Estimate of Atmospheric Emissions Originated by Wildfires in Portugal

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- **Objective**

  - **to estimate emissions of main trace gases from vegetation fires affecting forests, shrublands, grasslands, and agricultural areas.**

  - **to derive a simple relationship to estimate emissions, based on area burned.**

  - **to compare emissions from wildfires with those from main economic sectors.**

• Data and Methods

➢ **combine annual burned area maps and decadal land cover map, to quantify area burned by land cover type.**

➢ **compile field data and review the literature to determine, by land cover type :**

- ❑ **pre-fire biomass.**
- ❑ **combustion completeness.**
- ❑ **emissions factors.**

• Data and Methods

➢ **Integrate the data using the Seiler and Crutzen equation:**

$$M_{sc} = A_c * B_c * C_c * E_s$$

where:

M_{sc} = emission mass of species *s* in land cover *c* (Mt)

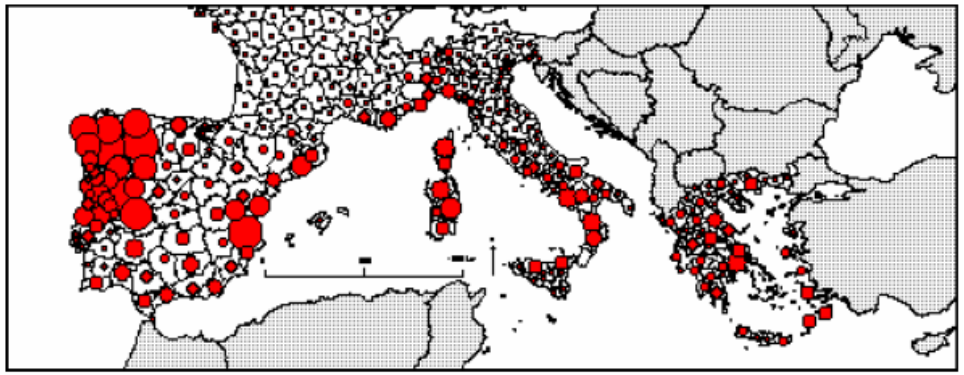
A_c = area burned of land cover *c* (ha)

B_c = biomass loading of land cover *c* ($t.ha^{-1}$ or $kg.m^{-2}$)

C_c = combustion completeness (dimensionless)

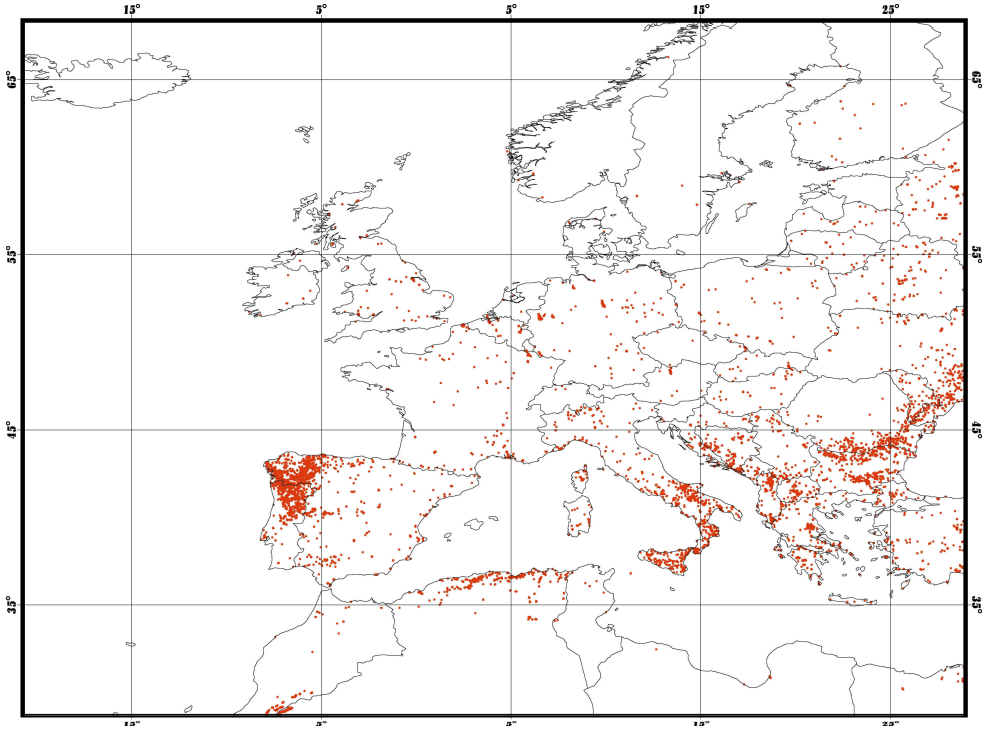
E_s = emission factor ($g.kg^{-1}$)

• Area burned



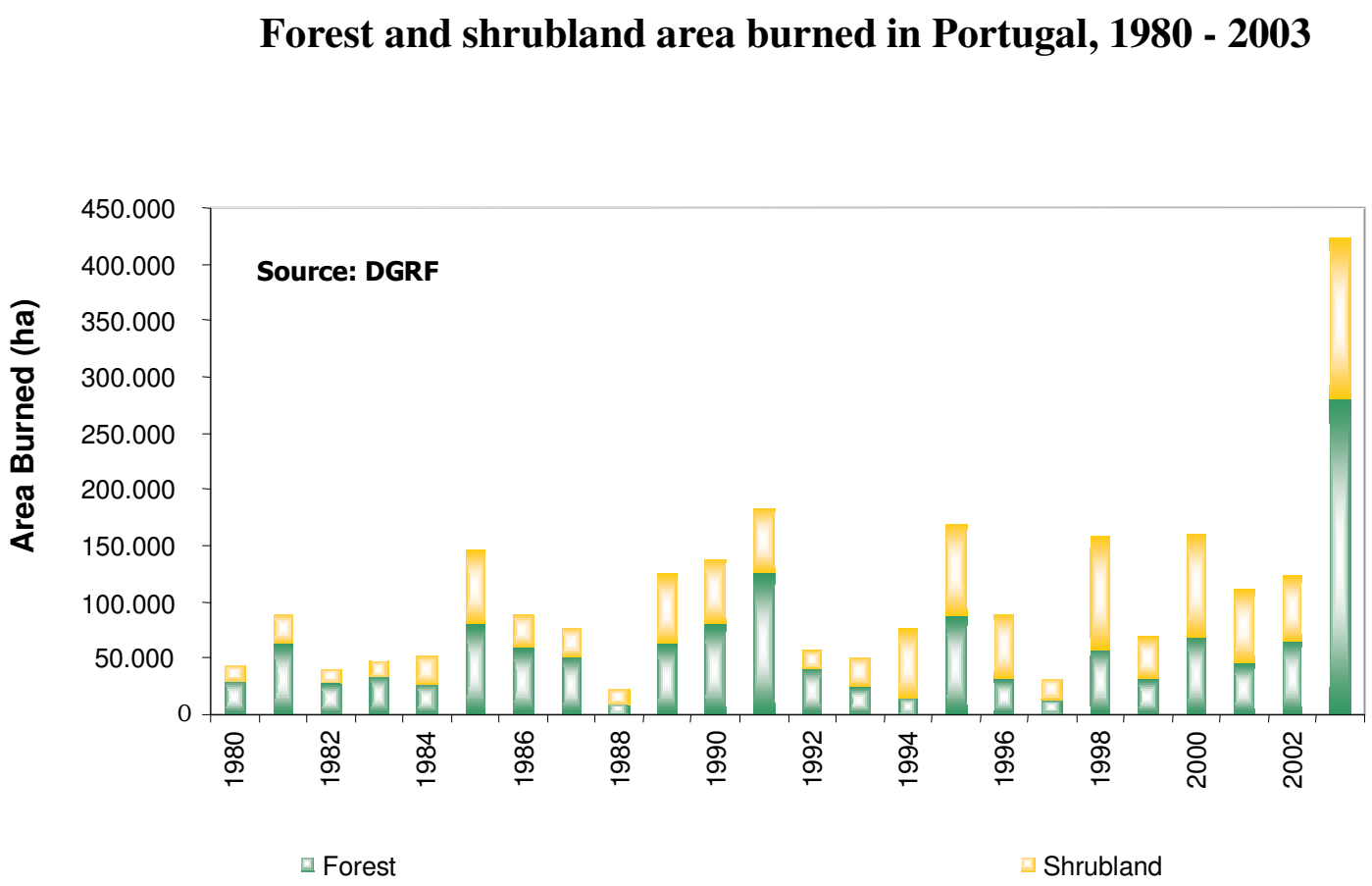
Area burned annualy, 1985-1997, European Commission

• NW Iberia, including Portugal, is a "hotspot" for vegetation fires in Europe



Night-time fires detected by satellite, 1997 – 2001, European Space Agency

- **Area burned**


Forest and shrubland area burned in Portugal, 1980 - 2003
Source: DGRF
Area Burned (ha)
450.000
400.000
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Forest
Shrubland

• Area burned

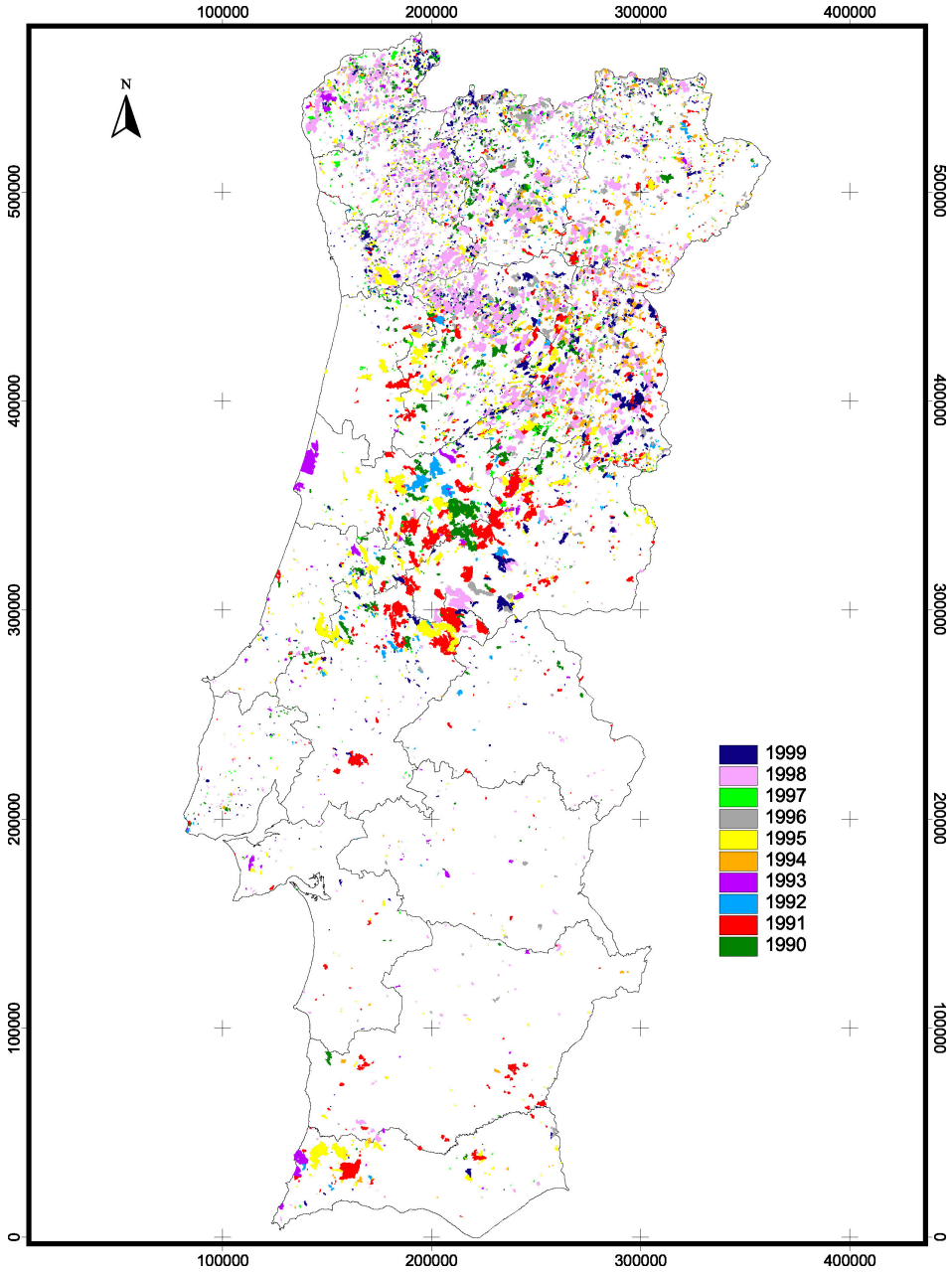
• Area burned in Portugal, 1990 – 1999.

•Mapped using Landsat satellite imagery.

• About 11000 fires with area > 5ha.

• Over 1.100.000 ha burned during the 1990s.

• Minimum of 28000 ha in 1997, maximum of 250000 ha in 1998.



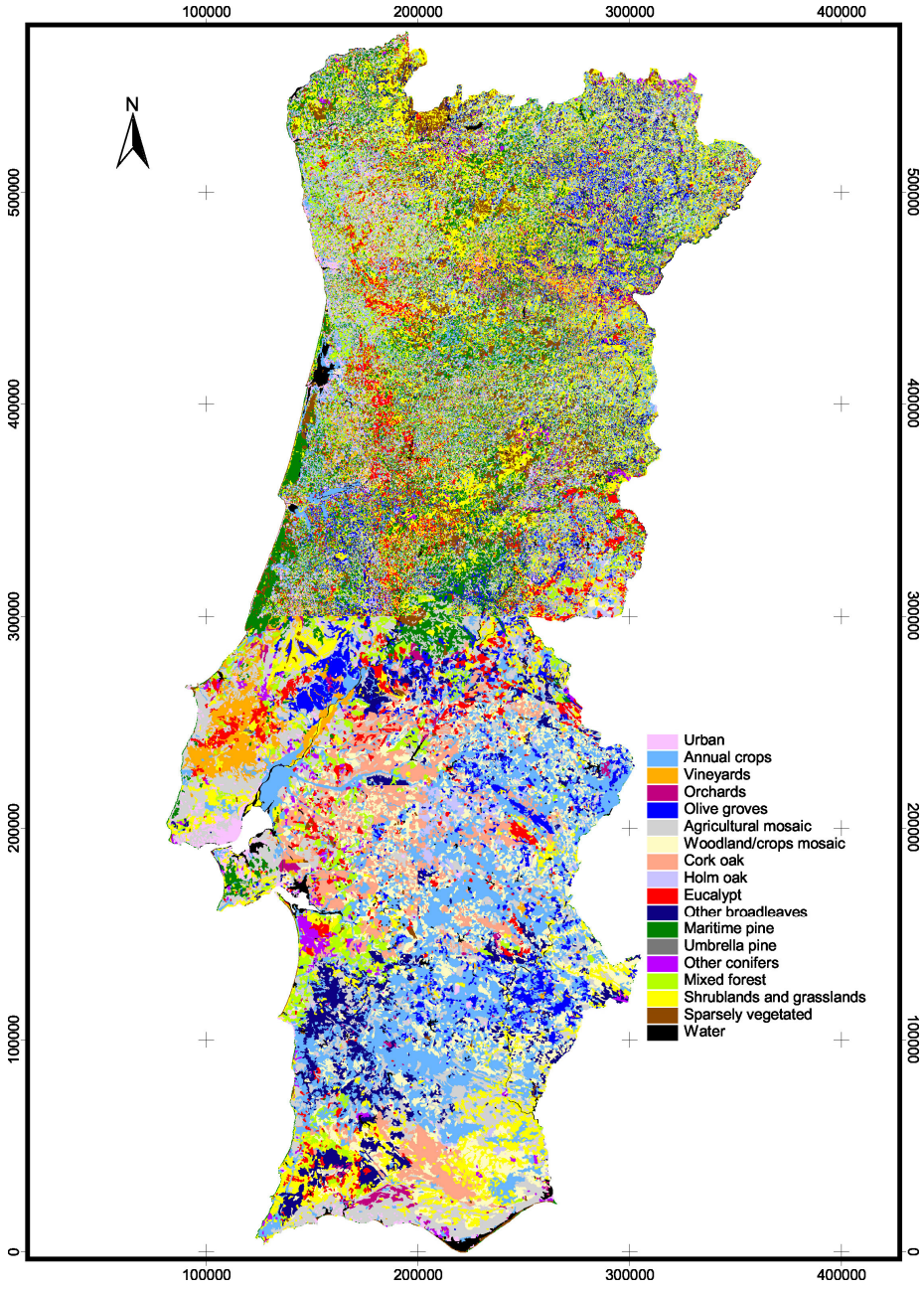
• Area burned

• Land cover map of Portugal.

• Northern half: aerial photo interpretation, 1990. Original scale 1:25000.

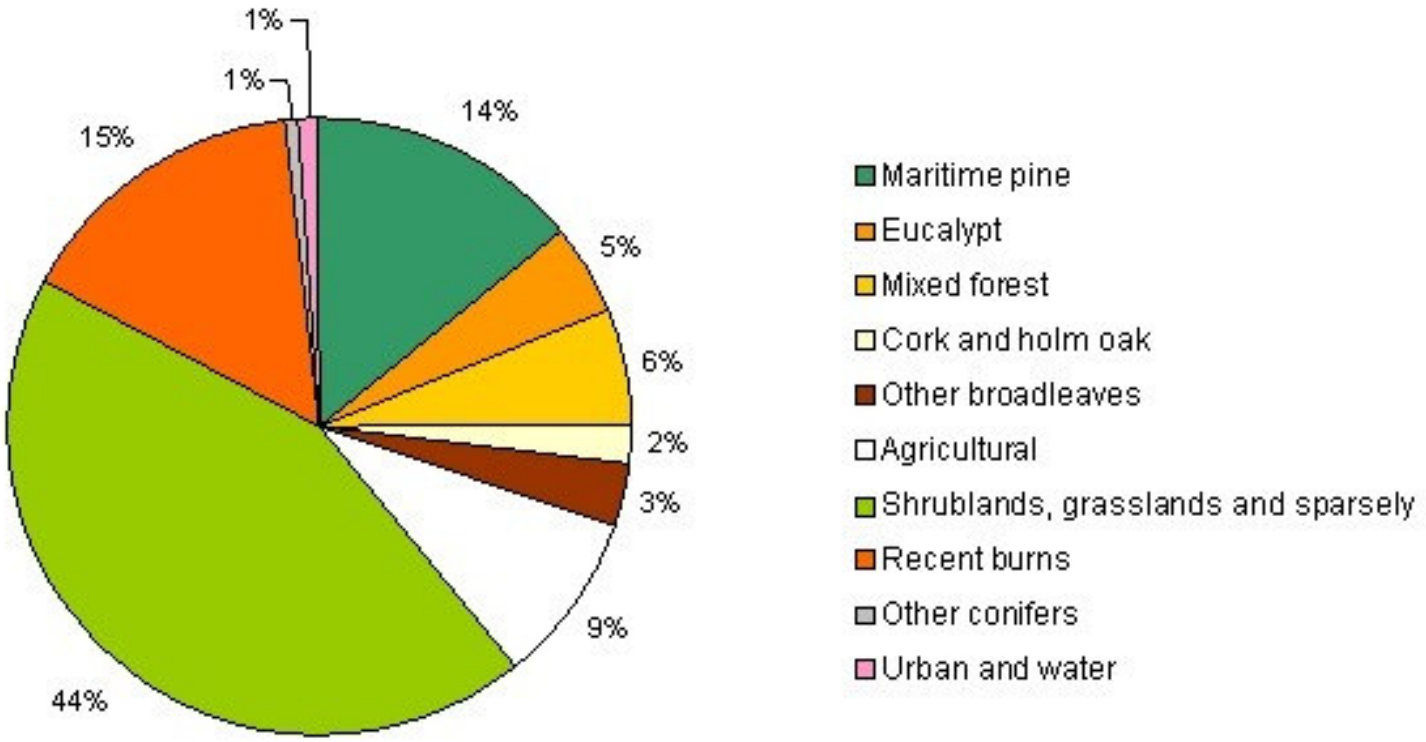
•Southern half: satellite image interpretation, 1986. Original scale: 1:100.000.

Legend simplified to 18 classes.



• Area burned

• Distribution of area burned 1990 – 1999, by major land cover type



• Biomass loadings

➢ **The following plant fuel types were individualized, for biomass loading assessment:**

- ❑ **Forests**
  - **– understory: litter, shrubs**
  - **– overstory: tree crowns**
- ❑ **Shrublands**
  - **– burned once**
  - **– burned > once**
  - **– litter**
- ❑ **Agriculture**

- **Biomass loadings**

  - **Data availability constraints imposed different approaches to assess the loadings of the various fuel beds.**

    - **Forests**
      - **understory**
        - **litter: literature review**
        - **shrubs: NFI data + literature review**
      - **overstory: allometric equations**
    - **Shrublands**
      - **burned once: estimation of patch age distribution**
      - **burned > once: fuel accumulation rate equation**
      - **litter: leaf accumulation and decomposition rate equations**
    - **Agriculture: correspondence with NFFL fuel models**

• Biomass loadings

➢ Forest litter

	Litter biomass ($t.ha^{-1}$)
Eucalypt	6
Cork oak	7
Holm oak	7
Other hardwoods	4,5
Maritime pine	10
Stone pine	6.5
Other conifers	7
Mixed forest	8

• Biomass loadings

➢Understory shrubs

The mean bulk density for forest understory shrubs obtained from the literature review was ≈2 kg.m^{-3}

Species	Bulk density (kg.m^{-3})
Phillyrea latifolia L. or*Rhamnus alaternus* L.	1,943
Rosmarinus officinalis L.	1,943
Pistacia lentiscus L.	1,943
Ilex aquifolium L.	1,943
Pterospartum tridentatum (L.)	3,488
Quercus coccifera L.	1,305
Quercus lusitanica Lam.	1,305
Pyrus spp.	1,943
Adenocarpus spp.	1,929
Cistus ladanifer L.	1,208
Cytisus spp., *Genista* spp. or *Spartium* spp.	1,929
Ruscus aculeatus L.	1,943
Phillyrea angustifolia L.	1,943
Arbutus unedo	1,476
Lavandula spp.	1,593
Cistus salvifolius L.	1,888
Rubus spp.	0,930
Dittrichia viscosa (L.) W. Greuter	1,943
Ulex spp.	3.666
Thymus vulgaris L.	1,593
Daphne gnidium L.	1,943
Erica spp. or *Calluna* spp.	1,947
Juniperus spp.	1,943

• Biomass loadings

➢Understory shrubs

➢**Phytovolume ($m^3.ha^{-1}$) was estimated from National Forest Inventory data on understory shrub % cover and height. Phytovolume combined with bulk density yields fuel loading.**

Forest cover type	Understory shrub fuel loading ($t.ha^{-1}$)	# sample points
Eucalypt	7.984	678
Cork oak	6.754	396
Holm oak	4.656	196
Other hardwoods	10.323	180
Maritime pine	11.158	735
Stone pine	8.005	58
Other conifers	13.250	22
Mixed forest	11. 453	175

• Biomass loadings

➢Tree crowns

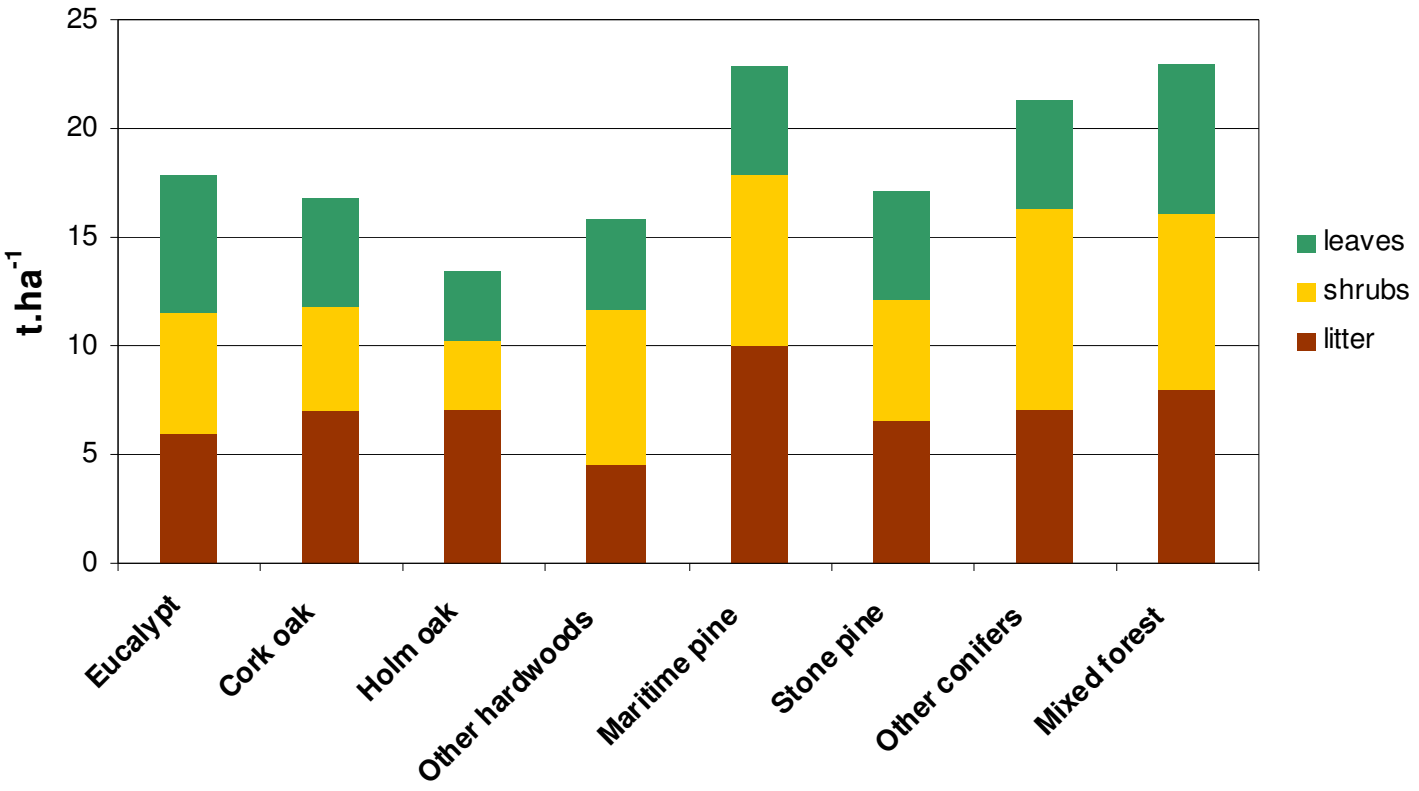
❑ **Only foliar biomass of maritime pine and eucalypt tree crowns was estimated, using allometric equations based on tree d.b.h. and height. It was not possible to estimate twig (∅ ≤ 6mm) biomass.**

❑ **Foliar biomass for other forest types was based on data from the European Environmental Agency.**

Forest type	Foliar biomass ($t.ha^{-1}$)
Eucalypt	6.3
Maritime pine	5
Mixed forest	7
Cork oak	5
Holm oak	3.2
Other hardwoods	4.1
Stone pine	5
Other conifers	5

- **Biomass loadings**

  - **Loadings for the forest ground, surface, and aerial fuel strata.**



- **Biomass loadings**

  - **Shrublands**

    - **For methodological reasons, it was necessary to separate shrublands that burned twice during the study period, from those that burned only once.**
    - **The biomass available for the second burning is a function of fuel accumulation rate and time since last fire (= patch age).**
    - **The biomass present in shrublands that burned only once during the study period must be estimated from knowledge of lanscape-level patch age structure, combined with fuel accumulation rate.**
    - **The patch age structure is a function of age-specific fire incidence, represented by the hazard function.**

• Biomass loadings

➢Shrublands

❑ **The fuel accumulation function used was developed by Rambal (2001) for Mediterranean-type shrublands:**

$$W = 2880(1-e^{-0,0896t}),$$ **where**

W = fuel loading ($g.m^{-2}$)

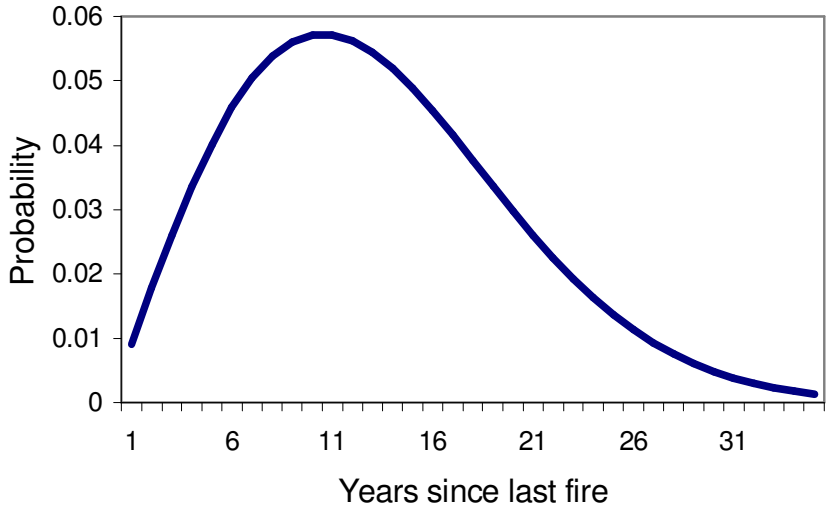
t = time since last fire (years)

	Shrub patch age (years)								
	1	2	3	4	5	6	7	8	9
Biomass ($t.ha^{-1}$)	2,5	4,7	6,8	8,7	10,4	12	13,4	14,7	15,9

• Biomass loadings

➢ Shrublands

❑ **The fuel hazard and age class distribution functions determined from the 1990 – 99 burned area maps are:**



❑**The mean shrub biomass at the time of first fire results from combining the age class distribution with the biomass as a function of age. We obtained a value of 18.3 t.ha^{-1}.**

❑ **The length of the time series (10 years) is short, which may affect the reliability of the functions.**

• Biomass loadings

➢ Shrublands

❑ **Shrub litter production was assessed as the net outcome of litter production and decomposition:**

	Shrub patch age (years)								
	1	2	3	4	5	6	7	8	9
Litter biomass ($t.ha^{-1}$)	1,1	1,7	2,1	2,3	2,4	2,5	2,5	2,6	2,6

• Biomass loadings

➢ Agriculture

❑ Attributed by correspondence with NFFL fuel models:

Land cover type	NFFL model	Description	Fuel loading (t.ha^{-1})				
			≤ 6mm Ø	6-25 mm Ø	25-75mm Ø	Live	Total
Orchards, olive groves, ag. mosaic, sparsely vegetated areas	1	Short grass	1,6	-	-	-	1,6
Agroforestry lands	2	Scattered trees w/ grass and sparse shrubs	4,5	2,2	1,1	1,1	8,9
Annual crops	3	Tall grass	6,7	-	-	-	6,7
Vineyards	5	Short dense shrubs (0,6m)	2,2	1,1	-	4,5	7,8

- **Combustion completeness**

  - **Represents the proportion of above ground biomass actually consumed by the fire.**
  - **The same combustion completeness (C) values were used for forests and shrublands**
    - **litter: 0.63**
    - **fine fuels (leaves + twigs < 6mm Ø): 0.80**
  - **Crown fine fuels were assumed to be completely consumed when crown fires occur, but their incidence varies by forest type, from about 0.4 to 0.6. Thus, crown fire incidence was used in the Seiler and Crutzen eq., for this fuel stratum.**
  - **C values for agricultural cover types varied slightly around 0.8.**

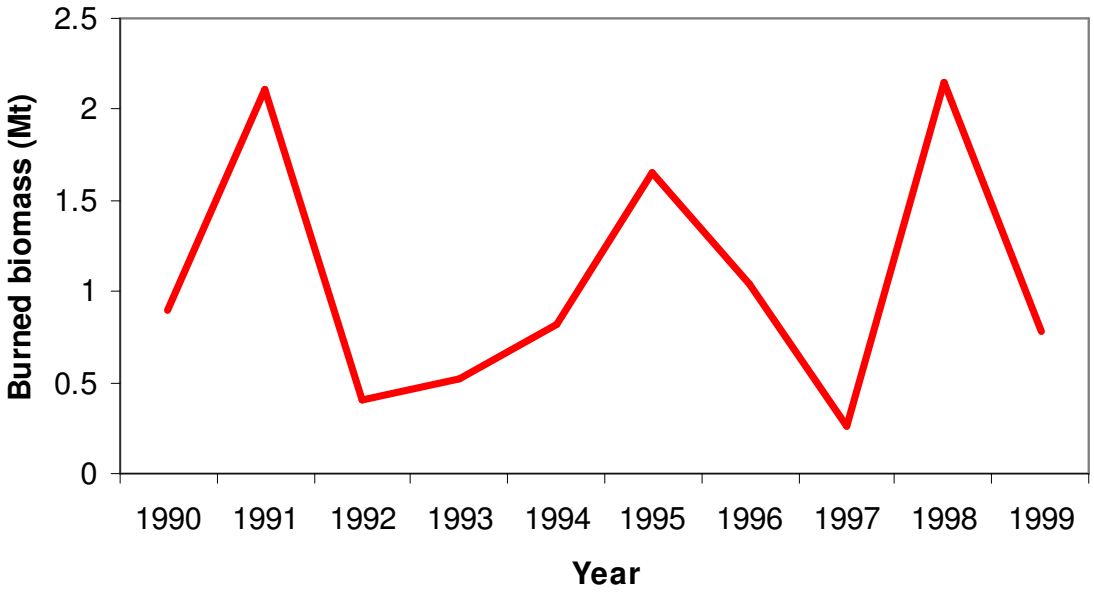
• Emission factors

➢ **Represent the amount of a compound released per amount of dry fuel consumed:**

	Emission factors ($g\text{-}kg^{-1}$)	
Chemical compounds	**Agriculture and sparsely vegetated**	**Forests and shrublands**
CO_2	1613	1569
CO	65	107
CH_4	2,3	4,7
THNM	3,4	5,7
N_2O	0,21	0,26
NO_x	3,9	3
$MP_{2,5}$	5,4	13
MPT	8,3	17,6
NF	0,48	0,48
C_{org}	3,4	9,15

• Results

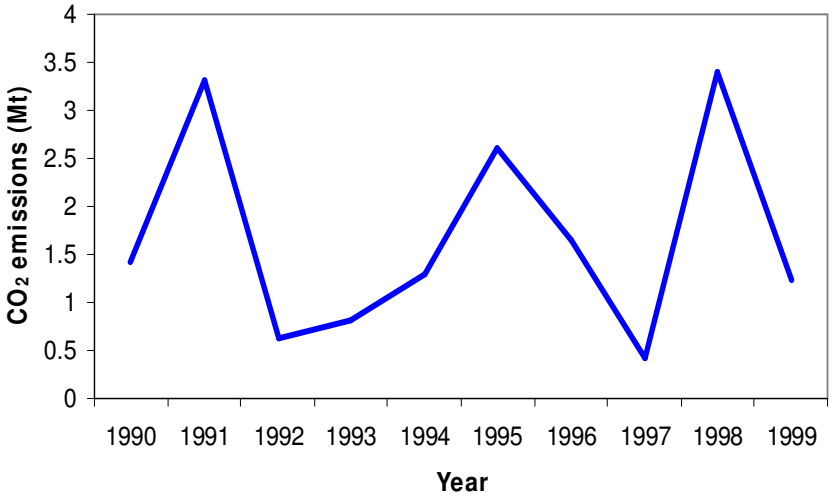
➢ **Biomass burned, per unit area of main land cover type, and per year**

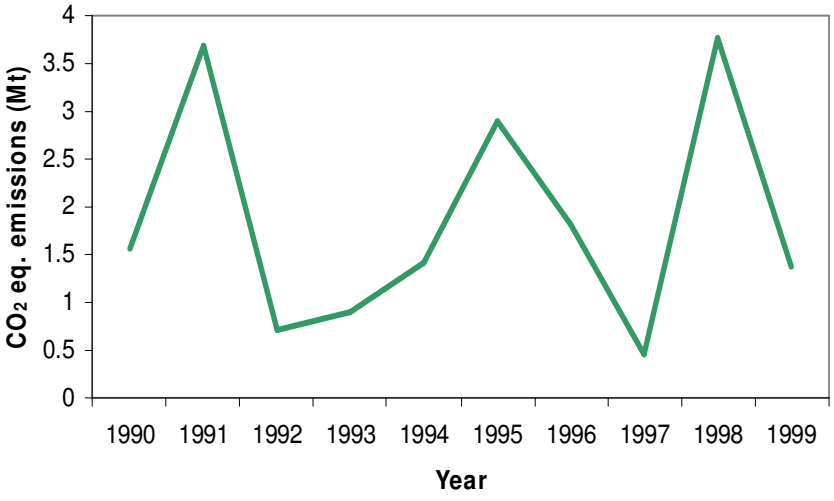


Land cover	Biomass burned ($t.ha^{-1}$)
Eucalypt	11.14
Cork oak	8.91
Holm oak	10.89
Other hardwoods	11.03
Maritime pine	15.29
Stone pine	11.13
Other conifers	14.38
Mixed forest	14.90
Shrublands	11.97
Reburned 1-9 yr old	2.01 – 10.57
Annual crops	5.36
Vineyards	2.42
Orchards	1.28
Olivetree groves	1.28
Agricultural mosaic	1.28
Agroforestry land	4.54
Sparsely vegetated	1.28

- **Results**

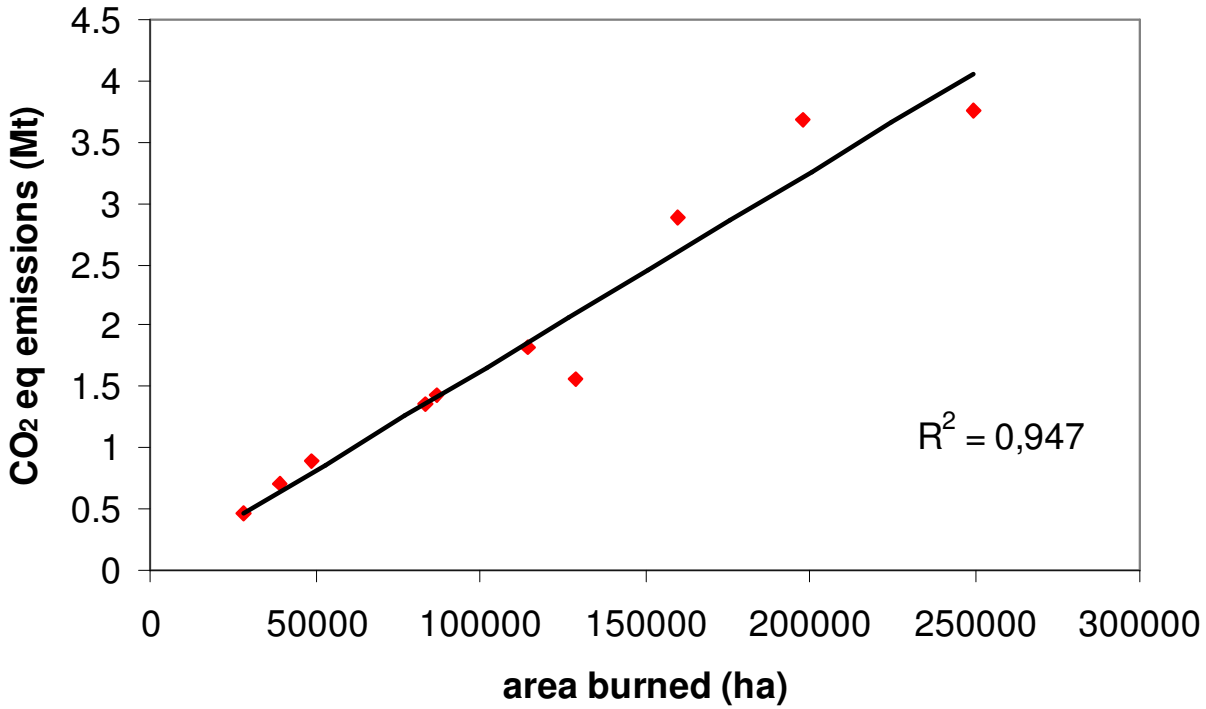
  - **Emissions are shown in CO_2 equivalent units, assuming a global warming potential of 21 for CH_4, and of 310 for N_2O.**





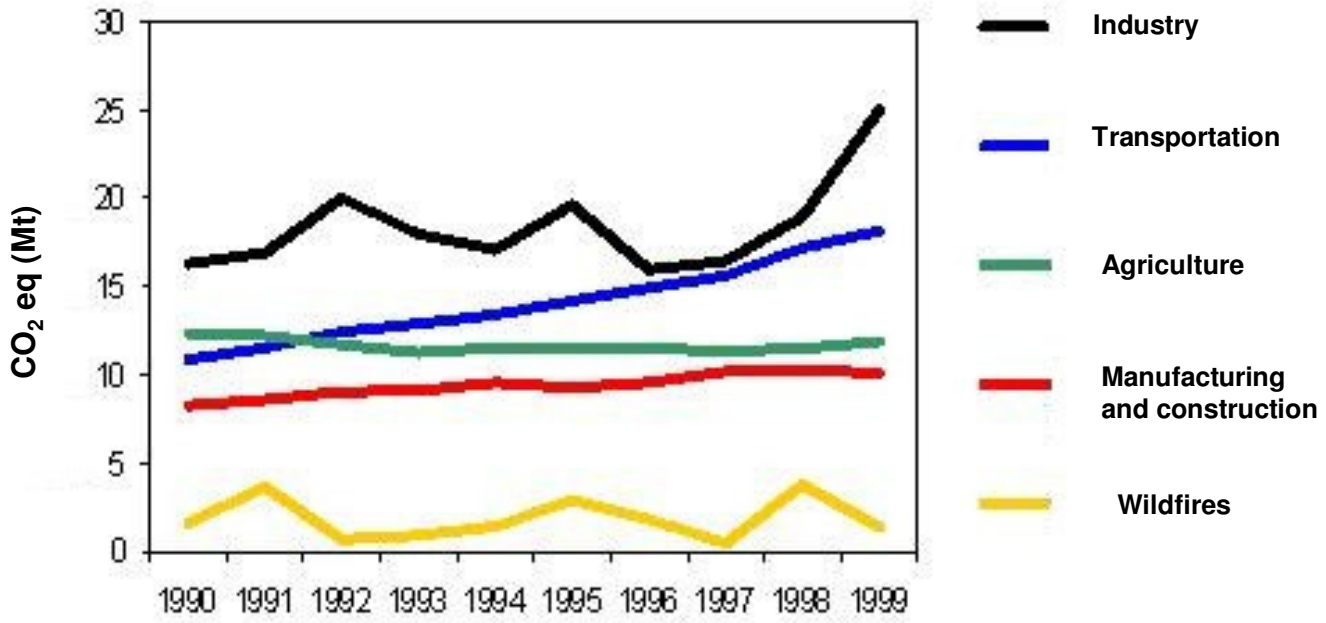
- **Results**

  - **Emissions can be accurately estimated from knowledge of area burned.**



- **Results**

  - **Emissions from wildfires are significant, when compared with those from the main economic sectors.**



- **Results**

➢ **2003 was the worse wildfire year on record in Portugal. It is estimated that a total of 423949 ha of forests and shrublands were burned.**

➢ **This estimate does not include agricultural areas, of which about 30000 ha burned.**

➢ **Using the relationship established in this study, pyrogenic emisssions (CO_2 eq) are estimated at 7,39 Mt.**

• Conclusions

➢ **Annual atmospheric emissions from wildfires were estimated for Portugal, during the 1990s.**

➢ **The available burned areas and emissions factors data are considered adequate for the estimation of emissions.**

➢ **It is important to reduce uncertainties associated primarily with:**

- ❑ **fuel loadings in shrublands**
- ❑ **incidence of crown fires**
- ❑ **combustion completeness**

- **In progress**

  - **The burned area map time series has now been extended to 1975-2007.**
  - **Two CORINE landcover maps are now available (1987 and 2000).**
  - **We have improved estimates of shrub patch age distributions**
  - **Post-fire fuel accumulation rates are now available for Portugal, derived from over 400 field transects.**
  - **Uncertainty assessment in progress, using simulation techniques.**