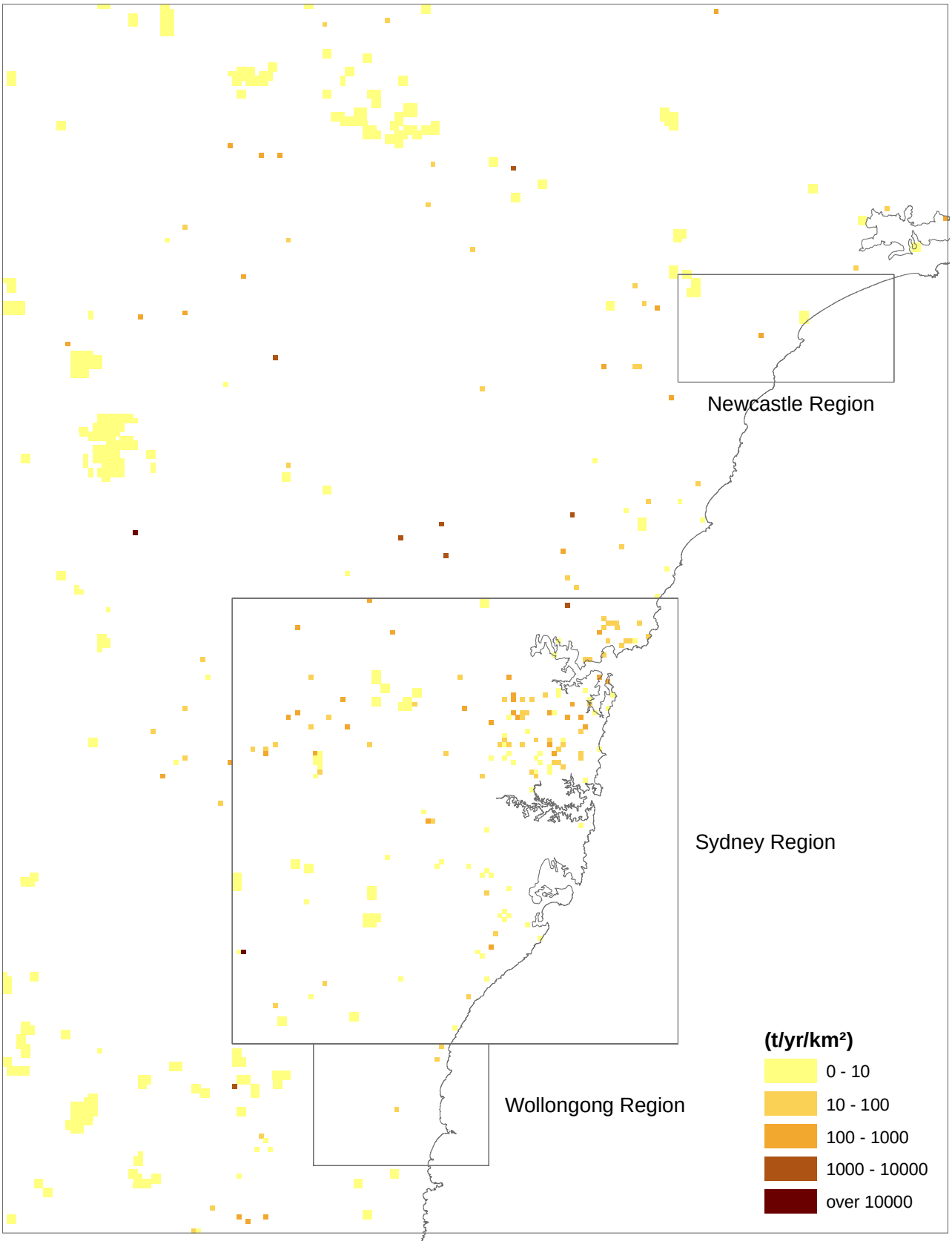


Figure 48. Gridded emissions of CO from all biogenic sources, GMR 2003

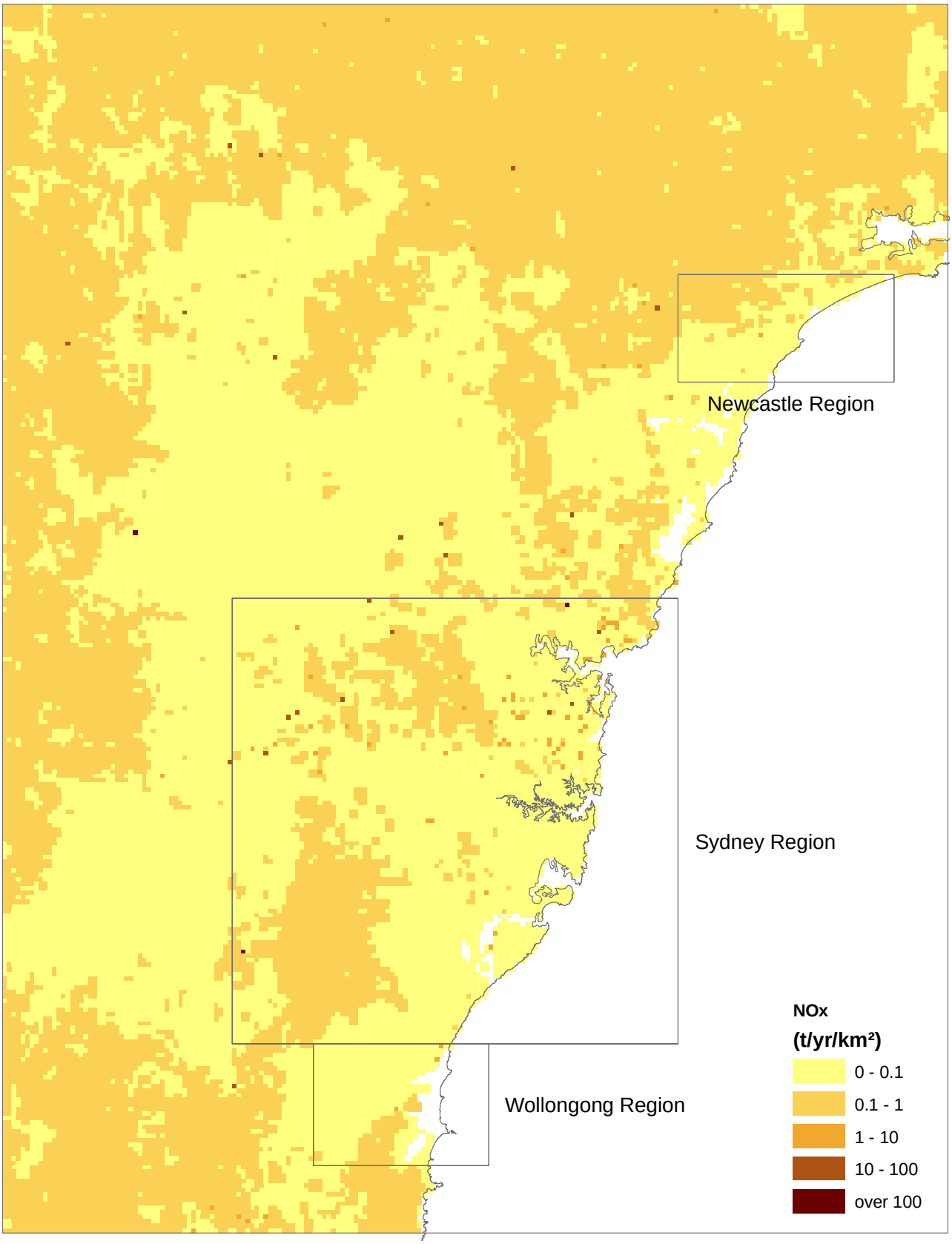


Figure 49. Gridded emissions of NO_x from all biogenic sources, GMR 2003

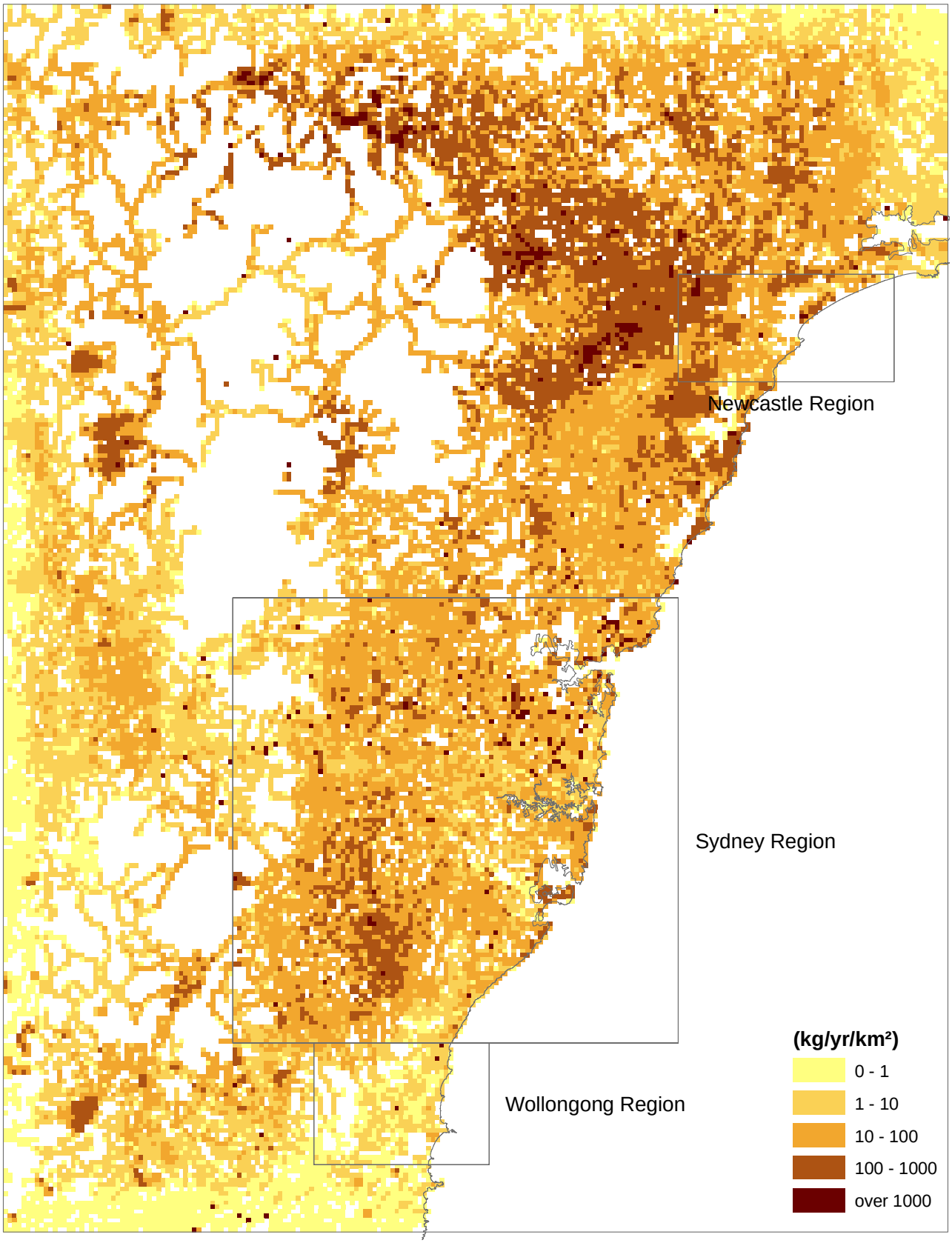


Figure 50. Gridded emissions of PM_{10} from all biogenic sources, GMR 2003

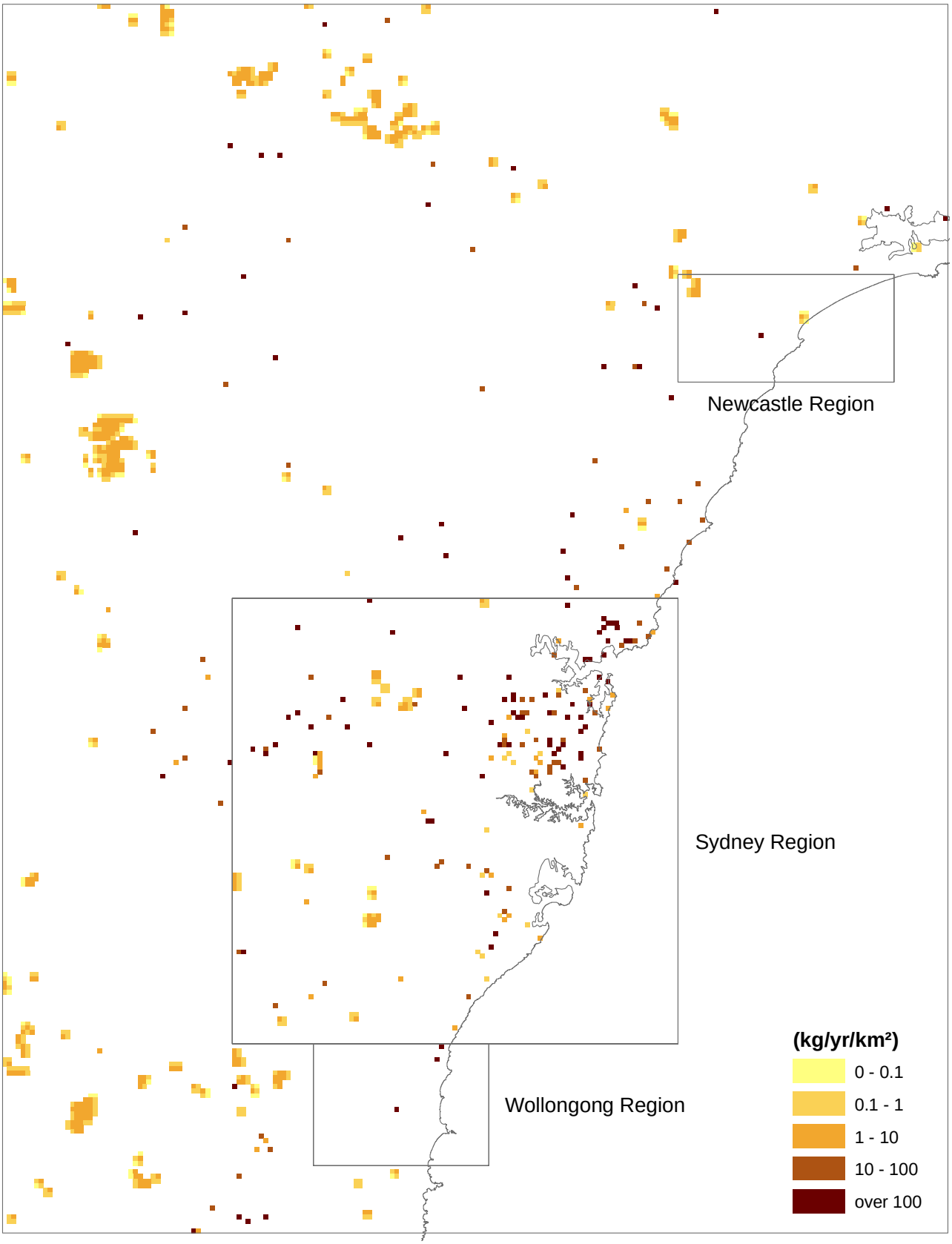


Figure 51. Gridded emissions of SO_2 from all biogenic sources, GMR 2003

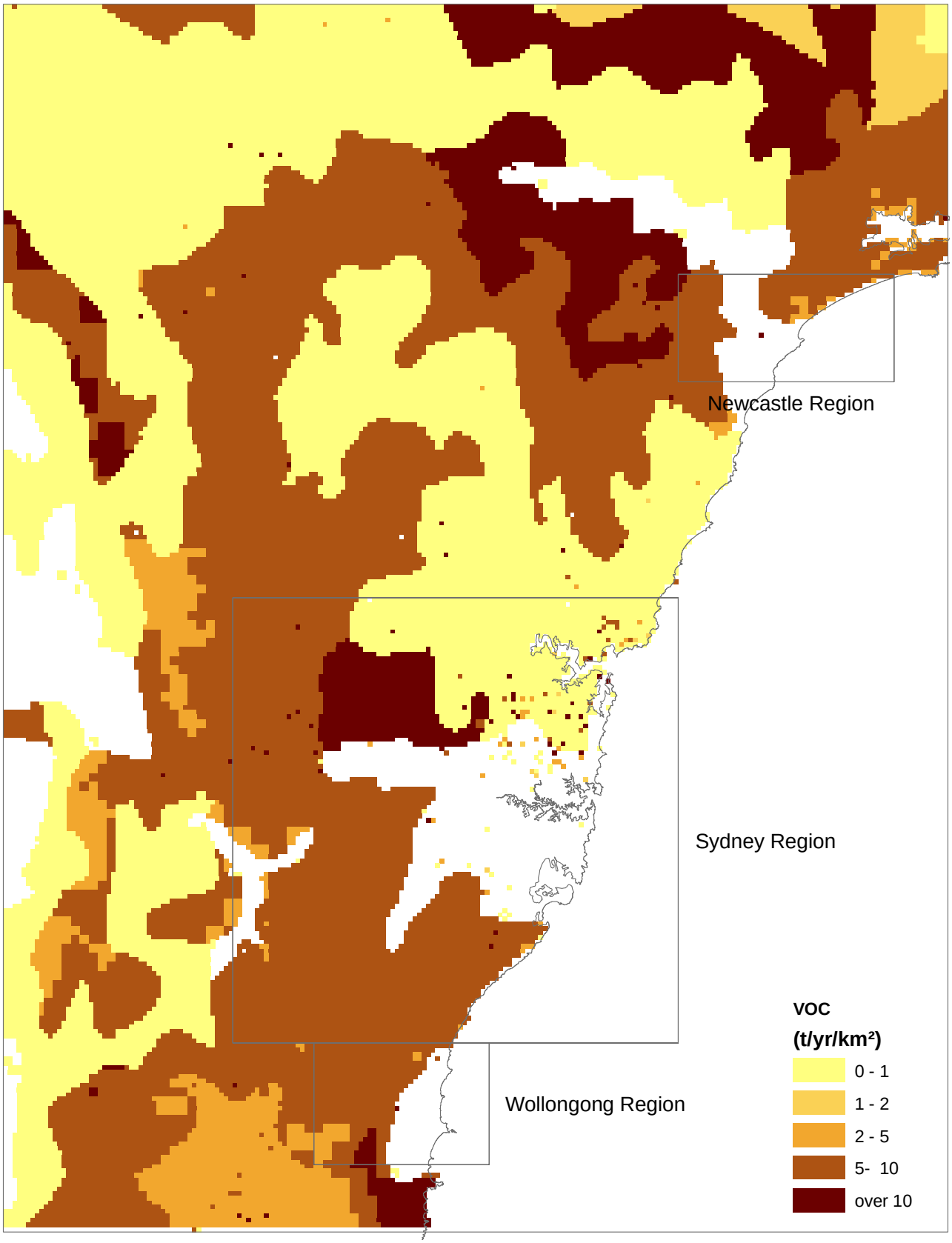


Figure 52. Gridded emissions of total VOC from all biogenic sources, GMR 2003

6.3 Temporal variation

Figure 53, Figure 54 and Figure 55 show respectively the monthly emissions of CO, PM_{10} and SO_2 from all biogenic sources in the GMR. As bushfires and prescribed burning dominate emissions of CO, PM_{10} and SO_2, the monthly variation of these emissions would look like that shown in Figure 13. However, large variation of emissions from year to year are expected from bushfires and prescribed burning.

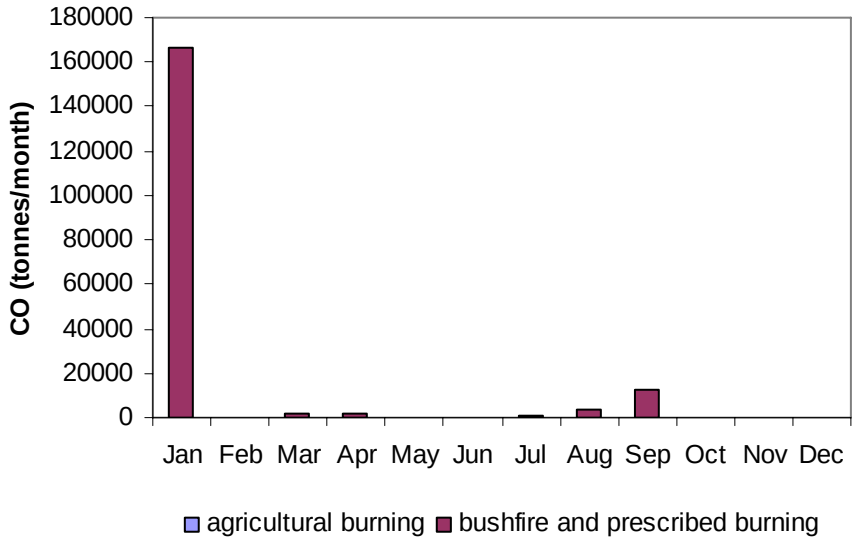


Figure 53. Monthly emissions of CO from all biogenic sources, GMR 2003

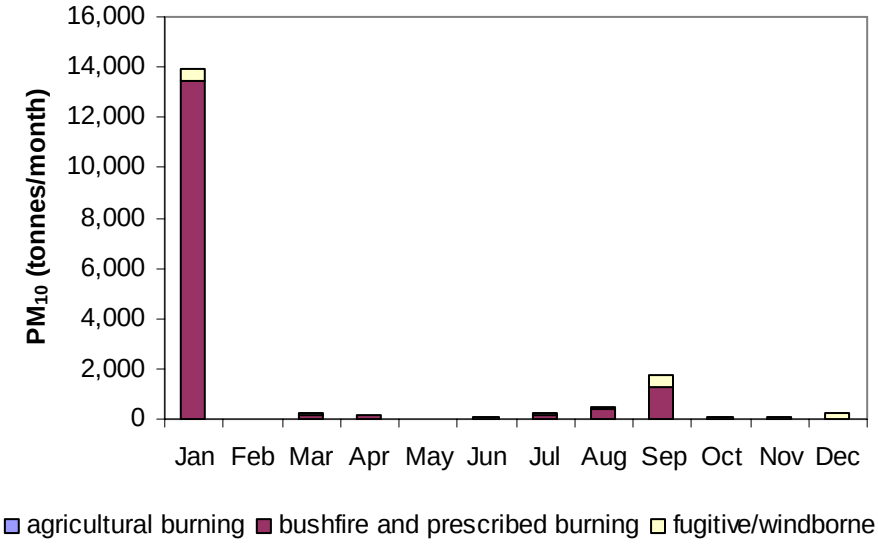


Figure 54. Monthly emissions of PM_{10} from all biogenic sources, GMR 2003

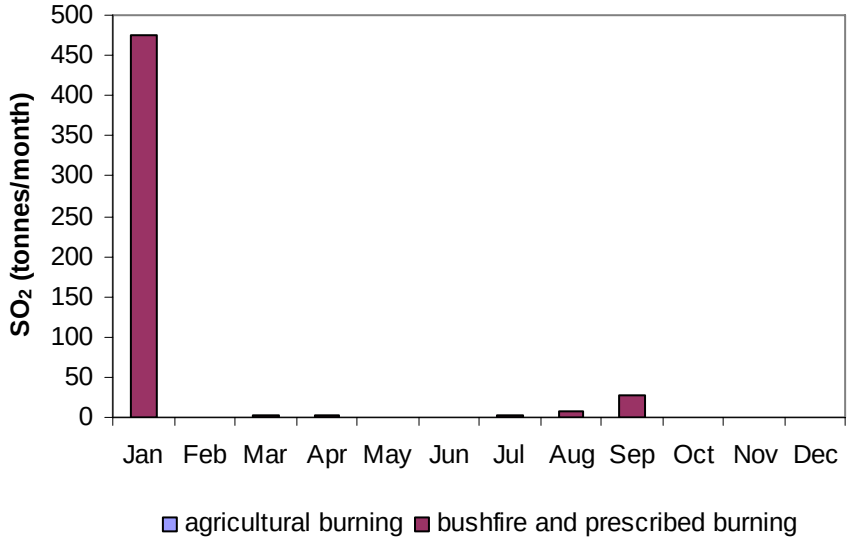


Figure 55. Monthly emissions of SO_2 from all biogenic sources, GMR 2003

Figure 56 shows the monthly emissions of NO_x from all biogenic sources. NO_x originates mostly from soil, except for months when large bushfires or prescribed burning occur.

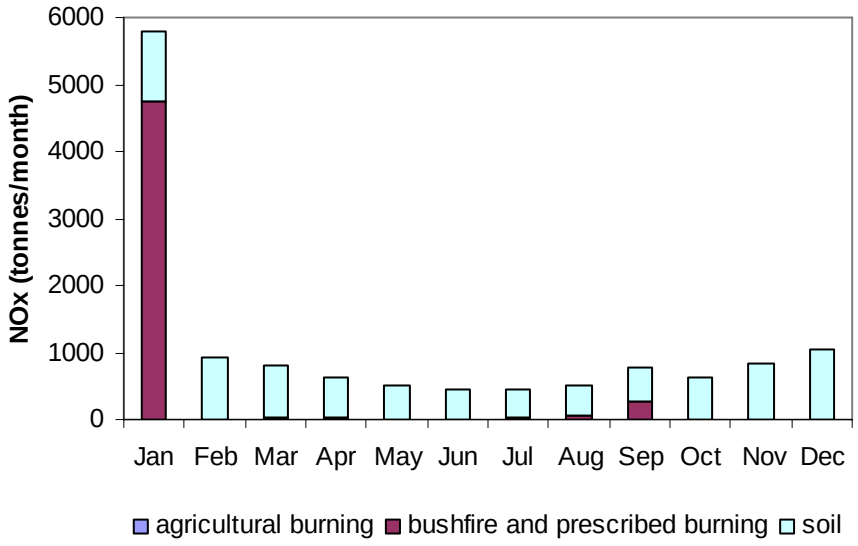


Figure 56. Monthly emissions of NO_x from all biogenic sources, GMR 2003

Figure 57 shows monthly emissions of total VOC from all biogenic sources. Nearly all total VOC originates from vegetation, except in January when a large bushfire occurred.

The emission estimates and percentage contributions of the full list of substances for each region and season are contained in Appendix 2. Estimates for average July and January weekday and weekend day emissions of primary pollutants and air toxics are listed in Appendix

3. It is assumed that no agricultural burning is carried out in July in the GMR and all months in Wollongong region. No bushfires or prescribed burning were recorded for Newcastle region in July and January, and Wollongong region in January.

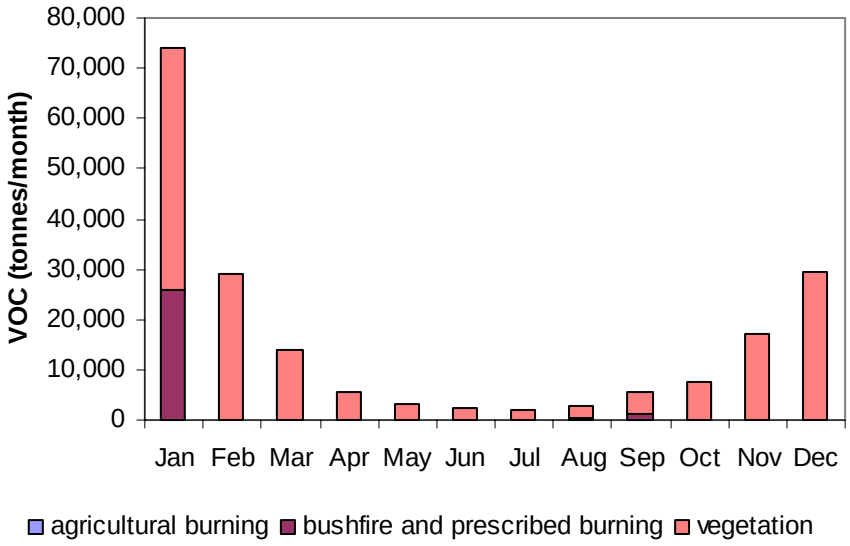


Figure 57. Monthly emissions of total VOC from all biogenic sources, GMR 2003

7 DATABASES AND SPREADSHEETS

7.1 Emissions data management system

An emissions data management system has been developed to store and calculate emissions data for biogenic sources (Biogenic EDMS). The system is based on and modified from EMADMS 2.2 (Ng 2005). The system stores the following data:

- activity data, emission factors, spatial data, temporal data and speciation data for agricultural burning, bushfires and prescribed burning;
- gridded data of crop area, unpaved road and soil type, gridded hourly data of precipitation, temperature and wind speed for each month, and canopy cover and soil cover for estimating windblown dust emissions;
- gridded land use data, and gridded hourly temperature data in each month for estimating biogenic emission from soil; and
- gridded hourly emission data for each month and speciation data for vegetation.

The system:

- calculates hourly (i.e. weekday and weekend day by month and season), daily (i.e. weekday and weekend day totals by month and season), monthly (i.e. total), seasonal (i.e. total) and annual (i.e. total) emissions from each source for the GMR, Sydney, Newcastle and Wollongong regions, and each LGA;
- exports gridded hourly (by month and season) and gridded annual emissions from each source for use in GIS; and
- exports files for import into the Emissions Data Management System developed by Pacific Air & Environment (Bawden et. al. 2004).

7.2 Other database and spreadsheets

Spreadsheets have been used to carry out simple calculations and format data to enter in the Biogenic EDMS or for use in this report. Some data used for emission estimation have been supplied in spreadsheets. To assign the prescribed burning location to suburb centroids, a database (fire.mdb) was created to link fire locations to coordinates of suburb centroids. Table 38 describes the database and spreadsheets that were used for the biogenic inventory.

Table 38. Other database and spreadsheets used for the biogenic inventory

Directory	File name	Purpose
Analysis\burning	fire.mdb	Assign prescribed burn locations to suburb centroids
Analysis\burning\ agricultural	agri_burn.xls	Prepare agricultural burning data for entry to Biogenic EDMS
	grrepmay2004.xls	May Grain Report data downloaded from DPI web site
	gr-sept-2004.xls	September Grain Report data downloaded from DPI web site
Analysis\burning\park	2003 & 2004 Calendar Year Parks & Reserve Prescribed Burns.xls	Prescribed burning data supplied by DEC
	2003 & 2004 Calendar Year Parks & Reserves Wildfires.xls	Bushfire data supplied by DEC
	activity.xls	Prepare bushfire and prescribed burning data for entry to Biogenic EDMS
	Wildfire & Fuel Mgt on NSW National Parks - Air Emissions Inventory 2002-2004.xls	Consolidated bushfire and prescribed burning data supplied by DEC
Analysis\burning\rural \activity	Baulkham Hills.xls etc.	Prescribed burning data supplied by RFS
Analysis\burning\rural \postcode	postcodes.xls	Postcode centroids supplied by DEC
Analysis\dust	dust.xls	Prepare fugitive/windborne data for entry to Biogenic EDMS
Analysis\grid	NSW Gridded Region+LGA.xls	Gridded region and LGA data supplied by DEC
Analysis\speciation	speciation.xls	Derive speciation factors
Analysis\vegetation	Canopy_&_Pasture_Summary .xls	Summary of vegetation results supplied by DEC
Report	agri_burn.xls	Format agricultural burning results for report
	dust.xls	Format fugitive/windborne results for report
	fire.xls	Format bushfire and prescribed burning results for report
	soil.xls	Format soil emission results for report
	summary.xls	Format summary results for report
	vegetation.xls	Format vegetation results for report

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APPENDIX 1: SUMMARY TABLES OF ANNUAL EMISSIONS

Table A1. Emissions (t/yr) of all substances from all biogenic sources by region in 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	10.6	5,190		8,144		13,344
sulfur dioxide	0.962	519				520
lead & compounds	7.90×10^{-04}	2.35	2.68			5.03
particulate matter < 10 µm	57.9	15,680	1,699			17,436
particulate matter < 2.5 µm	33.6	14,373	662			15,069
polycyclic aromatic hydrocarbons		1.88				1.88
total VOCs	38.5	27,398			165,157	192,594
total suspended particulates (TSP)	65.8	23,519	3,411			26,996
carbon monoxide	299	188,105				188,405
acetaldehyde					1,009	1,009
1,3-butadiene		158				158
antimony & compounds	0.00336		0.0234			0.0268
arsenic & compounds	4.61×10^{-04}		0.0516			0.0521
cadmium & compounds	0.00329	7.29	0.0829			7.38
chromium (III) compounds	9.77×10^{-04}	0.333	0.786			1.12
chromium (VI) compounds	4.05×10^{-04}	0.138	0.0326			0.171
cobalt & compounds	1.97×10^{-04}		0.479			0.479
copper & compounds	8.56×10^{-04}	0.470	0.287			0.759
manganese & compounds	0.0310	2.59	3.54			6.16
mercury & compounds	8.56×10^{-04}		0.0493			0.0501
nickel & compounds	5.92×10^{-04}	0.470	0.209			0.680
polychlorinated dioxins and furans	3.95×10^{-09}	1.20×10^{-06}				1.21×10^{-06}
selenium & compounds	3.95×10^{-04}		0.00388			0.00428
zinc & compounds	0.0111	10.8	1.91			12.7
nitrogen dioxide	0.532	259				260
nitric oxide	6.59	3,215		5,294		8,515
methyl alcohol					1,304	1,304
acetylene	0.732	2,552				2,553
ethylene	7.47	5,806				5,813

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
ethane		3,181				3,181
ethyl alcohol					1,298	1,298
1-propyne		125				125
propylene		1,194				1,194
propane	0.732	106				107
acetone					969	969
1-butene	2.27	246				248
n-butane	0.732	72.9				73.6
2-methylpropane; isobutane	0.732	33.4				34.2
isoprene					135,897	135,897
1-pentene	4.55					4.55
3-methyl-1-butene		51.6				51.6
n-pentane	0.732					0.732
n-hexane	5.36					5.36
n-heptane	5.36					5.36
n-octane	5.32					5.32
4-ethylphenanthrene		0.235				0.235
anthracene		0.235				0.235
fluoranthene		0.235				0.235
benzo(c)phenanthrene		0.235				0.235
chrysene		0.235				0.235
benzo(a)pyrene		0.235				0.235
benzo(e)pyrene		0.235				0.235
benzo(g,h,i)perylene		0.235				0.235
isomers of butene		280				280
isomers of pentane		45.6				45.6
monoterpenes					24,680	24,680
isomers of pentene	4.55					4.55
Sydney						
oxides of nitrogen	0.923	693		891		1,585
sulfur dioxide	0.0835	69.3				69.4
lead & compounds	6.86×10^{-05}	0.364	0.449			0.813
particulate matter < 10 µm	5.03	2,425	268			2,699
particulate matter < 2.5 µm	2.92	2,223	104			2,331
polycyclic aromatic hydrocarbons		0.291				0.291

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
total VOCs	3.34	3,428			30,557	33,989
total suspended particulates (TSP)	5.71	3,638	539			4,182
carbon monoxide	26.0	27,320				27,346
acetaldehyde					136	136
1,3-butadiene		19.8				19.8
antimony & compounds	2.91×10^{-04}		0.00373			0.00402
arsenic & compounds	4.00×10^{-05}		0.00812			0.00816
cadmium & compounds	2.86×10^{-04}	1.13	0.0133			1.14
chromium (III) compounds	8.48×10^{-05}	0.0514	0.125			0.177
chromium (VI) compounds	3.52×10^{-05}	0.0213	0.00519			0.0265
cobalt & compounds	1.71×10^{-05}		0.0776			0.0776
copper & compounds	7.43×10^{-05}	0.0728	0.0460			0.119
manganese & compounds	0.00269	0.400	0.562			0.965
mercury & compounds	7.43×10^{-05}		0.00791			0.00798
nickel & compounds	5.14×10^{-05}	0.0728	0.0334			0.106
polychlorinated dioxins and furans	3.43×10^{-10}	1.82×10^{-07}				1.83×10^{-07}
selenium & compounds	3.43×10^{-05}		5.81×10^{-04}			6.15×10^{-04}
zinc & compounds	9.66×10^{-04}	1.67	0.315			1.99
nitrogen dioxide	0.0462	34.7				34.7
nitric oxide	0.572	429		579		1,009
methyl alcohol					176	176
acetylene	0.0635	319				319
ethylene	0.649	726				727
ethane		398				398
ethyl alcohol					175	175
1-propyne		15.6				15.6
propylene		149				149
propane	0.0635	13.3				13.4
acetone					131	131
1-butene	0.197	30.8				31.0
n-butane	0.0635	9.12				9.19
2-methylpropane; isobutane	0.0635	4.18				4.24
isoprene					25,755	25,755
1-pentene	0.395					0.395
3-methyl-1-butene		6.46				6.46

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-pentane	0.0635					0.0635
n-hexane	0.465					0.465
n-heptane	0.465					0.465
n-octane	0.462					0.462
4-ethylphenanthrene		0.0364				0.0364
anthracene		0.0364				0.0364
fluoranthene		0.0364				0.0364
benzo(c)phenanthrene		0.0364				0.0364
chrysene		0.0364				0.0364
benzo(a)pyrene		0.0364				0.0364
benzo(e)pyrene		0.0364				0.0364
benzo(g,h,i)perylene		0.0364				0.0364
isomers of butene		35.0				35.0
isomers of pentane		5.70				5.70
monoterpenes					4,184	4,184
isomers of pentene	0.395					0.395
Newcastle						
oxides of nitrogen	0.200	4.56		98.4		103
sulfur dioxide	0.0181	0.456				0.474
lead & compounds	1.49×10^{-05}	0.00218	0.111			0.113
particulate matter < 10 µm	1.09	14.6	77.6			93.3
particulate matter < 2.5 µm	0.633	13.3	30.3			44.2
polycyclic aromatic hydrocarbons		0.00175				0.00175
total VOCs	0.726	23.5			3,260	3,285
total suspended particulates (TSP)	1.24	21.8	156			179
carbon monoxide	5.64	170				176
acetaldehyde					10.7	10.7
1,3-butadiene		0.136				0.136
antimony & compounds	6.32×10^{-05}		0.00106			0.00112
arsenic & compounds	8.68×10^{-06}		0.00237			0.00238
cadmium & compounds	6.20×10^{-05}	0.00677	0.00372			0.0105
chromium (III) compounds	1.84×10^{-05}	3.09×10^{-04}	0.0354			0.0358
chromium (VI) compounds	7.63×10^{-06}	1.28×10^{-04}	0.00147			0.00161
cobalt & compounds	3.72×10^{-06}		0.0210			0.0210
copper & compounds	1.61×10^{-05}	4.37×10^{-04}	0.0129			0.0133

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
manganese & compounds	5.84×10^{-04}	0.00240	0.160			0.163
mercury & compounds	1.61×10^{-05}		0.00220			0.00221
nickel & compounds	1.12×10^{-05}	4.37×10^{-04}	0.00936			0.00981
polychlorinated dioxins and furans	7.43×10^{-11}	1.11×10^{-09}				1.18×10^{-09}
selenium & compounds	7.44×10^{-06}		1.91×10^{-04}			1.99×10^{-04}
zinc & compounds	2.10×10^{-04}	0.0100	0.0808			0.0910
nitrogen dioxide	0.0100	0.228				0.238
nitric oxide	0.124	2.82		64.0		66.9
methyl alcohol					13.9	13.9
acetylene	0.0138	2.19				2.20
ethylene	0.141	4.98				5.12
ethane		2.73				2.73
ethyl alcohol					13.8	13.8
1-propyne		0.107				0.107
propylene		1.02				1.02
propane	0.0138	0.0912				0.105
acetone					10.3	10.3
1-butene	0.0428	0.211				0.254
n-butane	0.0138	0.0625				0.0763
2-methylpropane; isobutane	0.0138	0.0287				0.0425
isoprene					2,694	2,694
1-pentene	0.0857					0.0857
3-methyl-1-butene		0.0443				0.0443
n-pentane	0.0138					0.0138
n-hexane	0.101					0.101
n-heptane	0.101					0.101
n-octane	0.100					0.100
4-ethylphenanthrene		2.18×10^{-04}				2.18×10^{-04}
anthracene		2.18×10^{-04}				2.18×10^{-04}
fluoranthene		2.18×10^{-04}				2.18×10^{-04}
benzo(c)phenanthrene		2.18×10^{-04}				2.18×10^{-04}
chrysene		2.18×10^{-04}				2.18×10^{-04}
benzo(a)pyrene		2.18×10^{-04}				2.18×10^{-04}
benzo(e)pyrene		2.18×10^{-04}				2.18×10^{-04}
benzo(g,h,i)perylene		2.18×10^{-04}				2.18×10^{-04}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
isomers of butene		0.240				0.240
isomers of pentane		0.0391				0.0391
monoterpenes					517	517
isomers of pentene	0.0857					0.0857
Wollongong						
oxides of nitrogen		3.22		48.8		52.0
sulfur dioxide		0.322				0.322
lead & compounds		0.00210	0.00317			0.00527
particulate matter < 10 µm		14.0	1.75			15.8
particulate matter < 2.5 µm		12.8	0.681			13.5
polycyclic aromatic hydrocarbons		0.00168				0.00168
total VOCs		14.0			3,357	3,371
total suspended particulates (TSP)		21.0	3.51			24.5
carbon monoxide		145				145
acetaldehyde					10.2	10.2
1,3-butadiene		0.0808				0.0808
antimony & compounds			2.46×10^{-05}			2.46×10^{-05}
arsenic & compounds			5.27×10^{-05}			5.27×10^{-05}
cadmium & compounds		0.00652	8.78×10^{-05}			0.00661
chromium (III) compounds		2.97×10^{-04}	8.27×10^{-04}			0.00112
chromium (VI) compounds		1.23×10^{-04}	3.43×10^{-05}			1.57×10^{-04}
cobalt & compounds			5.24×10^{-04}			5.24×10^{-04}
copper & compounds		4.21×10^{-04}	3.06×10^{-04}			7.26×10^{-04}
manganese & compounds		0.00231	0.00369			0.00601
mercury & compounds			5.27×10^{-05}			5.27×10^{-05}
nickel & compounds		4.21×10^{-04}	2.21×10^{-04}			6.42×10^{-04}
polychlorinated dioxins and furans		1.03×10^{-09}				1.03×10^{-09}
selenium & compounds			3.51×10^{-06}			3.51×10^{-06}
zinc & compounds		0.00967	0.00219			0.0119
nitrogen dioxide		0.161				0.161
nitric oxide		2.00		31.7		33.7
methyl alcohol					13.2	13.2
acetylene		1.31				1.31
ethylene		2.97				2.97
ethane		1.63				1.63

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
ethyl alcohol					13.2	13.2
1-propyne		0.0637				0.0637
propylene		0.611				0.611
propane		0.0544				0.0544
acetone					9.84	9.84
1-butene		0.126				0.126
n-butane		0.0373				0.0373
2-methylpropane; isobutane		0.0171				0.0171
isoprene					2,795	2,795
3-methyl-1-butene		0.0264				0.0264
4-ethylphenanthrene		2.10×10^{-04}				2.10×10^{-04}
anthracene		2.10×10^{-04}				2.10×10^{-04}
fluoranthene		2.10×10^{-04}				2.10×10^{-04}
benzo(c)phenanthrene		2.10×10^{-04}				2.10×10^{-04}
chrysene		2.10×10^{-04}				2.10×10^{-04}
benzo(a)pyrene		2.10×10^{-04}				2.10×10^{-04}
benzo(e)pyrene		2.10×10^{-04}				2.10×10^{-04}
benzo(g,h,i)perylene		2.10×10^{-04}				2.10×10^{-04}
isomers of butene		0.143				0.143
isomers of pentane		0.0233				0.0233
monoterpenes					516	516
Non-Urban						
oxides of nitrogen	9.51	4,489		7,106		11,604
sulfur dioxide	0.861	449				450
lead & compounds	7.06×10^{-04}	1.98	2.11			4.10
particulate matter < 10 µm	51.8	13,226	1,351			14,629
particulate matter < 2.5 µm	30.1	12,123	527			12,680
polycyclic aromatic hydrocarbons		1.59				1.59
total VOCs	34.5	23,933			127,982	151,949
total suspended particulates (TSP)	58.9	19,838	2,713			22,610
carbon monoxide	268	160,470				160,737
acetaldehyde					852	852
1,3-butadiene		138				138
antimony & compounds	0.00300		0.0186			0.0216
arsenic & compounds	4.12×10^{-04}		0.0411			0.0415

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
cadmium & compounds	0.00294	6.15	0.0659			6.22
chromium (III) compounds	8.74×10^{-04}	0.281	0.625			0.906
chromium (VI) compounds	3.62×10^{-04}	0.116	0.0259			0.143
cobalt & compounds	1.77×10^{-04}		0.380			0.380
copper & compounds	7.65×10^{-04}	0.397	0.228			0.626
manganese & compounds	0.0277	2.18	2.81			5.02
mercury & compounds	7.65×10^{-04}		0.0391			0.0399
nickel & compounds	5.30×10^{-04}	0.397	0.166			0.563
polychlorinated dioxins and furans	3.53×10^{-09}	1.02×10^{-06}				1.02×10^{-06}
selenium & compounds	3.53×10^{-04}		0.00311			0.00346
zinc & compounds	0.00995	9.13	1.51			10.6
nitrogen dioxide	0.476	224				225
nitric oxide	5.89	2,781		4,619		7,406
methyl alcohol					1,100	1,100
acetylene	0.655	2,229				2,230
ethylene	6.68	5,072				5,078
ethane		2,779				2,779
ethyl alcohol					1,095	1,095
1-propyne		109				109
propylene		1,043				1,043
propane	0.655	92.9				93.5
acetone					818	818
1-butene	2.03	215				217
n-butane	0.655	63.7				64.3
2-methylpropane; isobutane	0.655	29.2				29.8
isoprene					104,653	104,653
1-pentene	4.07					4.07
3-methyl-1-butene		45.1				45.1
n-pentane	0.655					0.655
n-hexane	4.79					4.79
n-heptane	4.79					4.79
n-octane	4.75					4.75
4-ethylphenanthrene		0.198				0.198
anthracene		0.198				0.198
fluoranthene		0.198				0.198

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
benzo(c)phenanthrene		0.198				0.198
chrysene		0.198				0.198
benzo(a)pyrene		0.198				0.198
benzo(e)pyrene		0.198				0.198
benzo(g,h,i)perylene		0.198				0.198
isomers of butene		244				244
isomers of pentane		39.8				39.8
monoterpenes					19,463	19,463
isomers of pentene	4.07					4.07

Table A2. Contributions (%) to emissions of all substances from all biogenic sources by region in 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.080	39		61	
sulfur dioxide	0.19	100			
lead & compounds	0.016	47	53		
particulate matter < 10 µm	0.33	90	9.7		
particulate matter < 2.5 µm	0.22	95	4.4		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.020	14			86
total suspended particulates (TSP)	0.24	87	13		
carbon monoxide	0.16	100			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	13		87		
arsenic & compounds	0.88		99		
cadmium & compounds	0.045	99	1.1		
chromium (III) compounds	0.087	30	70		
chromium (VI) compounds	0.24	81	19		
cobalt & compounds	0.041		100		
copper & compounds	0.11	62	38		
manganese & compounds	0.50	42	57		
mercury & compounds	1.7		98		
nickel & compounds	0.087	69	31		
polychlorinated dioxins and furans	0.33	100			
selenium & compounds	9.2		91		
zinc & compounds	0.087	85	15		
nitrogen dioxide	0.20	100			
nitric oxide	0.077	38		62	
methyl alcohol					100
acetylene	0.029	100			
ethylene	0.13	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
propylene		100			
propane	0.68	99			
acetone					100
1-butene	0.92	99			
n-butane	0.99	99			
2-methylpropane; isobutane	2.1	98			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Sydney					
oxides of nitrogen	0.058	44		56	
sulfur dioxide	0.12	100			
lead & compounds	0.0084	45	55		
particulate matter < 10 µm	0.19	90	9.9		
particulate matter < 2.5 µm	0.13	95	4.5		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.0098	10			90
total suspended particulates (TSP)	0.14	87	13		
carbon monoxide	0.095	100			
acetaldehyde					100

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
1,3-butadiene		100			
antimony & compounds	7.3		93		
arsenic & compounds	0.49		100		
cadmium & compounds	0.025	99	1.2		
chromium (III) compounds	0.048	29	71		
chromium (VI) compounds	0.13	80	20		
cobalt & compounds	0.022		100		
copper & compounds	0.063	61	39		
manganese & compounds	0.28	41	58		
mercury & compounds	0.93		99		
nickel & compounds	0.048	69	31		
polychlorinated dioxins and furans	0.19	100			
selenium & compounds	5.6		94		
zinc & compounds	0.049	84	16		
nitrogen dioxide	0.13	100			
nitric oxide	0.057	43		57	
methyl alcohol					100
acetylene	0.020	100			
ethylene	0.089	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	0.48	100			
acetone					100
1-butene	0.64	99			
n-butane	0.69	99			
2-methylpropane; isobutane	1.5	99			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Newcastle					
oxides of nitrogen	0.19	4.4		95	
sulfur dioxide	3.8	96			
lead & compounds	0.013	1.9	98		
particulate matter < 10 µm	1.2	16	83		
particulate matter < 2.5 µm	1.4	30	68		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.022	0.72			99
total suspended particulates (TSP)	0.69	12	87		
carbon monoxide	3.2	97			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	5.7		94		
arsenic & compounds	0.36		100		
cadmium & compounds	0.59	64	35		
chromium (III) compounds	0.051	0.86	99		
chromium (VI) compounds	0.48	8.0	92		
cobalt & compounds	0.018		100		
copper & compounds	0.12	3.3	97		
manganese & compounds	0.36	1.5	98		
mercury & compounds	0.73		99		
nickel & compounds	0.11	4.5	95		
polychlorinated dioxins and furans	6.3	94			
selenium & compounds	3.7		96		
zinc & compounds	0.23	11	89		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
nitrogen dioxide	4.2	96			
nitric oxide	0.19	4.2		96	
methyl alcohol					100
acetylene	0.63	99			
ethylene	2.7	97			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	13	87			
acetone					100
1-butene	17	83			
n-butane	18	82			
2-methylpropane; isobutane	32	68			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Wollongong					
oxides of nitrogen		6.2		94	
sulfur dioxide		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		40	60		
particulate matter < 10 µm		89	11		
particulate matter < 2.5 µm		95	5.0		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.42			100
total suspended particulates (TSP)		86	14		
carbon monoxide		100			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds			100		
arsenic & compounds			100		
cadmium & compounds		99	1.3		
chromium (III) compounds		26	74		
chromium (VI) compounds		78	22		
cobalt & compounds			100		
copper & compounds		58	42		
manganese & compounds		39	61		
mercury & compounds			100		
nickel & compounds		66	34		
polychlorinated dioxins and furans		100			
selenium & compounds			100		
zinc & compounds		82	18		
nitrogen dioxide		100			
nitric oxide		5.9		94	
methyl alcohol					100
acetylene		100			
ethylene		100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane		100			
acetone					100
1-butene		100			
n-butane		100			
2-methylpropane; isobutane		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
isoprene					100
3-methyl-1-butene		100			
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
Non-Urban					
oxides of nitrogen	0.082	39		61	
sulfur dioxide	0.19	100			
lead & compounds	0.017	48	52		
particulate matter < 10 µm	0.35	90	9.2		
particulate matter < 2.5 µm	0.24	96	4.2		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.023	16			84
total suspended particulates (TSP)	0.26	88	12		
carbon monoxide	0.17	100			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	14		86		
arsenic & compounds	0.99		99		
cadmium & compounds	0.047	99	1.1		
chromium (III) compounds	0.096	31	69		
chromium (VI) compounds	0.25	82	18		
cobalt & compounds	0.046		100		
copper & compounds	0.12	63	36		
manganese & compounds	0.55	43	56		
mercury & compounds	1.9		98		
nickel & compounds	0.094	70	29		
polychlorinated dioxins and furans	0.34	100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
selenium & compounds	10		90		
zinc & compounds	0.093	86	14		
nitrogen dioxide	0.21	100			
nitric oxide	0.080	38		62	
methyl alcohol					100
acetylene	0.029	100			
ethylene	0.13	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	0.70	99			
acetone					100
1-butene	0.94	99			
n-butane	1.0	99			
2-methylpropane; isobutane	2.2	98			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				

APPENDIX 2: SUMMARY TABLES OF SEASONAL EMISSIONS

Table A3. Emissions (t/season) of all substances from all biogenic sources by region in Spring 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	3.01	277		1,964		2,244
sulfur dioxide	0.272	27.7				28.0
particulate matter < 10 µm	2.37×10^{-04}	0.191	1.14			1.33
particulate matter < 2.5 µm	17.3	1,273	663			1,953
polycyclic aromatic hydrocarbons	10.1	1,167	258			1,435
total VOCs		0.153				0.153
total suspended particulates (TSP)	11.2	1,161			29,122	30,294
carbon monoxide	19.7	1,910	1,330			3,260
acetaldehyde	86.5	12,941				13,027
1,3-butadiene					203	203
lead & compounds		6.70				6.70
antimony & compounds	0.00101		0.00924			0.0102
arsenic & compounds	1.38×10^{-04}		0.0200			0.0202
cadmium & compounds	9.86×10^{-04}	0.592	0.0329			0.626
chromium (III) compounds	2.93×10^{-04}	0.0270	0.311			0.338
chromium (VI) compounds	1.21×10^{-04}	0.0112	0.0129			0.0242
cobalt & compounds	5.91×10^{-05}		0.194			0.194
copper & compounds	2.56×10^{-04}	0.0382	0.114			0.153
manganese & compounds	0.00929	0.210	1.39			1.61
mercury & compounds	2.56×10^{-04}		0.0197			0.0199
nickel & compounds	1.77×10^{-04}	0.0382	0.0829			0.121
polychlorinated dioxins and furans	1.12×10^{-09}	9.26×10^{-08}				9.37×10^{-08}
selenium & compounds	1.18×10^{-04}		0.00140			0.00152
zinc & compounds	0.00333	0.879	0.795			1.68
nitrogen dioxide	0.150	13.9				14.0
nitric oxide	1.86	172		1,276		1,450
methyl alcohol					262	262
acetylene	0.213	108				108
ethylene	2.17	246				248

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
ethane		135				135
ethyl alcohol					261	261
1-propyne		5.28				5.28
propylene		50.6				50.6
propane	0.213	4.51				4.72
acetone					195	195
1-butene	0.661	10.4				11.1
n-butane	0.213	3.09				3.30
2-methylpropane; isobutane	0.213	1.42				1.63
isoprene					23,685	23,685
1-pentene	1.32					1.32
3-methyl-1-butene		2.19				2.19
n-pentane	0.213					0.213
n-hexane	1.56					1.56
n-heptane	1.56					1.56
n-octane	1.55					1.55
4-ethylphenanthrene		0.0191				0.0191
anthracene		0.0191				0.0191
fluoranthene		0.0191				0.0191
benzo(c)phenanthrene		0.0191				0.0191
chrysene		0.0191				0.0191
benzo(a)pyrene		0.0191				0.0191
benzo(e)pyrene		0.0191				0.0191
benzo(g,h,i)perylene		0.0191				0.0191
isomers of butene		11.8				11.8
isomers of pentane		1.93				1.93
monoterpenes					4,517	4,517
isomers of pentene	1.32					1.32
Sydney						
oxides of nitrogen	0.261	85.1		214		299
sulfur dioxide	0.0236	8.51				8.53
particulate matter < 10 µm	2.05×10^{-05}	0.0634	0.193			0.256
particulate matter < 2.5 µm	1.51	423	110			534
polycyclic aromatic hydrocarbons	0.874	387	42.8			431
total VOCs		0.0507				0.0507

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
total suspended particulates (TSP)	0.973	333			5,447	5,782
carbon monoxide	1.71	634	221			856
acetaldehyde	7.51	4,181				4,189
1,3-butadiene					27.4	27.4
lead & compounds		1.92				1.92
antimony & compounds	8.73×10^{-05}		0.00154			0.00162
arsenic & compounds	1.20×10^{-05}		0.00332			0.00333
cadmium & compounds	8.56×10^{-05}	0.197	0.00548			0.202
chromium (III) compounds	2.54×10^{-05}	0.00896	0.0517			0.0606
chromium (VI) compounds	1.05×10^{-05}	0.00371	0.00214			0.00587
cobalt & compounds	5.14×10^{-06}		0.0324			0.0324
copper & compounds	2.23×10^{-05}	0.0127	0.0191			0.0318
manganese & compounds	8.06×10^{-04}	0.0697	0.231			0.302
mercury & compounds	2.23×10^{-05}		0.00328			0.00330
nickel & compounds	1.54×10^{-05}	0.0127	0.0138			0.0265
polychlorinated dioxins and furans	9.69×10^{-11}	3.05×10^{-08}				3.06×10^{-08}
selenium & compounds	1.03×10^{-05}		2.28×10^{-04}			2.38×10^{-04}
zinc & compounds	2.89×10^{-04}	0.292	0.134			0.426
nitrogen dioxide	0.0131	4.25				4.27
nitric oxide	0.162	52.7		139		192
methyl alcohol					35.5	35.5
acetylene	0.0185	31.1				31.1
ethylene	0.189	70.7				70.8
ethane		38.7				38.7
ethyl alcohol					35.3	35.3
1-propyne		1.52				1.52
propylene		14.5				14.5
propane	0.0185	1.29				1.31
acetone					26.4	26.4
1-butene	0.0574	2.99				3.05
n-butane	0.0185	0.887				0.906
2-methylpropane; isobutane	0.0185	0.407				0.425
isoprene					4,500	4,500
1-pentene	0.115					0.115
3-methyl-1-butene		0.629				0.629

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-pentane	0.0185					0.0185
n-hexane	0.135					0.135
n-heptane	0.135					0.135
n-octane	0.134					0.134
4-ethylphenanthrene		0.00634				0.00634
anthracene		0.00634				0.00634
fluoranthene		0.00634				0.00634
benzo(c)phenanthrene		0.00634				0.00634
chrysene		0.00634				0.00634
benzo(a)pyrene		0.00634				0.00634
benzo(e)pyrene		0.00634				0.00634
benzo(g,h,i)perylene		0.00634				0.00634
isomers of butene		3.40				3.40
isomers of pentane		0.555				0.555
monoterpenes					823	823
isomers of pentene	0.115					0.115
Newcastle						
oxides of nitrogen	0.0567	0.520		23.9		24.5
sulfur dioxide	0.00513	0.0520				0.0571
particulate matter < 10 µm	4.46×10^{-06}	4.68×10^{-04}	0.0650			0.0655
particulate matter < 2.5 µm	0.327	3.12	38.6			42.0
polycyclic aromatic hydrocarbons	0.190	2.86	15.0			18.1
total VOCs		3.74×10^{-04}				3.74×10^{-04}
total suspended particulates (TSP)	0.211	1.66			632	634
carbon monoxide	0.371	4.68	77.5			82.5
acetaldehyde	1.63	29.1				30.7
1,3-butadiene					2.31	2.31
lead & compounds		0.00959				0.00959
antimony & compounds	1.89×10^{-05}		5.37×10^{-04}			5.55×10^{-04}
arsenic & compounds	2.60×10^{-06}		0.00117			0.00117
cadmium & compounds	1.86×10^{-05}	0.00145	0.00191			0.00338
chromium (III) compounds	5.52×10^{-06}	6.61×10^{-05}	0.0180			0.0181
chromium (VI) compounds	2.29×10^{-06}	2.74×10^{-05}	7.48×10^{-04}			7.77×10^{-04}
cobalt & compounds	1.11×10^{-06}		0.0112			0.0112
copper & compounds	4.83×10^{-06}	9.36×10^{-05}	0.00662			0.00672

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
manganese & compounds	1.75×10^{-04}	5.15×10^{-04}	0.0808			0.0815
mercury & compounds	4.83×10^{-06}		0.00114			0.00114
nickel & compounds	3.34×10^{-06}	9.36×10^{-05}	0.00481			0.00490
polychlorinated dioxins and furans	2.10×10^{-11}	2.21×10^{-10}				2.42×10^{-10}
selenium & compounds	2.23×10^{-06}		8.31×10^{-05}			8.54×10^{-05}
zinc & compounds	6.28×10^{-05}	0.00215	0.0456			0.0478
nitrogen dioxide	0.00283	0.0260				0.0288
nitric oxide	0.0351	0.322		15.5		15.9
methyl alcohol					2.98	2.98
acetylene	0.00401	0.155				0.159
ethylene	0.0410	0.352				0.393
ethane		0.193				0.193
ethyl alcohol					2.97	2.97
1-propyne		0.00756				0.00756
propylene		0.0725				0.0725
propane	0.00401	0.00646				0.0105
acetone					2.22	2.22
1-butene	0.0125	0.0149				0.0274
n-butane	0.00401	0.00443				0.00844
2-methylpropane; isobutane	0.00401	0.00203				0.00604
isoprene					507	507
1-pentene	0.0249					0.0249
3-methyl-1-butene		0.00314				0.00314
n-pentane	0.00401					0.00401
n-hexane	0.0293					0.0293
n-heptane	0.0293					0.0293
n-octane	0.0291					0.0291
4-ethylphenanthrene		4.68×10^{-05}				4.68×10^{-05}
anthracene		4.68×10^{-05}				4.68×10^{-05}
fluoranthene		4.68×10^{-05}				4.68×10^{-05}
benzo(c)phenanthrene		4.68×10^{-05}				4.68×10^{-05}
chrysene		4.68×10^{-05}				4.68×10^{-05}
benzo(a)pyrene		4.68×10^{-05}				4.68×10^{-05}
benzo(e)pyrene		4.68×10^{-05}				4.68×10^{-05}
benzo(g,h,i)perylene		4.68×10^{-05}				4.68×10^{-05}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
isomers of butene		0.0170				0.0170
isomers of pentane		0.00277				0.00277
monoterpenes					114	114
isomers of pentene	0.0249					0.0249
Wollongong						
oxides of nitrogen		1.57		11.6		13.2
sulfur dioxide		0.157				0.157
particulate matter < 10 µm		6.68×10^{-04}	0.00223			0.00289
particulate matter < 2.5 µm		4.46	1.23			5.69
polycyclic aromatic hydrocarbons		4.08	0.479			4.56
total VOCs		5.35×10^{-04}				5.35×10^{-04}
total suspended particulates (TSP)		8.51			567	575
carbon monoxide		6.68	2.47			9.15
acetaldehyde		55.0				55.0
1,3-butadiene					1.58	1.58
lead & compounds		0.0491				0.0491
antimony & compounds			1.73×10^{-05}			1.73×10^{-05}
arsenic & compounds			3.71×10^{-05}			3.71×10^{-05}
cadmium & compounds		0.00207	6.18×10^{-05}			0.00213
chromium (III) compounds		9.45×10^{-05}	5.81×10^{-04}			6.76×10^{-04}
chromium (VI) compounds		3.92×10^{-05}	2.41×10^{-05}			6.33×10^{-05}
cobalt & compounds			3.68×10^{-04}			3.68×10^{-04}
copper & compounds		1.34×10^{-04}	2.15×10^{-04}			3.49×10^{-04}
manganese & compounds		7.35×10^{-04}	0.00260			0.00333
mercury & compounds			3.71×10^{-05}			3.71×10^{-05}
nickel & compounds		1.34×10^{-04}	1.56×10^{-04}			2.89×10^{-04}
polychlorinated dioxins and furans		3.46×10^{-10}				3.46×10^{-10}
selenium & compounds			2.47×10^{-06}			2.47×10^{-06}
zinc & compounds		0.00307	0.00154			0.00461
nitrogen dioxide		0.0786				0.0786
nitric oxide		0.974		7.55		8.53
methyl alcohol					2.04	2.04
acetylene		0.793				0.793
ethylene		1.80				1.80
ethane		0.988				0.988

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
ethyl alcohol					2.03	2.03
1-propyne		0.0387				0.0387
propylene		0.371				0.371
propane		0.0330				0.0330
acetone					1.52	1.52
1-butene		0.0764				0.0764
n-butane		0.0226				0.0226
2-methylpropane; isobutane		0.0104				0.0104
isoprene					449	449
3-methyl-1-butene		0.0160				0.0160
4-ethylphenanthrene		6.68×10^{-05}				6.68×10^{-05}
anthracene		6.68×10^{-05}				6.68×10^{-05}
fluoranthene		6.68×10^{-05}				6.68×10^{-05}
benzo(c)phenanthrene		6.68×10^{-05}				6.68×10^{-05}
chrysene		6.68×10^{-05}				6.68×10^{-05}
benzo(a)pyrene		6.68×10^{-05}				6.68×10^{-05}
benzo(e)pyrene		6.68×10^{-05}				6.68×10^{-05}
benzo(g,h,i)perylene		6.68×10^{-05}				6.68×10^{-05}
isomers of butene		0.0868				0.0868
isomers of pentane		0.0142				0.0142
monoterpenes					111	111
Non-Urban						
oxides of nitrogen	2.69	190		1,714		1,907
sulfur dioxide	0.244	19.0				19.3
lead & compounds	2.12×10^{-04}	0.126	0.880			1.01
particulate matter < 10 µm	15.5	843	513			1,371
particulate matter < 2.5 µm	9.01	773	200			981
polycyclic aromatic hydrocarbons		0.101				0.101
total VOCs	10.0	818			22,476	23,303
total suspended particulates (TSP)	17.6	1,265	1,030			2,312
carbon monoxide	77.3	8,676				8,753
acetaldehyde					171	171
1,3-butadiene		4.71				4.71
antimony & compounds	8.99×10^{-04}		0.00715			0.00805
arsenic & compounds	1.23×10^{-04}		0.0155			0.0156

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
cadmium & compounds	8.82×10^{-04}	0.392	0.0255			0.418
chromium (III) compounds	2.62×10^{-04}	0.0179	0.240			0.258
chromium (VI) compounds	1.08×10^{-04}	0.00741	0.00997			0.0175
cobalt & compounds	5.29×10^{-05}		0.150			0.150
copper & compounds	2.29×10^{-04}	0.0253	0.0885			0.114
manganese & compounds	0.00831	0.139	1.08			1.22
mercury & compounds	2.29×10^{-04}		0.0152			0.0154
nickel & compounds	1.59×10^{-04}	0.0253	0.0641			0.0896
polychlorinated dioxins and furans	9.99×10^{-10}	6.15×10^{-08}				6.25×10^{-08}
selenium & compounds	1.06×10^{-04}		0.00109			0.00119
zinc & compounds	0.00298	0.582	0.614			1.20
nitrogen dioxide	0.135	9.51				9.65
nitric oxide	1.67	118		1,114		1,234
methyl alcohol					221	221
acetylene	0.190	76.1				76.3
ethylene	1.94	173				175
ethane		94.9				94.9
ethyl alcohol					220	220
1-propyne		3.72				3.72
propylene		35.6				35.6
propane	0.190	3.17				3.36
acetone					165	165
1-butene	0.591	7.34				7.93
n-butane	0.190	2.18				2.37
2-methylpropane; isobutane	0.190	0.997				1.19
isoprene					18,229	18,229
1-pentene	1.18					1.18
3-methyl-1-butene		1.54				1.54
n-pentane	0.190					0.190
n-hexane	1.39					1.39
n-heptane	1.39					1.39
n-octane	1.38					1.38
4-ethylphenanthrene		0.0126				0.0126
anthracene		0.0126				0.0126
fluoranthene		0.0126				0.0126

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
benzo(c)phenanthrene		0.0126				0.0126
chrysene		0.0126				0.0126
benzo(a)pyrene		0.0126				0.0126
benzo(e)pyrene		0.0126				0.0126
benzo(g,h,i)perylene		0.0126				0.0126
isomers of butene		8.34				8.34
isomers of pentane		1.36				1.36
monoterpenes					3,469	3,469
isomers of pentene	1.18					1.18

Table A4. Emissions (t/season) of all substances from all biogenic sources by region in Summer 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	6.02	4,756		3,017		7,779
sulfur dioxide	0.545	476				476
particulate matter < 10 µm	4.73×10^{-04}	2.02	1.16			3.18
particulate matter < 2.5 µm	34.7	13,477	644			14,156
polycyclic aromatic hydrocarbons	20.1	12,354	251			12,625
total VOCs		1.62				1.62
total suspended particulates (TSP)	22.4	25,732			106,817	132,572
carbon monoxide	39.4	20,215	1,294			21,548
acetaldehyde	173	166,469				166,642
1,3-butadiene					692	692
lead & compounds		148				148
antimony & compounds	0.00201		0.00904			0.0111
arsenic & compounds	2.76×10^{-04}		0.0194			0.0197
cadmium & compounds	0.00197	6.27	0.0323			6.30
chromium (III) compounds	5.85×10^{-04}	0.286	0.304			0.590
chromium (VI) compounds	2.43×10^{-04}	0.118	0.0126			0.131
cobalt & compounds	1.18×10^{-04}		0.192			0.192
copper & compounds	5.13×10^{-04}	0.404	0.112			0.517
manganese & compounds	0.0186	2.22	1.36			3.60
mercury & compounds	5.13×10^{-04}		0.0194			0.0199
nickel & compounds	3.55×10^{-04}	0.404	0.0813			0.486
polychlorinated dioxins and furans	2.23×10^{-09}	1.05×10^{-06}				1.05×10^{-06}
selenium & compounds	2.37×10^{-04}		0.00131			0.00154
zinc & compounds	0.00666	9.30	0.799			10.1
nitrogen dioxide	0.301	238				238
nitric oxide	3.73	2,947		1,961		4,911
methyl alcohol					894	894
acetylene	0.426	2,397				2,397
ethylene	4.35	5,453				5,457
ethane		2,988				2,988
ethyl alcohol					889	889
1-propyne		117				117

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
propylene		1,121				1,121
propane	0.426	99.9				100
acetone					664	664
1-butene	1.32	231				232
n-butane	0.426	68.5				68.9
2-methylpropane; isobutane	0.426	31.4				31.8
isoprene					89,938	89,938
1-pentene	2.64					2.64
3-methyl-1-butene		48.5				48.5
n-pentane	0.426					0.426
n-hexane	3.11					3.11
n-heptane	3.11					3.11
n-octane	3.09					3.09
4-ethylphenanthrene		0.202				0.202
anthracene		0.202				0.202
fluoranthene		0.202				0.202
benzo(c)phenanthrene		0.202				0.202
chrysene		0.202				0.202
benzo(a)pyrene		0.202				0.202
benzo(e)pyrene		0.202				0.202
benzo(g,h,i)perylene		0.202				0.202
isomers of butene		263				263
isomers of pentane		42.8				42.8
monoterpenes					13,740	13,740
isomers of pentene	2.64					2.64
Sydney						
oxides of nitrogen	0.523	520		330		850
sulfur dioxide	0.0473	52.0				52.0
particulate matter < 10 µm	4.11×10^{-05}	0.221	0.192			0.413
particulate matter < 2.5 µm	3.01	1,474	107			1,584
polycyclic aromatic hydrocarbons	1.75	1,351	41.6			1,394
total VOCs		0.177				0.177
total suspended particulates (TSP)	1.95	2,812			19,386	22,200
carbon monoxide	3.42	2,211	214			2,429
acetaldehyde	15.0	18,201				18,216

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
1,3-butadiene					93.0	93.0
lead & compounds		16.2				16.2
antimony & compounds	1.75×10^{-04}		0.00150			0.00167
arsenic & compounds	2.40×10^{-05}		0.00322			0.00324
cadmium & compounds	1.71×10^{-04}	0.685	0.00536			0.691
chromium (III) compounds	5.08×10^{-05}	0.0313	0.0504			0.0817
chromium (VI) compounds	2.11×10^{-05}	0.0130	0.00209			0.0151
cobalt & compounds	1.03×10^{-05}		0.0319			0.0319
copper & compounds	4.45×10^{-05}	0.0442	0.0186			0.0629
manganese & compounds	0.00161	0.243	0.225			0.470
mercury & compounds	4.45×10^{-05}		0.00321			0.00326
nickel & compounds	3.08×10^{-05}	0.0442	0.0135			0.0577
polychlorinated dioxins and furans	1.94×10^{-10}	1.14×10^{-07}				1.15×10^{-07}
selenium & compounds	2.05×10^{-05}		2.15×10^{-04}			2.36×10^{-04}
zinc & compounds	5.79×10^{-04}	1.02	0.133			1.15
nitrogen dioxide	0.0261	26.0				26.0
nitric oxide	0.324	322		214		537
methyl alcohol					120	120
acetylene	0.0370	262				262
ethylene	0.377	596				596
ethane		326				326
ethyl alcohol					120	120
1-propyne		12.8				12.8
propylene		123				123
propane	0.0370	10.9				11.0
acetone					89.3	89.3
1-butene	0.115	25.3				25.4
n-butane	0.0370	7.48				7.52
2-methylpropane; isobutane	0.0370	3.43				3.47
isoprene					16,814	16,814
1-pentene	0.230					0.230
3-methyl-1-butene		5.30				5.30
n-pentane	0.0370					0.0370
n-hexane	0.270					0.270
n-heptane	0.270					0.270

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-octane	0.268					0.268
4-ethylphenanthrene		0.0221				0.0221
anthracene		0.0221				0.0221
fluoranthene		0.0221				0.0221
benzo(c)phenanthrene		0.0221				0.0221
chrysene		0.0221				0.0221
benzo(a)pyrene		0.0221				0.0221
benzo(e)pyrene		0.0221				0.0221
benzo(g,h,i)perylene		0.0221				0.0221
isomers of butene		28.7				28.7
isomers of pentane		4.68				4.68
monoterpenes					2,150	2,150
isomers of pentene	0.230					0.230
Newcastle						
oxides of nitrogen	0.113	4.04		35.1		39.3
sulfur dioxide	0.0103	0.404				0.414
particulate matter < 10 µm	8.92×10^{-06}	0.00172	0.0300			0.0317
particulate matter < 2.5 µm	0.654	11.4	17.0			29.1
polycyclic aromatic hydrocarbons	0.379	10.5	6.61			17.5
total VOCs		0.00137				0.00137
total suspended particulates (TSP)	0.422	21.8			1,940	1,962
carbon monoxide	0.743	17.2	34.1			52.0
acetaldehyde	3.26	141				145
1,3-butadiene					7.06	7.06
lead & compounds		0.126				0.126
antimony & compounds	3.79×10^{-05}		2.38×10^{-04}			2.76×10^{-04}
arsenic & compounds	5.20×10^{-06}		5.12×10^{-04}			5.17×10^{-04}
cadmium & compounds	3.71×10^{-05}	0.00532	8.48×10^{-04}			0.00620
chromium (III) compounds	1.10×10^{-05}	2.43×10^{-04}	0.00799			0.00824
chromium (VI) compounds	4.57×10^{-06}	1.01×10^{-04}	3.31×10^{-04}			4.36×10^{-04}
cobalt & compounds	2.23×10^{-06}		0.00503			0.00503
copper & compounds	9.66×10^{-06}	3.43×10^{-04}	0.00295			0.00330
manganese & compounds	3.50×10^{-04}	0.00189	0.0357			0.0380
mercury & compounds	9.66×10^{-06}		5.08×10^{-04}			5.17×10^{-04}
nickel & compounds	6.69×10^{-06}	3.43×10^{-04}	0.00214			0.00249

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
polychlorinated dioxins and furans	4.21×10^{-11}	8.88×10^{-10}				9.30×10^{-10}
selenium & compounds	4.46×10^{-06}		3.49×10^{-05}			3.94×10^{-05}
zinc & compounds	1.26×10^{-04}	0.00789	0.0208			0.0288
nitrogen dioxide	0.00567	0.202				0.207
nitric oxide	0.0703	2.50		22.8		25.4
methyl alcohol					9.12	9.12
acetylene	0.00802	2.03				2.04
ethylene	0.0819	4.63				4.71
ethane		2.54				2.54
ethyl alcohol					9.08	9.08
1-propyne		0.0993				0.0993
propylene		0.952				0.952
propane	0.00802	0.0848				0.0928
acetone					6.78	6.78
1-butene	0.0249	0.196				0.221
n-butane	0.00802	0.0581				0.0661
2-methylpropane; isobutane	0.00802	0.0266				0.0347
isoprene					1,674	1,674
1-pentene	0.0498					0.0498
3-methyl-1-butene		0.0412				0.0412
n-pentane	0.00802					0.00802
n-hexane	0.0587					0.0587
n-heptane	0.0587					0.0587
n-octane	0.0583					0.0583
4-ethylphenanthrene		1.72×10^{-04}				1.72×10^{-04}
anthracene		1.72×10^{-04}				1.72×10^{-04}
fluoranthene		1.72×10^{-04}				1.72×10^{-04}
benzo(c)phenanthrene		1.72×10^{-04}				1.72×10^{-04}
chrysene		1.72×10^{-04}				1.72×10^{-04}
benzo(a)pyrene		1.72×10^{-04}				1.72×10^{-04}
benzo(e)pyrene		1.72×10^{-04}				1.72×10^{-04}
benzo(g,h,i)perylene		1.72×10^{-04}				1.72×10^{-04}
isomers of butene		0.223				0.223
isomers of pentane		0.0363				0.0363
monoterpenes					233	233

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
isomers of pentene	0.0498					0.0498
Wollongong						
oxides of nitrogen		0.105		16.7		16.8
sulfur dioxide		0.0105				0.0105
particulate matter < 10 µm		4.46×10^{-05}	4.31×10^{-04}			4.76×10^{-04}
particulate matter < 2.5 µm		0.297	0.238			0.536
polycyclic aromatic hydrocarbons		0.272	0.0928			0.365
total VOCs		3.56×10^{-05}				3.56×10^{-05}
total suspended particulates (TSP)		0.567			2,132	2,133
carbon monoxide		0.446	0.479			0.924
acetaldehyde		3.67				3.67
1,3-butadiene					7.74	7.74
lead & compounds		0.00327				0.00327
antimony & compounds			3.35×10^{-06}			3.35×10^{-06}
arsenic & compounds			7.18×10^{-06}			7.18×10^{-06}
cadmium & compounds		1.38×10^{-04}	1.20×10^{-05}			1.50×10^{-04}
chromium (III) compounds		6.30×10^{-06}	1.13×10^{-04}			1.19×10^{-04}
chromium (VI) compounds		2.61×10^{-06}	4.67×10^{-06}			7.28×10^{-06}
cobalt & compounds			7.13×10^{-05}			7.13×10^{-05}
copper & compounds		8.91×10^{-06}	4.17×10^{-05}			5.06×10^{-05}
manganese & compounds		4.90×10^{-05}	5.03×10^{-04}			5.52×10^{-04}
mercury & compounds			7.18×10^{-06}			7.18×10^{-06}
nickel & compounds		8.91×10^{-06}	3.02×10^{-05}			3.91×10^{-05}
polychlorinated dioxins and furans		2.31×10^{-11}				2.31×10^{-11}
selenium & compounds			4.79×10^{-07}			4.79×10^{-07}
zinc & compounds		2.05×10^{-04}	2.98×10^{-04}			5.03×10^{-04}
nitrogen dioxide		0.00524				0.00524
nitric oxide		0.0650		10.8		10.9
methyl alcohol					9.99	9.99
acetylene		0.0528				0.0528
ethylene		0.120				0.120
ethane		0.0659				0.0659
ethyl alcohol					9.95	9.95
1-propyne		0.00258				0.00258
propylene		0.0247				0.0247

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
propane		0.00220				0.00220
acetone					7.43	7.43
1-butene		0.00509				0.00509
n-butane		0.00151				0.00151
2-methylpropane; isobutane		6.92×10^{-04}				6.92×10^{-04}
isoprene					1,866	1,866
3-methyl-1-butene		0.00107				0.00107
4-ethylphenanthrene		4.46×10^{-06}				4.46×10^{-06}
anthracene		4.46×10^{-06}				4.46×10^{-06}
fluoranthene		4.46×10^{-06}				4.46×10^{-06}
benzo(c)phenanthrene		4.46×10^{-06}				4.46×10^{-06}
chrysene		4.46×10^{-06}				4.46×10^{-06}
benzo(a)pyrene		4.46×10^{-06}				4.46×10^{-06}
benzo(e)pyrene		4.46×10^{-06}				4.46×10^{-06}
benzo(g,h,i)perylene		4.46×10^{-06}				4.46×10^{-06}
isomers of butene		0.00579				0.00579
isomers of pentane		9.43×10^{-04}				9.43×10^{-04}
monoterpenes					231	231
Non-Urban						
oxides of nitrogen	5.38	4,232		2,635		6,873
sulfur dioxide	0.487	423				424
lead & compounds	4.23×10^{-04}	1.80	0.933			2.73
particulate matter < 10 µm	31.0	11,991	520			12,543
particulate matter < 2.5 µm	18.0	10,992	202			11,212
polycyclic aromatic hydrocarbons		1.44				1.44
total VOCs	20.0	22,898			83,359	106,277
total suspended particulates (TSP)	35.3	17,987	1,045			19,067
carbon monoxide	155	148,123				148,277
acetaldehyde					584	584
1,3-butadiene		132				132
antimony & compounds	0.00180		0.00730			0.00910
arsenic & compounds	2.47×10^{-04}		0.0157			0.0159
cadmium & compounds	0.00176	5.58	0.0261			5.60
chromium (III) compounds	5.24×10^{-04}	0.254	0.245			0.500
chromium (VI) compounds	2.17×10^{-04}	0.105	0.0102			0.116

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
cobalt & compounds	1.06×10^{-04}		0.155			0.155
copper & compounds	4.58×10^{-04}	0.360	0.0907			0.451
manganese & compounds	0.0166	1.98	1.10			3.09
mercury & compounds	4.58×10^{-04}		0.0156			0.0161
nickel & compounds	3.17×10^{-04}	0.360	0.0657			0.426
polychlorinated dioxins and furans	2.00×10^{-09}	9.31×10^{-07}				9.33×10^{-07}
selenium & compounds	2.12×10^{-04}		0.00105			0.00127
zinc & compounds	0.00596	8.27	0.645			8.93
nitrogen dioxide	0.269	212				212
nitric oxide	3.33	2,622		1,713		4,338
methyl alcohol					754	754
acetylene	0.381	2,133				2,133
ethylene	3.89	4,852				4,856
ethane		2,658				2,658
ethyl alcohol					751	751
1-propyne		104				104
propylene		998				998
propane	0.381	88.9				89.2
acetone					561	561
1-butene	1.18	206				207
n-butane	0.381	60.9				61.3
2-methylpropane; isobutane	0.381	27.9				28.3
isoprene					69,584	69,584
1-pentene	2.36					2.36
3-methyl-1-butene		43.2				43.2
n-pentane	0.381					0.381
n-hexane	2.79					2.79
n-heptane	2.79					2.79
n-octane	2.77					2.77
4-ethylphenanthrene		0.180				0.180
anthracene		0.180				0.180
fluoranthene		0.180				0.180
benzo(c)phenanthrene		0.180				0.180
chrysene		0.180				0.180
benzo(a)pyrene		0.180				0.180

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
benzo(e)pyrene		0.180				0.180
benzo(g,h,i)perylene		0.180				0.180
isomers of butene		234				234
isomers of pentane		38.1				38.1
monoterpenes					11,126	11,126
isomers of pentene	2.36					2.36

Table A5. Emissions (t/season) of all substances from all biogenic sources by region in Autumn 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	0.803	59.7		1,852		1,912
sulfur dioxide	0.0727	5.97				6.04
particulate matter < 10 µm	4.01×10^{-05}	0.0537	0.0853			0.139
particulate matter < 2.5 µm	2.94	358	91.7			453
polycyclic aromatic hydrocarbons	1.70	328	35.9			366
total suspended particulates (TSP)		0.0430				0.0430
carbon monoxide	2.46	191			22,436	22,630
acetaldehyde	3.34	537	184			725
1,3-butadiene	19.9	3,343				3,363
lead & compounds					115	115
antimony & compounds		1.10				1.10
arsenic & compounds	1.70×10^{-04}		0.00119			0.00136
cadmium & compounds	2.34×10^{-05}		0.00286			0.00288
chromium (III) compounds	1.67×10^{-04}	0.167	0.00412			0.171
chromium (VI) compounds	4.96×10^{-05}	0.00760	0.0400			0.0477
cobalt & compounds	2.05×10^{-05}	0.00315	0.00166			0.00483
copper & compounds	1.00×10^{-05}		0.0215			0.0215
manganese & compounds	4.34×10^{-05}	0.0107	0.0141			0.0249
mercury & compounds	0.00157	0.0591	0.184			0.245
nickel & compounds	4.34×10^{-05}		0.00238			0.00242
polychlorinated dioxins and furans	3.00×10^{-05}	0.0107	0.0104			0.0211
selenium & compounds	2.98×10^{-10}	2.54×10^{-08}				2.57×10^{-08}
total VOCs	2.00×10^{-05}		2.80×10^{-04}			3.00×10^{-04}
zinc & compounds	5.64×10^{-04}	0.247	0.0705			0.318
nitrogen dioxide	0.0401	2.99				3.03
nitric oxide	0.497	37.0		1,203		1,241
methyl alcohol					148	148
acetylene	0.0467	17.8				17.8
ethylene	0.476	40.5				41.0
ethane		22.2				22.2
ethyl alcohol					147	147
1-propyne		0.869				0.869

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
propylene		8.33				8.33
propane	0.0467	0.742				0.788
acetone					110	110
1-butene	0.145	1.72				1.86
n-butane	0.0467	0.508				0.555
2-methylpropane; isobutane	0.0467	0.233				0.280
isoprene					17,738	17,738
1-pentene	0.290					0.290
3-methyl-1-butene		0.360				0.360
n-pentane	0.0467					0.0467
n-hexane	0.341					0.341
n-heptane	0.341					0.341
n-octane	0.339					0.339
4-ethylphenanthrene		0.00537				0.00537
anthracene		0.00537				0.00537
fluoranthene		0.00537				0.00537
benzo(c)phenanthrene		0.00537				0.00537
chrysene		0.00537				0.00537
benzo(a)pyrene		0.00537				0.00537
benzo(e)pyrene		0.00537				0.00537
benzo(g,h,i)perylene		0.00537				0.00537
isomers of butene		1.95				1.95
isomers of pentane		0.318				0.318
monoterpenes					4,178	4,178
isomers of pentene	0.290					0.290
Sydney						
oxides of nitrogen	0.0697	6.77		204		211
sulfur dioxide	0.00631	0.677				0.683
particulate matter < 10 µm	3.48×10^{-06}	0.00609	0.00546			0.0116
particulate matter < 2.5 µm	0.255	40.6	3.78			44.6
polycyclic aromatic hydrocarbons	0.148	37.2	1.47			38.8
total VOCs		0.00487				0.00487
total suspended particulates (TSP)	0.213	21.7			4,361	4,383
carbon monoxide	0.290	60.9	7.59			68.8
acetaldehyde	1.73	379				381

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
1,3-butadiene					16.0	16.0
lead & compounds		0.125				0.125
antimony & compounds	1.48×10^{-05}		5.15×10^{-05}			6.63×10^{-05}
arsenic & compounds	2.03×10^{-06}		1.15×10^{-04}			1.18×10^{-04}
cadmium & compounds	1.45×10^{-05}	0.0189	1.82×10^{-04}			0.0191
chromium (III) compounds	4.30×10^{-06}	8.61×10^{-04}	0.00173			0.00259
chromium (VI) compounds	1.78×10^{-06}	3.57×10^{-04}	7.17×10^{-05}			4.30×10^{-04}
cobalt & compounds	8.69×10^{-07}		0.00103			0.00103
copper & compounds	3.77×10^{-06}	0.00122	6.28×10^{-04}			0.00185
manganese & compounds	1.36×10^{-04}	0.00670	0.00782			0.0147
mercury & compounds	3.77×10^{-06}		1.07×10^{-04}			1.11×10^{-04}
nickel & compounds	2.61×10^{-06}	0.00122	4.57×10^{-04}			0.00168
polychlorinated dioxins and furans	2.59×10^{-11}	2.88×10^{-09}				2.90×10^{-09}
selenium & compounds	1.74×10^{-06}		9.23×10^{-06}			1.10×10^{-05}
zinc & compounds	4.90×10^{-05}	0.0280	0.00397			0.0320
nitrogen dioxide	0.00348	0.338				0.342
nitric oxide	0.0432	4.19		133		137
methyl alcohol					20.6	20.6
acetylene	0.00405	2.02				2.02
ethylene	0.0414	4.59				4.63
ethane		2.51				2.51
ethyl alcohol					20.5	20.5
1-propyne		0.0984				0.0984
propylene		0.944				0.944
propane	0.00405	0.0840				0.0881
acetone					15.4	15.4
1-butene	0.0126	0.194				0.207
n-butane	0.00405	0.0576				0.0617
2-methylpropane; isobutane	0.00405	0.0264				0.0305
isoprene					3,502	3,502
1-pentene	0.0252					0.0252
3-methyl-1-butene		0.0408				0.0408
n-pentane	0.00405					0.00405
n-hexane	0.0296					0.0296
n-heptane	0.0296					0.0296

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-octane	0.0294					0.0294
4-ethylphenanthrene		6.09×10^{-04}				6.09×10^{-04}
anthracene		6.09×10^{-04}				6.09×10^{-04}
fluoranthene		6.09×10^{-04}				6.09×10^{-04}
benzo(c)phenanthrene		6.09×10^{-04}				6.09×10^{-04}
chrysene		6.09×10^{-04}				6.09×10^{-04}
benzo(a)pyrene		6.09×10^{-04}				6.09×10^{-04}
benzo(e)pyrene		6.09×10^{-04}				6.09×10^{-04}
benzo(g,h,i)perylene		6.09×10^{-04}				6.09×10^{-04}
isomers of butene		0.221				0.221
isomers of pentane		0.0360				0.0360
monoterpenes					787	787
isomers of pentene	0.0252					0.0252
Newcastle						
oxides of nitrogen	0.0151			22.9		22.9
sulfur dioxide	0.00137					0.00137
particulate matter < 10 µm	7.55×10^{-07}	0.00247				0.00247
particulate matter < 2.5 µm	0.0553	3.28				3.33
total VOCs	0.0321	1.28				1.32
total suspended particulates (TSP)	0.0463				518	518
carbon monoxide	0.0629	6.58				6.64
acetaldehyde	0.375					0.375
lead & compounds					1.38	1.38
antimony & compounds	3.21×10^{-06}	4.19×10^{-05}				4.51×10^{-05}
arsenic & compounds	4.40×10^{-07}	1.03×10^{-04}				1.03×10^{-04}
cadmium & compounds	3.14×10^{-06}	1.44×10^{-04}				1.47×10^{-04}
chromium (III) compounds	9.34×10^{-07}	0.00141				0.00141
chromium (VI) compounds	3.87×10^{-07}	5.83×10^{-05}				5.87×10^{-05}
cobalt & compounds	1.89×10^{-07}	7.25×10^{-04}				7.25×10^{-04}
copper & compounds	8.17×10^{-07}	4.90×10^{-04}				4.91×10^{-04}
manganese & compounds	2.96×10^{-05}	0.00651				0.00654
mercury & compounds	8.17×10^{-07}	8.22×10^{-05}				8.30×10^{-05}
nickel & compounds	5.66×10^{-07}	3.61×10^{-04}				3.61×10^{-04}
polychlorinated dioxins and furans	5.61×10^{-12}					5.61×10^{-12}
selenium & compounds	3.77×10^{-07}	1.07×10^{-05}				1.11×10^{-05}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
zinc & compounds	1.06×10^{-05}		0.00220			0.00221
nitrogen dioxide	7.56×10^{-04}					7.56×10^{-04}
nitric oxide	0.00937			14.9		14.9
methyl alcohol					1.78	1.78
acetylene	8.79×10^{-04}					8.79×10^{-04}
ethylene	0.00898					0.00898
ethyl alcohol					1.77	1.77
propane	8.79×10^{-04}					8.79×10^{-04}
acetone					1.32	1.32
1-butene	0.00273					0.00273
n-butane	8.79×10^{-04}					8.79×10^{-04}
2-methylpropane; isobutane	8.79×10^{-04}					8.79×10^{-04}
isoprene					402	402
1-pentene	0.00546					0.00546
n-pentane	8.79×10^{-04}					8.79×10^{-04}
n-hexane	0.00643					0.00643
n-heptane	0.00643					0.00643
n-octane	0.00639					0.00639
monoterpenes					110	110
isomers of pentene	0.00546					0.00546
Wollongong						
oxides of nitrogen				11.7		11.7
particulate matter < 10 µm			1.68×10^{-05}			1.68×10^{-05}
particulate matter < 2.5 µm			0.00928			0.00928
total VOCs			0.00361			0.00361
total suspended particulates (TSP)					485	485
acetaldehyde			0.0186			0.0186
lead & compounds					0.922	0.922
antimony & compounds			1.30×10^{-07}			1.30×10^{-07}
arsenic & compounds			2.79×10^{-07}			2.79×10^{-07}
cadmium & compounds			4.66×10^{-07}			4.66×10^{-07}
chromium (III) compounds			4.38×10^{-06}			4.38×10^{-06}
chromium (VI) compounds			1.82×10^{-07}			1.82×10^{-07}
cobalt & compounds			2.78×10^{-06}			2.78×10^{-06}
copper & compounds			1.62×10^{-06}			1.62×10^{-06}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
manganese & compounds			1.96×10^{-05}			1.96×10^{-05}
mercury & compounds			2.79×10^{-07}			2.79×10^{-07}
nickel & compounds			1.17×10^{-06}			1.17×10^{-06}
selenium & compounds			1.86×10^{-08}			1.86×10^{-08}
zinc & compounds			1.16×10^{-05}			1.16×10^{-05}
nitric oxide				7.63		7.63
methyl alcohol					1.19	1.19
ethyl alcohol					1.19	1.19
acetone					0.886	0.886
isoprene					369	369
monoterpenes					111	111
Non-Urban						
oxides of nitrogen	0.718	52.9		1,613		1,667
sulfur dioxide	0.0650	5.29				5.36
lead & compounds	3.58×10^{-05}	0.0476	0.0773			0.125
particulate matter < 10 µm	2.63	318	84.7			405
particulate matter < 2.5 µm	1.52	291	33.1			326
polycyclic aromatic hydrocarbons		0.0381				0.0381
total VOCs	2.20	169			17,072	17,244
total suspended particulates (TSP)	2.98	476	170			649
carbon monoxide	17.8	2,965				2,982
acetaldehyde					96.4	96.4
1,3-butadiene		0.977				0.977
antimony & compounds	1.52×10^{-04}		0.00110			0.00125
arsenic & compounds	2.09×10^{-05}		0.00264			0.00266
cadmium & compounds	1.49×10^{-04}	0.148	0.00380			0.152
chromium (III) compounds	4.43×10^{-05}	0.00674	0.0369			0.0437
chromium (VI) compounds	1.84×10^{-05}	0.00279	0.00153			0.00434
cobalt & compounds	8.95×10^{-06}		0.0197			0.0197
copper & compounds	3.88×10^{-05}	0.00953	0.0130			0.0226
manganese & compounds	0.00141	0.0524	0.170			0.224
mercury & compounds	3.88×10^{-05}		0.00219			0.00223
nickel & compounds	2.69×10^{-05}	0.00953	0.00954			0.0191
polychlorinated dioxins and furans	2.66×10^{-10}	2.25×10^{-08}				2.28×10^{-08}
selenium & compounds	1.79×10^{-05}		2.60×10^{-04}			2.78×10^{-04}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
zinc & compounds	5.04×10^{-04}	0.219	0.0643			0.284
nitrogen dioxide	0.0359	2.65				2.68
nitric oxide	0.445	32.8		1,048		1,082
methyl alcohol					125	125
acetylene	0.0417	15.8				15.8
ethylene	0.426	35.9				36.3
ethane		19.7				19.7
ethyl alcohol					124	124
1-propyne		0.770				0.770
propylene		7.38				7.38
propane	0.0417	0.657				0.699
acetone					92.6	92.6
1-butene	0.130	1.52				1.65
n-butane	0.0417	0.451				0.493
2-methylpropane; isobutane	0.0417	0.207				0.248
isoprene					13,465	13,465
1-pentene	0.259					0.259
3-methyl-1-butene		0.319				0.319
n-pentane	0.0417					0.0417
n-hexane	0.305					0.305
n-heptane	0.305					0.305
n-octane	0.303					0.303
4-ethylphenanthrene		0.00476				0.00476
anthracene		0.00476				0.00476
fluoranthene		0.00476				0.00476
benzo(c)phenanthrene		0.00476				0.00476
chrysene		0.00476				0.00476
benzo(a)pyrene		0.00476				0.00476
benzo(e)pyrene		0.00476				0.00476
benzo(g,h,i)perylene		0.00476				0.00476
isomers of butene		1.73				1.73
isomers of pentane		0.282				0.282
monoterpenes					3,171	3,171
isomers of pentene	0.259					0.259

Table A6. Emissions (t/season) of all substances from all biogenic sources by region in Winter 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	0.803	96.5		1,312		1,410
sulfur dioxide	0.0727	9.65				9.72
particulate matter < 10 µm	4.01×10^{-05}	0.0857	0.279			0.365
particulate matter < 2.5 µm	2.94	571	159			733
polycyclic aromatic hydrocarbons	1.70	524	61.9			587
total VOCs		0.0686				0.0686
total suspended particulates (TSP)	2.46	314			6,782	7,098
carbon monoxide	3.34	857	319			1,179
acetaldehyde	19.9	5,352				5,372
1,3-butadiene					0.108	0.108
lead & compounds		1.81				1.81
antimony & compounds	1.70×10^{-04}		0.00223			0.00240
arsenic & compounds	2.34×10^{-05}		0.00480			0.00482
cadmium & compounds	1.67×10^{-04}	0.266	0.00793			0.274
chromium (III) compounds	4.96×10^{-05}	0.0121	0.0748			0.0869
chromium (VI) compounds	2.05×10^{-05}	0.00502	0.00310			0.00814
cobalt & compounds	1.00×10^{-05}		0.0470			0.0470
copper & compounds	4.34×10^{-05}	0.0171	0.0276			0.0448
manganese & compounds	0.00157	0.0943	0.335			0.430
mercury & compounds	4.34×10^{-05}		0.00475			0.00479
nickel & compounds	3.00×10^{-05}	0.0171	0.0200			0.0372
polychlorinated dioxins and furans	2.98×10^{-10}	4.05×10^{-08}				4.08×10^{-08}
selenium & compounds	2.00×10^{-05}		3.29×10^{-04}			3.49×10^{-04}
zinc & compounds	5.64×10^{-04}	0.394	0.194			0.589
nitrogen dioxide	0.0401	4.82				4.86
nitric oxide	0.497	59.8		853		913
methyl alcohol					0.140	0.140
acetylene	0.0467	29.2				29.3
ethylene	0.476	66.5				67.0
ethane		36.4				36.4
ethyl alcohol					0.139	0.139
1-propyne		1.43				1.43

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
propylene		13.7				13.7
propane	0.0467	1.22				1.26
acetone					0.104	0.104
1-butene	0.145	2.82				2.96
n-butane	0.0467	0.835				0.882
2-methylpropane; isobutane	0.0467	0.383				0.430
isoprene					4,536	4,536
1-pentene	0.290					0.290
3-methyl-1-butene		0.592				0.592
n-pentane	0.0467					0.0467
n-hexane	0.341					0.341
n-heptane	0.341					0.341
n-octane	0.339					0.339
4-ethylphenanthrene		0.00857				0.00857
anthracene		0.00857				0.00857
fluoranthene		0.00857				0.00857
benzo(c)phenanthrene		0.00857				0.00857
chrysene		0.00857				0.00857
benzo(a)pyrene		0.00857				0.00857
benzo(e)pyrene		0.00857				0.00857
benzo(g,h,i)perylene		0.00857				0.00857
isomers of butene		3.20				3.20
isomers of pentane		0.522				0.522
monoterpenes					2,245	2,245
isomers of pentene	0.290					0.290
Sydney						
oxides of nitrogen	0.0697	81.4		144		225
sulfur dioxide	0.00631	8.14				8.15
particulate matter < 10 µm	3.48×10^{-06}	0.0732	0.0571			0.130
particulate matter < 2.5 µm	0.255	488	32.5			521
polycyclic aromatic hydrocarbons	0.148	448	12.6			460
total VOCs		0.0586				0.0586
total suspended particulates (TSP)	0.213	261			1,363	1,624
carbon monoxide	0.290	732	65.2			798
acetaldehyde	1.73	4,558				4,560

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
1,3-butadiene					0.00796	0.00796
lead & compounds		1.50				1.50
antimony & compounds	1.48×10^{-05}		4.54×10^{-04}			4.69×10^{-04}
arsenic & compounds	2.03×10^{-06}		9.80×10^{-04}			9.82×10^{-04}
cadmium & compounds	1.45×10^{-05}	0.227	0.00162			0.229
chromium (III) compounds	4.30×10^{-06}	0.0104	0.0153			0.0256
chromium (VI) compounds	1.78×10^{-06}	0.00429	6.33×10^{-04}			0.00493
cobalt & compounds	8.69×10^{-07}		0.00959			0.00959
copper & compounds	3.77×10^{-06}	0.0146	0.00563			0.0203
manganese & compounds	1.36×10^{-04}	0.0806	0.0683			0.149
mercury & compounds	3.77×10^{-06}		9.70×10^{-04}			9.74×10^{-04}
nickel & compounds	2.61×10^{-06}	0.0146	0.00408			0.0187
polychlorinated dioxins and furans	2.59×10^{-11}	3.46×10^{-08}				3.46×10^{-08}
selenium & compounds	1.74×10^{-06}		6.72×10^{-05}			6.89×10^{-05}
zinc & compounds	4.90×10^{-05}	0.337	0.0397			0.377
nitrogen dioxide	0.00348	4.07				4.08
nitric oxide	0.0432	50.5		93.3		144
methyl alcohol					0.0103	0.0103
acetylene	0.00405	24.3				24.3
ethylene	0.0414	55.3				55.3
ethane		30.3				30.3
ethyl alcohol					0.0102	0.0102
1-propyne		1.19				1.19
propylene		11.4				11.4
propane	0.00405	1.01				1.02
acetone					0.00765	0.00765
1-butene	0.0126	2.34				2.35
n-butane	0.00405	0.694				0.698
2-methylpropane; isobutane	0.00405	0.318				0.322
isoprene					939	939
1-pentene	0.0252					0.0252
3-methyl-1-butene		0.492				0.492
n-pentane	0.00405					0.00405
n-hexane	0.0296					0.0296
n-heptane	0.0296					0.0296

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-octane	0.0294					0.0294
4-ethylphenanthrene		0.00732				0.00732
anthracene		0.00732				0.00732
fluoranthene		0.00732				0.00732
benzo(c)phenanthrene		0.00732				0.00732
chrysene		0.00732				0.00732
benzo(a)pyrene		0.00732				0.00732
benzo(e)pyrene		0.00732				0.00732
benzo(g,h,i)perylene		0.00732				0.00732
isomers of butene		2.66				2.66
isomers of pentane		0.434				0.434
monoterpenes					424	424
isomers of pentene	0.0252					0.0252
Newcastle						
oxides of nitrogen	0.0151			16.5		16.5
sulfur dioxide	0.00137					0.00137
particulate matter < 10 µm	7.55×10^{-07}		0.0119			0.0119
particulate matter < 2.5 µm	0.0553		7.34			7.39
total VOCs	0.0321		2.86			2.89
total suspended particulates (TSP)	0.0463				171	171
carbon monoxide	0.0629		14.7			14.8
acetaldehyde	0.375					0.375
lead & compounds					5.42×10^{-04}	5.42×10^{-04}
antimony & compounds	3.21×10^{-06}		1.01×10^{-04}			1.05×10^{-04}
arsenic & compounds	4.40×10^{-07}		2.23×10^{-04}			2.23×10^{-04}
cadmium & compounds	3.14×10^{-06}		3.60×10^{-04}			3.63×10^{-04}
chromium (III) compounds	9.34×10^{-07}		0.00341			0.00341
chromium (VI) compounds	3.87×10^{-07}		1.41×10^{-04}			1.42×10^{-04}
cobalt & compounds	1.89×10^{-07}		0.00209			0.00209
copper & compounds	8.17×10^{-07}		0.00125			0.00125
manganese & compounds	2.96×10^{-05}		0.0153			0.0154
mercury & compounds	8.17×10^{-07}		2.14×10^{-04}			2.15×10^{-04}
nickel & compounds	5.66×10^{-07}		9.07×10^{-04}			9.07×10^{-04}
polychlorinated dioxins and furans	5.61×10^{-12}					5.61×10^{-12}
selenium & compounds	3.77×10^{-07}		1.63×10^{-05}			1.67×10^{-05}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
zinc & compounds	1.06×10^{-05}		0.00842			0.00843
nitrogen dioxide	7.56×10^{-04}					7.56×10^{-04}
nitric oxide	0.00937			10.7		10.7
methyl alcohol					7.00×10^{-04}	7.00×10^{-04}
acetylene	8.79×10^{-04}					8.79×10^{-04}
ethylene	0.00898					0.00898
ethyl alcohol					6.97×10^{-04}	6.97×10^{-04}
propane	8.79×10^{-04}					8.79×10^{-04}
acetone					5.21×10^{-04}	5.21×10^{-04}
1-butene	0.00273					0.00273
n-butane	8.79×10^{-04}					8.79×10^{-04}
2-methylpropane; isobutane	8.79×10^{-04}					8.79×10^{-04}
isoprene					111	111
1-pentene	0.00546					0.00546
n-pentane	8.79×10^{-04}					8.79×10^{-04}
n-hexane	0.00643					0.00643
n-heptane	0.00643					0.00643
n-octane	0.00639					0.00639
monoterpenes					60.0	60.0
isomers of pentene	0.00546					0.00546
Wollongong						
oxides of nitrogen		1.54		8.77		10.3
sulfur dioxide		0.154				0.154
particulate matter < 10 µm		0.00139	4.92×10^{-04}			0.00188
particulate matter < 2.5 µm		9.26	0.272			9.54
polycyclic aromatic hydrocarbons		8.49	0.106			8.60
total VOCs		0.00111				0.00111
total suspended particulates (TSP)		4.94			173	178
carbon monoxide		13.9	0.546			14.4
1,3-butadiene		86.5				86.5
lead & compounds		0.0285				0.0285
antimony & compounds			3.82×10^{-06}			3.82×10^{-06}
arsenic & compounds			8.19×10^{-06}			8.19×10^{-06}
cadmium & compounds		0.00431	1.37×10^{-05}			0.00432
chromium (III) compounds		1.97×10^{-04}	1.28×10^{-04}			3.25×10^{-04}

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
chromium (VI) compounds		8.14×10^{-05}	5.33×10^{-06}			8.68×10^{-05}
cobalt & compounds			8.14×10^{-05}			8.14×10^{-05}
copper & compounds		2.78×10^{-04}	4.75×10^{-05}			3.25×10^{-04}
manganese & compounds		0.00153	5.74×10^{-04}			0.00210
mercury & compounds			8.19×10^{-06}			8.19×10^{-06}
nickel & compounds		2.78×10^{-04}	3.44×10^{-05}			3.12×10^{-04}
polychlorinated dioxins and furans		6.56×10^{-10}				6.56×10^{-10}
selenium & compounds			5.46×10^{-07}			5.46×10^{-07}
zinc & compounds		0.00639	3.40×10^{-04}			0.00673
nitrogen dioxide		0.0772				0.0772
nitric oxide		0.957		5.70		6.66
acetylene		0.460				0.460
ethylene		1.05				1.05
ethane		0.574				0.574
1-propyne		0.0225				0.0225
propylene		0.215				0.215
propane		0.0192				0.0192
1-butene		0.0444				0.0444
n-butane		0.0131				0.0131
2-methylpropane; isobutane		0.00603				0.00603
isoprene					110	110
3-methyl-1-butene		0.00931				0.00931
4-ethylphenanthrene		1.39×10^{-04}				1.39×10^{-04}
anthracene		1.39×10^{-04}				1.39×10^{-04}
fluoranthene		1.39×10^{-04}				1.39×10^{-04}
benzo(c)phenanthrene		1.39×10^{-04}				1.39×10^{-04}
chrysene		1.39×10^{-04}				1.39×10^{-04}
benzo(a)pyrene		1.39×10^{-04}				1.39×10^{-04}
benzo(e)pyrene		1.39×10^{-04}				1.39×10^{-04}
benzo(g,h,i)perylene		1.39×10^{-04}				1.39×10^{-04}
isomers of butene		0.0504				0.0504
isomers of pentane		0.00822				0.00822
monoterpenes					63.6	63.6
Non-Urban						
oxides of nitrogen	0.718	13.5		1,143		1,158

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
sulfur dioxide	0.0650	1.35				1.41
lead & compounds	3.58×10^{-05}	0.0110	0.210			0.221
particulate matter < 10 µm	2.63	73.7	119			195
particulate matter < 2.5 µm	1.52	67.5	46.3			115
polycyclic aromatic hydrocarbons		0.00884				0.00884
total VOCs	2.20	48.2			5,075	5,125
total suspended particulates (TSP)	2.98	110	239			352
carbon monoxide	17.8	707				725
acetaldehyde					0.0998	0.0998
1,3-butadiene		0.278				0.278
antimony & compounds	1.52×10^{-04}		0.00167			0.00182
arsenic & compounds	2.09×10^{-05}		0.00359			0.00361
cadmium & compounds	1.49×10^{-04}	0.0343	0.00594			0.0403
chromium (III) compounds	4.43×10^{-05}	0.00156	0.0560			0.0576
chromium (VI) compounds	1.84×10^{-05}	6.48×10^{-04}	0.00232			0.00299
cobalt & compounds	8.95×10^{-06}		0.0352			0.0352
copper & compounds	3.88×10^{-05}	0.00221	0.0206			0.0229
manganese & compounds	0.00141	0.0122	0.250			0.264
mercury & compounds	3.88×10^{-05}		0.00356			0.00360
nickel & compounds	2.69×10^{-05}	0.00221	0.0150			0.0172
polychlorinated dioxins and furans	2.66×10^{-10}	5.26×10^{-09}				5.53×10^{-09}
selenium & compounds	1.79×10^{-05}		2.45×10^{-04}			2.63×10^{-04}
zinc & compounds	5.04×10^{-04}	0.0508	0.146			0.197
nitrogen dioxide	0.0359	0.674				0.710
nitric oxide	0.445	8.35		743		752
methyl alcohol					0.129	0.129
acetylene	0.0417	4.49				4.53
ethylene	0.426	10.2				10.6
ethane		5.59				5.59
ethyl alcohol					0.128	0.128
1-propyne		0.219				0.219
propylene		2.10				2.10
propane	0.0417	0.187				0.229
acetone					0.0958	0.0958
1-butene	0.130	0.433				0.562

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
n-butane	0.0417	0.128				0.170
2-methylpropane; isobutane	0.0417	0.0588				0.101
isoprene					3,376	3,376
1-pentene	0.259					0.259
3-methyl-1-butene		0.0908				0.0908
n-pentane	0.0417					0.0417
n-hexane	0.305					0.305
n-heptane	0.305					0.305
n-octane	0.303					0.303
4-ethylphenanthrene		0.00110				0.00110
anthracene		0.00110				0.00110
fluoranthene		0.00110				0.00110
benzo(c)phenanthrene		0.00110				0.00110
chrysene		0.00110				0.00110
benzo(a)pyrene		0.00110				0.00110
benzo(e)pyrene		0.00110				0.00110
benzo(g,h,i)perylene		0.00110				0.00110
isomers of butene		0.492				0.492
isomers of pentane		0.0801				0.0801
monoterpenes					1,698	1,698
isomers of pentene	0.259					0.259

Table A7. Contributions (%) to emissions of all substances from all biogenic sources by region in Spring 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.13	12		88	
sulfur dioxide	0.97	99			
particulate matter < 10 µm	0.018	14	86		
particulate matter < 2.5 µm	0.89	65	34		
polycyclic aromatic hydrocarbons	0.70	81	18		
total VOCs		100			
total suspended particulates (TSP)	0.037	3.8			96
carbon monoxide	0.60	59	41		
acetaldehyde	0.66	99			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds	9.8		90		
arsenic & compounds	0.68		99		
cadmium & compounds	0.16	95	5.3		
chromium (III) compounds	0.087	8.0	92		
chromium (VI) compounds	0.50	46	53		
cobalt & compounds	0.030		100		
copper & compounds	0.17	25	75		
manganese & compounds	0.58	13	86		
mercury & compounds	1.3		99		
nickel & compounds	0.15	31	68		
polychlorinated dioxins and furans	1.2	99			
selenium & compounds	7.8		92		
zinc & compounds	0.20	52	47		
nitrogen dioxide	1.1	99			
nitric oxide	0.13	12		88	
methyl alcohol					100
acetylene	0.20	100			
ethylene	0.88	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
propylene		100			
propane	4.5	95			
acetone					100
1-butene	6.0	94			
n-butane	6.4	94			
2-methylpropane; isobutane	13	87			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Sydney					
oxides of nitrogen	0.087	28		71	
sulfur dioxide	0.28	100			
particulate matter < 10 µm	0.0080	25	75		
particulate matter < 2.5 µm	0.28	79	21		
polycyclic aromatic hydrocarbons	0.20	90	9.9		
total VOCs		100			
total suspended particulates (TSP)	0.017	5.8			94
carbon monoxide	0.20	74	26		
acetaldehyde	0.18	100			
1,3-butadiene					100

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		100			
antimony & compounds	5.4		95		
arsenic & compounds	0.36		100		
cadmium & compounds	0.042	97	2.7		
chromium (III) compounds	0.042	15	85		
chromium (VI) compounds	0.18	63	37		
cobalt & compounds	0.016		100		
copper & compounds	0.070	40	60		
manganese & compounds	0.27	23	77		
mercury & compounds	0.67		99		
nickel & compounds	0.058	48	52		
polychlorinated dioxins and furans	0.32	100			
selenium & compounds	4.3		96		
zinc & compounds	0.068	68	31		
nitrogen dioxide	0.31	100			
nitric oxide	0.084	27		72	
methyl alcohol					100
acetylene	0.059	100			
ethylene	0.27	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	1.4	99			
acetone					100
1-butene	1.9	98			
n-butane	2.0	98			
2-methylpropane; isobutane	4.3	96			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Newcastle					
oxides of nitrogen	0.23	2.1		98	
sulfur dioxide	9.0	91			
particulate matter < 10 µm	0.0068	0.71	99		
particulate matter < 2.5 µm	0.78	7.4	92		
polycyclic aromatic hydrocarbons	1.0	16	83		
total VOCs		100			
total suspended particulates (TSP)	0.033	0.26			100
carbon monoxide	0.45	5.7	94		
acetaldehyde	5.3	95			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds	3.4		97		
arsenic & compounds	0.22		100		
cadmium & compounds	0.55	43	57		
chromium (III) compounds	0.030	0.37	100		
chromium (VI) compounds	0.29	3.5	96		
cobalt & compounds	0.0100		100		
copper & compounds	0.072	1.4	99		
manganese & compounds	0.21	0.63	99		
mercury & compounds	0.42		100		
nickel & compounds	0.068	1.9	98		
polychlorinated dioxins and furans	8.7	91			
selenium & compounds	2.6		97		
zinc & compounds	0.13	4.5	95		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
nitrogen dioxide	9.8	90			
nitric oxide	0.22	2.0		98	
methyl alcohol					100
acetylene	2.5	97			
ethylene	10	90			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	38	62			
acetone					100
1-butene	45	55			
n-butane	48	52			
2-methylpropane; isobutane	66	34			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Wollongong					
oxides of nitrogen		12		88	
sulfur dioxide		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
particulate matter < 10 µm		23	77		
particulate matter < 2.5 µm		78	22		
polycyclic aromatic hydrocarbons		90	10		
total VOCs		100			
total suspended particulates (TSP)		1.5			99
carbon monoxide		73	27		
acetaldehyde		100			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds			100		
arsenic & compounds			100		
cadmium & compounds		97	2.9		
chromium (III) compounds		14	86		
chromium (VI) compounds		62	38		
cobalt & compounds			100		
copper & compounds		38	62		
manganese & compounds		22	78		
mercury & compounds			100		
nickel & compounds		46	54		
polychlorinated dioxins and furans		100			
selenium & compounds			100		
zinc & compounds		67	33		
nitrogen dioxide		100			
nitric oxide		11		89	
methyl alcohol					100
acetylene		100			
ethylene		100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane		100			
acetone					100
1-butene		100			
n-butane		100			
2-methylpropane; isobutane		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
isoprene					100
3-methyl-1-butene		100			
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
Non-Urban					
oxides of nitrogen	0.14	10		90	
sulfur dioxide	1.3	99			
lead & compounds	0.021	13	87		
particulate matter < 10 µm	1.1	61	37		
particulate matter < 2.5 µm	0.92	79	20		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.043	3.5			96
total suspended particulates (TSP)	0.76	55	45		
carbon monoxide	0.88	99			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	11		89		
arsenic & compounds	0.79		99		
cadmium & compounds	0.21	94	6.1		
chromium (III) compounds	0.10	6.9	93		
chromium (VI) compounds	0.62	42	57		
cobalt & compounds	0.035		100		
copper & compounds	0.20	22	78		
manganese & compounds	0.68	11	88		
mercury & compounds	1.5		99		
nickel & compounds	0.18	28	72		
polychlorinated dioxins and furans	1.6	98			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
selenium & compounds	8.9		91		
zinc & compounds	0.25	49	51		
nitrogen dioxide	1.4	99			
nitric oxide	0.14	9.6		90	
methyl alcohol					100
acetylene	0.25	100			
ethylene	1.1	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	5.7	94			
acetone					100
1-butene	7.5	93			
n-butane	8.0	92			
2-methylpropane; isobutane	16	84			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				

Table A8. Contributions (%) to emissions of all substances from all biogenic sources by region in Summer 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.077	61		39	
sulfur dioxide	0.11	100			
particulate matter < 10 µm	0.015	64	36		
particulate matter < 2.5 µm	0.25	95	4.6		
polycyclic aromatic hydrocarbons	0.16	98	2.0		
total VOCs		100			
total suspended particulates (TSP)	0.017	19			81
carbon monoxide	0.18	94	6.0		
acetaldehyde	0.10	100			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds	18		82		
arsenic & compounds	1.4		99		
cadmium & compounds	0.031	99	0.51		
chromium (III) compounds	0.099	48	51		
chromium (VI) compounds	0.18	90	9.6		
cobalt & compounds	0.062		100		
copper & compounds	0.099	78	22		
manganese & compounds	0.52	62	38		
mercury & compounds	2.6		97		
nickel & compounds	0.073	83	17		
polychlorinated dioxins and furans	0.21	100			
selenium & compounds	15		85		
zinc & compounds	0.066	92	7.9		
nitrogen dioxide	0.13	100			
nitric oxide	0.076	60		40	
methyl alcohol					100
acetylene	0.018	100			
ethylene	0.080	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
propylene		100			
propane	0.42	100			
acetone					100
1-butene	0.57	99			
n-butane	0.62	99			
2-methylpropane; isobutane	1.3	99			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Sydney					
oxides of nitrogen	0.061	61		39	
sulfur dioxide	0.091	100			
particulate matter < 10 µm	0.0099	53	47		
particulate matter < 2.5 µm	0.19	93	6.7		
polycyclic aromatic hydrocarbons	0.13	97	3.0		
total VOCs		100			
total suspended particulates (TSP)	0.0088	13			87
carbon monoxide	0.14	91	8.8		
acetaldehyde	0.082	100			
1,3-butadiene					100

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		100			
antimony & compounds	10		90		
arsenic & compounds	0.74		99		
cadmium & compounds	0.025	99	0.78		
chromium (III) compounds	0.062	38	62		
chromium (VI) compounds	0.14	86	14		
cobalt & compounds	0.032		100		
copper & compounds	0.071	70	30		
manganese & compounds	0.34	52	48		
mercury & compounds	1.4		99		
nickel & compounds	0.053	77	23		
polychlorinated dioxins and furans	0.17	100			
selenium & compounds	8.7		91		
zinc & compounds	0.050	88	12		
nitrogen dioxide	0.10	100			
nitric oxide	0.060	60		40	
methyl alcohol					100
acetylene	0.014	100			
ethylene	0.063	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	0.34	100			
acetone					100
1-butene	0.45	100			
n-butane	0.49	100			
2-methylpropane; isobutane	1.1	99			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Newcastle					
oxides of nitrogen	0.29	10		89	
sulfur dioxide	2.5	98			
particulate matter < 10 µm	0.028	5.4	95		
particulate matter < 2.5 µm	2.2	39	58		
polycyclic aromatic hydrocarbons	2.2	60	38		
total VOCs		100			
total suspended particulates (TSP)	0.022	1.1			99
carbon monoxide	1.4	33	66		
acetaldehyde	2.3	98			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds	14		86		
arsenic & compounds	1.0		99		
cadmium & compounds	0.60	86	14		
chromium (III) compounds	0.13	2.9	97		
chromium (VI) compounds	1.0	23	76		
cobalt & compounds	0.044		100		
copper & compounds	0.29	10	89		
manganese & compounds	0.92	5.0	94		
mercury & compounds	1.9		98		
nickel & compounds	0.27	14	86		
polychlorinated dioxins and furans	4.5	95			
selenium & compounds	11		89		
zinc & compounds	0.44	27	72		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
nitrogen dioxide	2.7	97			
nitric oxide	0.28	9.8		90	
methyl alcohol					100
acetylene	0.39	100			
ethylene	1.7	98			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	8.6	91			
acetone					100
1-butene	11	89			
n-butane	12	88			
2-methylpropane; isobutane	23	77			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Wollongong					
oxides of nitrogen		0.62		99	
sulfur dioxide		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
particulate matter < 10 µm		9.4	91		
particulate matter < 2.5 µm		55	45		
polycyclic aromatic hydrocarbons		75	25		
total VOCs		100			
total suspended particulates (TSP)		0.027			100
carbon monoxide		48	52		
acetaldehyde		100			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds			100		
arsenic & compounds			100		
cadmium & compounds		92	8.0		
chromium (III) compounds		5.3	95		
chromium (VI) compounds		36	64		
cobalt & compounds			100		
copper & compounds		18	82		
manganese & compounds		8.9	91		
mercury & compounds			100		
nickel & compounds		23	77		
polychlorinated dioxins and furans		100			
selenium & compounds			100		
zinc & compounds		41	59		
nitrogen dioxide		100			
nitric oxide		0.60		99	
methyl alcohol					100
acetylene		100			
ethylene		100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane		100			
acetone					100
1-butene		100			
n-butane		100			
2-methylpropane; isobutane		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
isoprene					100
3-methyl-1-butene		100			
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
Non-Urban					
oxides of nitrogen	0.078	62		38	
sulfur dioxide	0.11	100			
lead & compounds	0.015	66	34		
particulate matter < 10 µm	0.25	96	4.1		
particulate matter < 2.5 µm	0.16	98	1.8		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.019	22			78
total suspended particulates (TSP)	0.18	94	5.5		
carbon monoxide	0.10	100			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	20		80		
arsenic & compounds	1.6		98		
cadmium & compounds	0.031	100	0.47		
chromium (III) compounds	0.10	51	49		
chromium (VI) compounds	0.19	91	8.8		
cobalt & compounds	0.068		100		
copper & compounds	0.10	80	20		
manganese & compounds	0.54	64	35		
mercury & compounds	2.8		97		
nickel & compounds	0.075	84	15		
polychlorinated dioxins and furans	0.21	100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
selenium & compounds	17		83		
zinc & compounds	0.067	93	7.2		
nitrogen dioxide	0.13	100			
nitric oxide	0.077	60		39	
methyl alcohol					100
acetylene	0.018	100			
ethylene	0.080	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	0.43	100			
acetone					100
1-butene	0.57	99			
n-butane	0.62	99			
2-methylpropane; isobutane	1.3	99			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				

Table A9. Contributions (%) to emissions of all substances from all biogenic sources by region in Autumn 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.042	3.1		97	
sulfur dioxide	1.2	99			
particulate matter < 10 µm	0.029	39	61		
particulate matter < 2.5 µm	0.65	79	20		
polycyclic aromatic hydrocarbons	0.47	90	9.8		
total suspended particulates (TSP)		100			
carbon monoxide	0.011	0.84			99
acetaldehyde	0.46	74	25		
1,3-butadiene	0.59	99			
lead & compounds					100
antimony & compounds		100			
arsenic & compounds	12		88		
cadmium & compounds	0.81		99		
chromium (III) compounds	0.098	97	2.4		
chromium (VI) compounds	0.10	16	84		
cobalt & compounds	0.43	65	34		
copper & compounds	0.047		100		
manganese & compounds	0.17	43	57		
mercury & compounds	0.64	24	75		
nickel & compounds	1.8		98		
polychlorinated dioxins and furans	0.14	51	49		
selenium & compounds	1.2	99			
total VOCs	6.7		93		
zinc & compounds	0.18	78	22		
nitrogen dioxide	1.3	99			
nitric oxide	0.040	3.0		97	
methyl alcohol					100
acetylene	0.26	100			
ethylene	1.2	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
propylene		100			
propane	5.9	94			
acetone					100
1-butene	7.8	92			
n-butane	8.4	92			
2-methylpropane; isobutane	17	83			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Sydney					
oxides of nitrogen	0.033	3.2		97	
sulfur dioxide	0.92	99			
particulate matter < 10 µm	0.030	53	47		
particulate matter < 2.5 µm	0.57	91	8.5		
polycyclic aromatic hydrocarbons	0.38	96	3.8		
total VOCs		100			
total suspended particulates (TSP)	0.0049	0.49			100
carbon monoxide	0.42	89	11		
acetaldehyde	0.45	100			
1,3-butadiene					100

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		100			
antimony & compounds	22		78		
arsenic & compounds	1.7		98		
cadmium & compounds	0.076	99	0.95		
chromium (III) compounds	0.17	33	67		
chromium (VI) compounds	0.41	83	17		
cobalt & compounds	0.084		100		
copper & compounds	0.20	66	34		
manganese & compounds	0.93	46	53		
mercury & compounds	3.4		97		
nickel & compounds	0.16	73	27		
polychlorinated dioxins and furans	0.89	99			
selenium & compounds	16		84		
zinc & compounds	0.15	87	12		
nitrogen dioxide	1.0	99			
nitric oxide	0.032	3.1		97	
methyl alcohol					100
acetylene	0.20	100			
ethylene	0.89	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	4.6	95			
acetone					100
1-butene	6.1	94			
n-butane	6.6	93			
2-methylpropane; isobutane	13	87			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Newcastle					
oxides of nitrogen	0.066			100	
sulfur dioxide	100				
particulate matter < 10 µm	0.031		100		
particulate matter < 2.5 µm	1.7		98		
total VOCs	2.4		98		
total suspended particulates (TSP)	0.0089				100
carbon monoxide	0.95		99		
acetaldehyde	100				
lead & compounds					100
antimony & compounds	7.1		93		
arsenic & compounds	0.43		100		
cadmium & compounds	2.1		98		
chromium (III) compounds	0.066		100		
chromium (VI) compounds	0.66		99		
cobalt & compounds	0.026		100		
copper & compounds	0.17		100		
manganese & compounds	0.45		100		
mercury & compounds	0.98		99		
nickel & compounds	0.16		100		
polychlorinated dioxins and furans	100				
selenium & compounds	3.4		97		
zinc & compounds	0.48		100		
nitrogen dioxide	100				
nitric oxide	0.063			100	

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
methyl alcohol					100
acetylene	100				
ethylene	100				
ethyl alcohol					100
propane	100				
acetone					100
1-butene	100				
n-butane	100				
2-methylpropane; isobutane	100				
isoprene					100
1-pentene	100				
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
monoterpenes					100
isomers of pentene	100				
Wollongong					
oxides of nitrogen				100	
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs			100		
total suspended particulates (TSP)					100
acetaldehyde			100		
lead & compounds					100
antimony & compounds			100		
arsenic & compounds			100		
cadmium & compounds			100		
chromium (III) compounds			100		
chromium (VI) compounds			100		
cobalt & compounds			100		
copper & compounds			100		
manganese & compounds			100		
mercury & compounds			100		
nickel & compounds			100		
selenium & compounds			100		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
zinc & compounds			100		
nitric oxide				100	
methyl alcohol					100
ethyl alcohol					100
acetone					100
isoprene					100
monoterpenes					100
Non-Urban					
oxides of nitrogen	0.043	3.2		97	
sulfur dioxide	1.2	99			
lead & compounds	0.029	38	62		
particulate matter < 10 µm	0.65	78	21		
particulate matter < 2.5 µm	0.47	89	10		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.013	0.98			99
total suspended particulates (TSP)	0.46	73	26		
carbon monoxide	0.60	99			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	12		88		
arsenic & compounds	0.79		99		
cadmium & compounds	0.098	97	2.5		
chromium (III) compounds	0.10	15	84		
chromium (VI) compounds	0.42	64	35		
cobalt & compounds	0.045		100		
copper & compounds	0.17	42	58		
manganese & compounds	0.63	23	76		
mercury & compounds	1.7		98		
nickel & compounds	0.14	50	50		
polychlorinated dioxins and furans	1.2	99			
selenium & compounds	6.4		94		
zinc & compounds	0.18	77	23		
nitrogen dioxide	1.3	99			
nitric oxide	0.041	3.0		97	
methyl alcohol					100
acetylene	0.26	100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
ethylene	1.2	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	6.0	94			
acetone					100
1-butene	7.8	92			
n-butane	8.5	92			
2-methylpropane; isobutane	17	83			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				

Table A10. Contributions (%) to emissions of all substances from all biogenic sources by region in Winter 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.057	6.8		93	
sulfur dioxide	0.75	99			
particulate matter < 10 µm	0.011	23	77		
particulate matter < 2.5 µm	0.40	78	22		
polycyclic aromatic hydrocarbons	0.29	89	11		
total VOCs		100			
total suspended particulates (TSP)	0.035	4.4			96
carbon monoxide	0.28	73	27		
acetaldehyde	0.37	100			
1,3-butadiene					100
lead & compounds		100			
antimony & compounds	7.1		93		
arsenic & compounds	0.48		100		
cadmium & compounds	0.061	97	2.9		
chromium (III) compounds	0.057	14	86		
chromium (VI) compounds	0.25	62	38		
cobalt & compounds	0.021		100		
copper & compounds	0.097	38	62		
manganese & compounds	0.37	22	78		
mercury & compounds	0.91		99		
nickel & compounds	0.081	46	54		
polychlorinated dioxins and furans	0.73	99			
selenium & compounds	5.7		94		
zinc & compounds	0.096	67	33		
nitrogen dioxide	0.83	99			
nitric oxide	0.054	6.5		93	
methyl alcohol					100
acetylene	0.16	100			
ethylene	0.71	99			
ethane		100			
ethyl alcohol					100
1-propyne		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
propylene		100			
propane	3.7	96			
acetone					100
1-butene	4.9	95			
n-butane	5.3	95			
2-methylpropane; isobutane	11	89			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Sydney					
oxides of nitrogen	0.031	36		64	
sulfur dioxide	0.077	100			
particulate matter < 10 µm	0.0027	56	44		
particulate matter < 2.5 µm	0.049	94	6.2		
polycyclic aromatic hydrocarbons	0.032	97	2.7		
total VOCs		100			
total suspended particulates (TSP)	0.013	16			84
carbon monoxide	0.036	92	8.2		
acetaldehyde	0.038	100			
1,3-butadiene					100

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		100			
antimony & compounds	3.1		97		
arsenic & compounds	0.21		100		
cadmium & compounds	0.0063	99	0.71		
chromium (III) compounds	0.017	40	60		
chromium (VI) compounds	0.036	87	13		
cobalt & compounds	0.0091		100		
copper & compounds	0.019	72	28		
manganese & compounds	0.092	54	46		
mercury & compounds	0.39		100		
nickel & compounds	0.014	78	22		
polychlorinated dioxins and furans	0.075	100			
selenium & compounds	2.5		97		
zinc & compounds	0.013	89	11		
nitrogen dioxide	0.086	100			
nitric oxide	0.030	35		65	
methyl alcohol					100
acetylene	0.017	100			
ethylene	0.075	100			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	0.40	100			
acetone					100
1-butene	0.53	99			
n-butane	0.58	99			
2-methylpropane; isobutane	1.3	99			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				
Newcastle					
oxides of nitrogen	0.092			100	
sulfur dioxide	100				
particulate matter < 10 µm	0.0063		100		
particulate matter < 2.5 µm	0.75		99		
total VOCs	1.1		99		
total suspended particulates (TSP)	0.027				100
carbon monoxide	0.43		100		
acetaldehyde	100				
lead & compounds					100
antimony & compounds	3.1		97		
arsenic & compounds	0.20		100		
cadmium & compounds	0.87		99		
chromium (III) compounds	0.027		100		
chromium (VI) compounds	0.27		100		
cobalt & compounds	0.0090		100		
copper & compounds	0.065		100		
manganese & compounds	0.19		100		
mercury & compounds	0.38		100		
nickel & compounds	0.062		100		
polychlorinated dioxins and furans	100				
selenium & compounds	2.3		98		
zinc & compounds	0.13		100		
nitrogen dioxide	100				
nitric oxide	0.088			100	

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
methyl alcohol					100
acetylene	100				
ethylene	100				
ethyl alcohol					100
propane	100				
acetone					100
1-butene	100				
n-butane	100				
2-methylpropane; isobutane	100				
isoprene					100
1-pentene	100				
n-pentane	100				
n-hexane	100				
n-heptane	100				
n-octane	100				
monoterpenes					100
isomers of pentene	100				
Wollongong					
oxides of nitrogen		15		85	
sulfur dioxide		100			
particulate matter < 10 µm		74	26		
particulate matter < 2.5 µm		97	2.9		
polycyclic aromatic hydrocarbons		99	1.2		
total VOCs		100			
total suspended particulates (TSP)		2.8			97
carbon monoxide		96	3.8		
1,3-butadiene		100			
lead & compounds		100			
antimony & compounds			100		
arsenic & compounds			100		
cadmium & compounds		100	0.32		
chromium (III) compounds		60	40		
chromium (VI) compounds		94	6.1		
cobalt & compounds			100		
copper & compounds		85	15		
manganese & compounds		73	27		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
mercury & compounds			100		
nickel & compounds		89	11		
polychlorinated dioxins and furans		100			
selenium & compounds			100		
zinc & compounds		95	5.0		
nitrogen dioxide		100			
nitric oxide		14		86	
acetylene		100			
ethylene		100			
ethane		100			
1-propyne		100			
propylene		100			
propane		100			
1-butene		100			
n-butane		100			
2-methylpropane; isobutane		100			
isoprene					100
3-methyl-1-butene		100			
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
Non-Urban					
oxides of nitrogen	0.062	1.2		99	
sulfur dioxide	4.6	95			
lead & compounds	0.016	5.0	95		
particulate matter < 10 µm	1.3	38	61		
particulate matter < 2.5 µm	1.3	59	40		
polycyclic aromatic hydrocarbons		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
total VOCs	0.043	0.94			99
total suspended particulates (TSP)	0.85	31	68		
carbon monoxide	2.5	98			
acetaldehyde					100
1,3-butadiene		100			
antimony & compounds	8.4		92		
arsenic & compounds	0.58		99		
cadmium & compounds	0.37	85	15		
chromium (III) compounds	0.077	2.7	97		
chromium (VI) compounds	0.61	22	78		
cobalt & compounds	0.025		100		
copper & compounds	0.17	9.7	90		
manganese & compounds	0.53	4.6	95		
mercury & compounds	1.1		99		
nickel & compounds	0.16	13	87		
polychlorinated dioxins and furans	4.8	95			
selenium & compounds	6.8		93		
zinc & compounds	0.26	26	74		
nitrogen dioxide	5.1	95			
nitric oxide	0.059	1.1		99	
methyl alcohol					100
acetylene	0.92	99			
ethylene	4.0	96			
ethane		100			
ethyl alcohol					100
1-propyne		100			
propylene		100			
propane	18	82			
acetone					100
1-butene	23	77			
n-butane	25	75			
2-methylpropane; isobutane	42	58			
isoprene					100
1-pentene	100				
3-methyl-1-butene		100			
n-pentane	100				

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
n-hexane	100				
n-heptane	100				
n-octane	100				
4-ethylphenanthrene		100			
anthracene		100			
fluoranthene		100			
benzo(c)phenanthrene		100			
chrysene		100			
benzo(a)pyrene		100			
benzo(e)pyrene		100			
benzo(g,h,i)perylene		100			
isomers of butene		100			
isomers of pentane		100			
monoterpenes					100
isomers of pentene	100				

APPENDIX 3: SUMMARY TABLES OF JULY AND JANUARY WEEKDAY AND WEEKEND DAY EMISSIONS

Table A11. Emissions (tonnes/day) from all biogenic sources, July weekday 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen		0.984		13.9		14.8
sulfur dioxide		0.0984				0.0984
lead & compounds		8.86×10^{-04}	0.00395			0.00483
particulate matter < 10 µm		5.91	2.25			8.16
particulate matter < 2.5 µm		5.41	0.877			6.29
polycyclic aromatic hydrocarbons		7.09×10^{-04}				7.09×10^{-04}
total VOCs		3.15			65.0	68.2
total suspended particulates (TSP)		8.86	4.52			13.4
carbon monoxide		55.1				55.1
acetaldehyde					1.92×10^{-06}	1.92×10^{-06}
1,3-butadiene		0.0182				0.0182
Sydney						
oxides of nitrogen		0.980		1.51		2.49
sulfur dioxide		0.0980				0.0980
lead & compounds		8.82×10^{-04}	8.69×10^{-04}			0.00175
particulate matter < 10 µm		5.88	0.494			6.38
particulate matter < 2.5 µm		5.39	0.192			5.58
polycyclic aromatic hydrocarbons		7.06×10^{-04}				7.06×10^{-04}
total VOCs		3.14			13.0	16.1
total suspended particulates (TSP)		8.82	0.992			9.81
carbon monoxide		54.9				54.9
1,3-butadiene		0.0181				0.0181
Newcastle						
oxides of nitrogen				0.173		0.173
lead & compounds			1.44×10^{-04}			1.44×10^{-04}
particulate matter < 10 µm			0.0873			0.0873
particulate matter < 2.5 µm			0.0340			0.0340
total VOCs					1.64	1.64

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
total suspended particulates (TSP)			0.175			0.175
Wollongong						
oxides of nitrogen				0.0930		0.0930
lead & compounds			2.82×10^{-06}			2.82×10^{-06}
particulate matter < 10 µm			0.00156			0.00156
particulate matter < 2.5 µm			6.06×10^{-04}			6.06×10^{-04}
total VOCs					1.66	1.66
total suspended particulates (TSP)			0.00313			0.00313
Non-Urban						
oxides of nitrogen		0.00422		12.1		12.1
sulfur dioxide		4.22×10^{-04}				4.22×10^{-04}
lead & compounds		3.80×10^{-06}	0.00293			0.00294
particulate matter < 10 µm		0.0253	1.67			1.69
particulate matter < 2.5 µm		0.0232	0.650			0.673
polycyclic aromatic hydrocarbons		3.04×10^{-06}				3.04×10^{-06}
total VOCs		0.0135			48.8	48.8
total suspended particulates (TSP)		0.0380	3.35			3.39
carbon monoxide		110				110
acetaldehyde					1.92×10^{-06}	1.92×10^{-06}
1,3-butadiene		7.79×10^{-05}				7.79×10^{-05}

Table A12. Emissions (tonnes/day) from all biogenic sources, January weekday 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	0.111	209		34.0		243
sulfur dioxide	0.0100	20.9				20.9
lead & compounds	8.71×10^{-06}	0.0888	0.0254			0.114
particulate matter < 10 µm	0.639	592	14.1			606
particulate matter < 2.5 µm	0.371	542	5.50			548
polycyclic aromatic hydrocarbons		0.0710				0.0710
total VOCs	0.413	1130			1595	2726
total suspended particulates (TSP)	0.726	888	28.4			917
carbon monoxide	3.18	7310				7313
acetaldehyde					8.29	8.29
1,3-butadiene		6.52				6.52
Sydney						
oxides of nitrogen	0.00962	14.1		3.77		17.9
sulfur dioxide	8.71×10^{-04}	1.41				1.42
lead & compounds	7.56×10^{-07}	0.00601	0.00377			0.00979
particulate matter < 10 µm	0.0554	40.1	2.09			42.2
particulate matter < 2.5 µm	0.0322	36.7	0.814			37.6
polycyclic aromatic hydrocarbons		0.00481				0.00481
total VOCs	0.0358	76.5			287	363
total suspended particulates (TSP)	0.0630	60.1	4.20			64.4
carbon monoxide	0.276	495				495
acetaldehyde					1.12	1.12
1,3-butadiene		0.441				0.441
Newcastle						
oxides of nitrogen	0.00209	0.186		0.397		0.584
sulfur dioxide	1.89×10^{-04}	0.0186				0.0188
lead & compounds	1.64×10^{-07}	7.90×10^{-05}	6.12×10^{-04}			6.91×10^{-04}
particulate matter < 10 µm	0.0120	0.526	0.342			0.881
particulate matter < 2.5 µm	0.00699	0.482	0.133			0.623
polycyclic aromatic hydrocarbons		6.32×10^{-05}				6.32×10^{-05}
total VOCs	0.00777	1.01			27.0	28.0
total suspended particulates (TSP)	0.0137	0.790	0.687			1.49

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
carbon monoxide	0.0600	6.50				6.56
acetaldehyde					0.0843	0.0843
1,3-butadiene		0.00580				0.00580
Wollongong						
oxides of nitrogen				0.186		0.186
lead & compounds			2.95×10^{-06}			2.95×10^{-06}
particulate matter < 10 µm			0.00163			0.00163
particulate matter < 2.5 µm			6.35×10^{-04}			6.35×10^{-04}
total VOCs					32.0	32.0
total suspended particulates (TSP)			0.00327			0.00327
acetaldehyde					0.0921	0.0921
Non-Urban						
oxides of nitrogen	0.0991	195		29.7		224
sulfur dioxide	0.00897	19.5				19.5
lead & compounds	7.79×10^{-06}	0.0827	0.0210			0.104
particulate matter < 10 µm	0.571	551	11.7			563
particulate matter < 2.5 µm	0.332	505	4.55			510
polycyclic aromatic hydrocarbons		0.0661				0.0661
total VOCs	0.369	1052			1250	2303
total suspended particulates (TSP)	0.649	827	23.5			851
carbon monoxide	2.85	6808				6811
acetaldehyde					6.99	6.99
1,3-butadiene		6.07				6.07

Table A13. Contributions (%) to emissions from all biogenic sources, July weekday 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen		6.6		93	
sulfur dioxide		100			
lead & compounds		18	82		
particulate matter < 10 µm		72	28		
particulate matter < 2.5 µm		86	14		
polycyclic aromatic hydrocarbons		100			
total VOCs		4.6			95
total suspended particulates (TSP)		66	34		
carbon monoxide		100			
acetaldehyde					100
1,3-butadiene		100			
Sydney					
oxides of nitrogen		39		61	
sulfur dioxide		100			
lead & compounds		50	50		
particulate matter < 10 µm		92	7.8		
particulate matter < 2.5 µm		97	3.4		
polycyclic aromatic hydrocarbons		100			
total VOCs		19			81
total suspended particulates (TSP)		90	10		
carbon monoxide		100			
1,3-butadiene		100			
Newcastle					
oxides of nitrogen				100	
lead & compounds			100		
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs					100
total suspended particulates (TSP)			100		
Wollongong					
oxides of nitrogen				100	
lead & compounds			100		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs					100
total suspended particulates (TSP)			100		
Non-Urban					
oxides of nitrogen		0.035		100	
sulfur dioxide		100			
lead & compounds		0.13	100		
particulate matter < 10 µm		1.5	99		
particulate matter < 2.5 µm		3.5	97		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.028			100
total suspended particulates (TSP)		1.1	99		
carbon monoxide		100			
acetaldehyde					100
1,3-butadiene		100			

Table A14. Contributions (%) to emissions from all biogenic sources, January weekday 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.046	86		14	
sulfur dioxide	0.048	100			
lead & compounds	0.0076	78	22		
particulate matter < 10 µm	0.11	98	2.3		
particulate matter < 2.5 µm	0.068	99	1.0		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.015	41			59
total suspended particulates (TSP)	0.079	97	3.1		
carbon monoxide	0.044	100			
acetaldehyde					100
1,3-butadiene		100			
Sydney					
oxides of nitrogen	0.054	79		21	
sulfur dioxide	0.062	100			
lead & compounds	0.0077	61	39		
particulate matter < 10 µm	0.13	95	5.0		
particulate matter < 2.5 µm	0.086	98	2.2		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.0099	21			79
total suspended particulates (TSP)	0.098	93	6.5		
carbon monoxide	0.056	100			
acetaldehyde					100
1,3-butadiene		100			
Newcastle					
oxides of nitrogen	0.36	32		68	
sulfur dioxide	1.0	99			
lead & compounds	0.024	11	89		
particulate matter < 10 µm	1.4	60	39		
particulate matter < 2.5 µm	1.1	77	21		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.028	3.6			96
total suspended particulates (TSP)	0.92	53	46		

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
carbon monoxide	0.91	99			
acetaldehyde					100
1,3-butadiene		100			
Wollongong					
oxides of nitrogen				100	
lead & compounds			100		
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs					100
total suspended particulates (TSP)			100		
acetaldehyde					100
Non-Urban					
oxides of nitrogen	0.044	87		13	
sulfur dioxide	0.046	100			
lead & compounds	0.0075	80	20		
particulate matter < 10 µm	0.10	98	2.1		
particulate matter < 2.5 µm	0.065	99	0.89		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.016	46			54
total suspended particulates (TSP)	0.076	97	2.8		
carbon monoxide	0.042	100			
acetaldehyde					100
1,3-butadiene		100			

Table A15. Emissions (tonnes/day) from all biogenic sources, July weekend day 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen		0.0963		13.9		14.0
sulfur dioxide		0.00963				0.00963
lead & compounds		8.67×10^{-05}	0.00395			0.00403
particulate matter < 10 µm		0.578	2.25			2.83
particulate matter < 2.5 µm		0.530	0.877			1.41
polycyclic aromatic hydrocarbons		6.93×10^{-05}				6.93×10^{-05}
total VOCs		0.308			65.0	65.3
total suspended particulates (TSP)		0.867	4.52			5.39
carbon monoxide		5.39				5.39
acetaldehyde					1.92×10^{-06}	1.92×10^{-06}
1,3-butadiene		0.00178				0.00178
Sydney						
oxides of nitrogen		0.00131		1.51		1.51
sulfur dioxide		1.31×10^{-04}				1.31×10^{-04}
lead & compounds		1.15×10^{-06}	8.69×10^{-04}			8.70×10^{-04}
particulate matter < 10 µm		0.00770	0.494			0.502
particulate matter < 2.5 µm		0.00706	0.192			0.199
polycyclic aromatic hydrocarbons		9.24×10^{-07}				9.24×10^{-07}
total VOCs		0.00434			13.0	13.0
total suspended particulates (TSP)		0.0115	0.992			1.00
carbon monoxide		0.0724				0.0724
1,3-butadiene		2.50×10^{-05}				2.50×10^{-05}
Newcastle						
oxides of nitrogen				0.173		0.173
lead & compounds			1.44×10^{-04}			1.44×10^{-04}
particulate matter < 10 µm			0.0873			0.0873
particulate matter < 2.5 µm			0.0340			0.0340
total VOCs					1.64	1.64
total suspended particulates (TSP)			0.175			0.175
Wollongong						
oxides of nitrogen		0.0581		0.0930		0.151

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
sulfur dioxide		0.00581				0.00581
lead & compounds		5.22×10^{-05}	2.82×10^{-06}			5.51×10^{-05}
particulate matter < 10 µm		0.348	0.00156			0.350
particulate matter < 2.5 µm		0.319	6.06×10^{-04}			0.320
polycyclic aromatic hydrocarbons		4.18×10^{-05}				4.18×10^{-05}
total VOCs		0.186			1.66	1.84
total suspended particulates (TSP)		0.522	0.00313			0.526
carbon monoxide		3.25				3.25
1,3-butadiene		0.00107				0.00107
Non-Urban						
oxides of nitrogen		0.0369		12.1		12.1
sulfur dioxide		0.00369				0.00369
lead & compounds		3.32×10^{-05}	0.00293			0.00297
particulate matter < 10 µm		0.222	1.67			1.89
particulate matter < 2.5 µm		0.203	0.650			0.853
polycyclic aromatic hydrocarbons		2.66×10^{-05}				2.66×10^{-05}
total VOCs		0.118			48.8	48.9
total suspended particulates (TSP)		0.332	3.35			3.68
carbon monoxide		2.21				2.21
acetaldehyde					1.92×10^{-06}	1.92×10^{-06}
1,3-butadiene		6.82×10^{-04}				6.82×10^{-04}

Table A16. Emissions (tonnes/day) from all biogenic sources, January weekend day 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
Greater Metropolitan						
oxides of nitrogen	0.0693	24.3		34.0		58.4
sulfur dioxide	0.00627	2.43				2.44
lead & compounds	5.44×10^{-06}	0.0103	0.0254			0.0358
particulate matter < 10 µm	0.399	69.0	14.1			83.5
particulate matter < 2.5 µm	0.232	63.2	5.50			69.0
polycyclic aromatic hydrocarbons		0.00828				0.00828
total VOCs	0.258	132			1,554	1,686
total suspended particulates (TSP)	0.454	103	28.4			132
carbon monoxide	1.99	852				854
acetaldehyde					8.29	8.29
1,3-butadiene		0.760				0.760
Sydney						
oxides of nitrogen	0.00601	24.1		3.77		27.9
sulfur dioxide	5.44×10^{-04}	2.41				2.41
lead & compounds	4.73×10^{-07}	0.0103	0.00377			0.0140
particulate matter < 10 µm	0.0347	68.4	2.09			70.5
particulate matter < 2.5 µm	0.0201	62.7	0.814			63.5
polycyclic aromatic hydrocarbons		0.00821				0.00821
total VOCs	0.0224	131			281	412
total suspended particulates (TSP)	0.0394	103	4.20			107
carbon monoxide	0.173	845				845
acetaldehyde					1.12	1.12
1,3-butadiene		0.753				0.753
Newcastle						
oxides of nitrogen	0.00130			0.397		0.398
sulfur dioxide	1.18×10^{-04}					1.18×10^{-04}
lead & compounds	1.03×10^{-07}		6.12×10^{-04}			6.12×10^{-04}
particulate matter < 10 µm	0.00752		0.342			0.350
particulate matter < 2.5 µm	0.00437		0.133			0.138
total VOCs	0.00486				26.6	26.6
total suspended particulates (TSP)	0.00855		0.687			0.696
carbon monoxide	0.0375					0.0375

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation	Total
acetaldehyde					0.0843	0.0843
Wollongong						
oxides of nitrogen				0.186		0.186
lead & compounds			2.95×10^{-06}			2.95×10^{-06}
particulate matter < 10 µm			0.00163			0.00163
particulate matter < 2.5 µm			6.35×10^{-04}			6.35×10^{-04}
total VOCs					31.6	31.6
total suspended particulates (TSP)			0.00327			0.00327
acetaldehyde					0.0921	0.0921
Non-Urban						
oxides of nitrogen	0.0619	0.205		29.7		29.9
sulfur dioxide	0.00561	0.0205				0.0261
lead & compounds	4.87×10^{-06}	8.72×10^{-05}	0.0210			0.0211
particulate matter < 10 µm	0.357	0.581	11.7			12.6
particulate matter < 2.5 µm	0.207	0.533	4.55			5.29
polycyclic aromatic hydrocarbons		6.97×10^{-05}				6.97×10^{-05}
total VOCs	0.231	1.11			1,215	1,216
total suspended particulates (TSP)	0.406	0.872	23.5			24.8
carbon monoxide	1.78	7.18				8.96
acetaldehyde					6.99	6.99
1,3-butadiene		0.00640				0.00640

Table A17. Contributions (%) to emissions from all biogenic sources, July weekend day 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen		0.69		99	
sulfur dioxide		100			
lead & compounds		2.1	98		
particulate matter < 10 µm		20	80		
particulate matter < 2.5 µm		38	62		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.47			100
total suspended particulates (TSP)		16	84		
carbon monoxide		100			
acetaldehyde					100
1,3-butadiene		100			
Sydney					
oxides of nitrogen		0.087		100	
sulfur dioxide		100			
lead & compounds		0.13	100		
particulate matter < 10 µm		1.5	98		
particulate matter < 2.5 µm		3.5	96		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.033			100
total suspended particulates (TSP)		1.2	99		
carbon monoxide		100			
1,3-butadiene		100			
Newcastle					
oxides of nitrogen				100	
lead & compounds			100		
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs					100
total suspended particulates (TSP)			100		
Wollongong					
oxides of nitrogen		38		62	
sulfur dioxide		100			

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
lead & compounds		95	5.1		
particulate matter < 10 µm		100	0.45		
particulate matter < 2.5 µm		100	0.19		
polycyclic aromatic hydrocarbons		100			
total VOCs		10			90
total suspended particulates (TSP)		99	0.60		
carbon monoxide		100			
1,3-butadiene		100			
Non-Urban					
oxides of nitrogen		0.30		100	
sulfur dioxide		100			
lead & compounds		1.1	99		
particulate matter < 10 µm		12	88		
particulate matter < 2.5 µm		24	76		
polycyclic aromatic hydrocarbons		100			
total VOCs		0.24			100
total suspended particulates (TSP)		9.0	91		
carbon monoxide		100			
acetaldehyde					100
1,3-butadiene		100			

Table A18. Contributions (%) to emissions from all biogenic sources, January weekend day 2003

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
Greater Metropolitan					
oxides of nitrogen	0.12	42		58	
sulfur dioxide	0.26	100			
lead & compounds	0.015	29	71		
particulate matter < 10 µm	0.48	83	17		
particulate matter < 2.5 µm	0.34	92	8.0		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.015	7.8			92
total suspended particulates (TSP)	0.34	78	21		
carbon monoxide	0.23	100			
acetaldehyde					100
1,3-butadiene		100			
Sydney					
oxides of nitrogen	0.022	86		13	
sulfur dioxide	0.023	100			
lead & compounds	0.0034	73	27		
particulate matter < 10 µm	0.049	97	3.0		
particulate matter < 2.5 µm	0.032	99	1.3		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.0054	32			68
total suspended particulates (TSP)	0.037	96	3.9		
carbon monoxide	0.020	100			
acetaldehyde					100
1,3-butadiene		100			
Newcastle					
oxides of nitrogen	0.33			100	
sulfur dioxide	100				
lead & compounds	0.017		100		
particulate matter < 10 µm	2.1		98		
particulate matter < 2.5 µm	3.2		97		
total VOCs	0.018				100
total suspended particulates (TSP)	1.2		99		
carbon monoxide	100				

Substance	Agricultural burning	Bushfires and prescribed burning	Fugitive/ windborne	Soil	Vegetation
acetaldehyde					100
Wollongong					
oxides of nitrogen				100	
lead & compounds			100		
particulate matter < 10 µm			100		
particulate matter < 2.5 µm			100		
total VOCs					100
total suspended particulates (TSP)			100		
acetaldehyde					100
Non-Urban					
lead & compounds	0.023	0.41	100		
particulate matter < 10 µm	2.8	4.6	93		
particulate matter < 2.5 µm	3.9	10	86		
polycyclic aromatic hydrocarbons		100			
total VOCs	0.019	0.091			100
total suspended particulates (TSP)	1.6	3.5	95		
carbon monoxide	20	80			
acetaldehyde					100
1,3-butadiene		100			