Soil - Atmosphere N_2O and CH_4 exchanges in Mediterranean Sclerophyllous Woodlands as affected by Global Change

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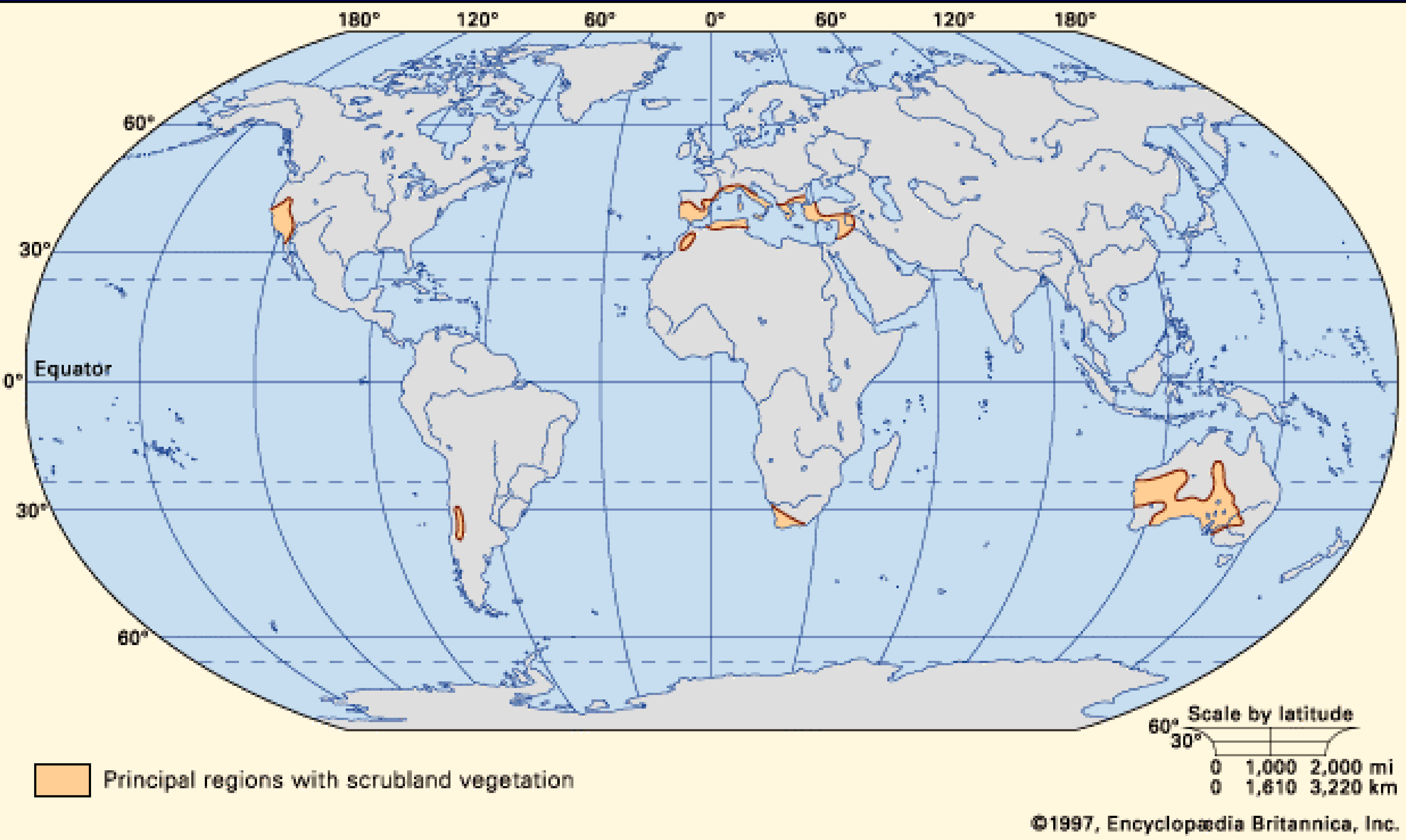
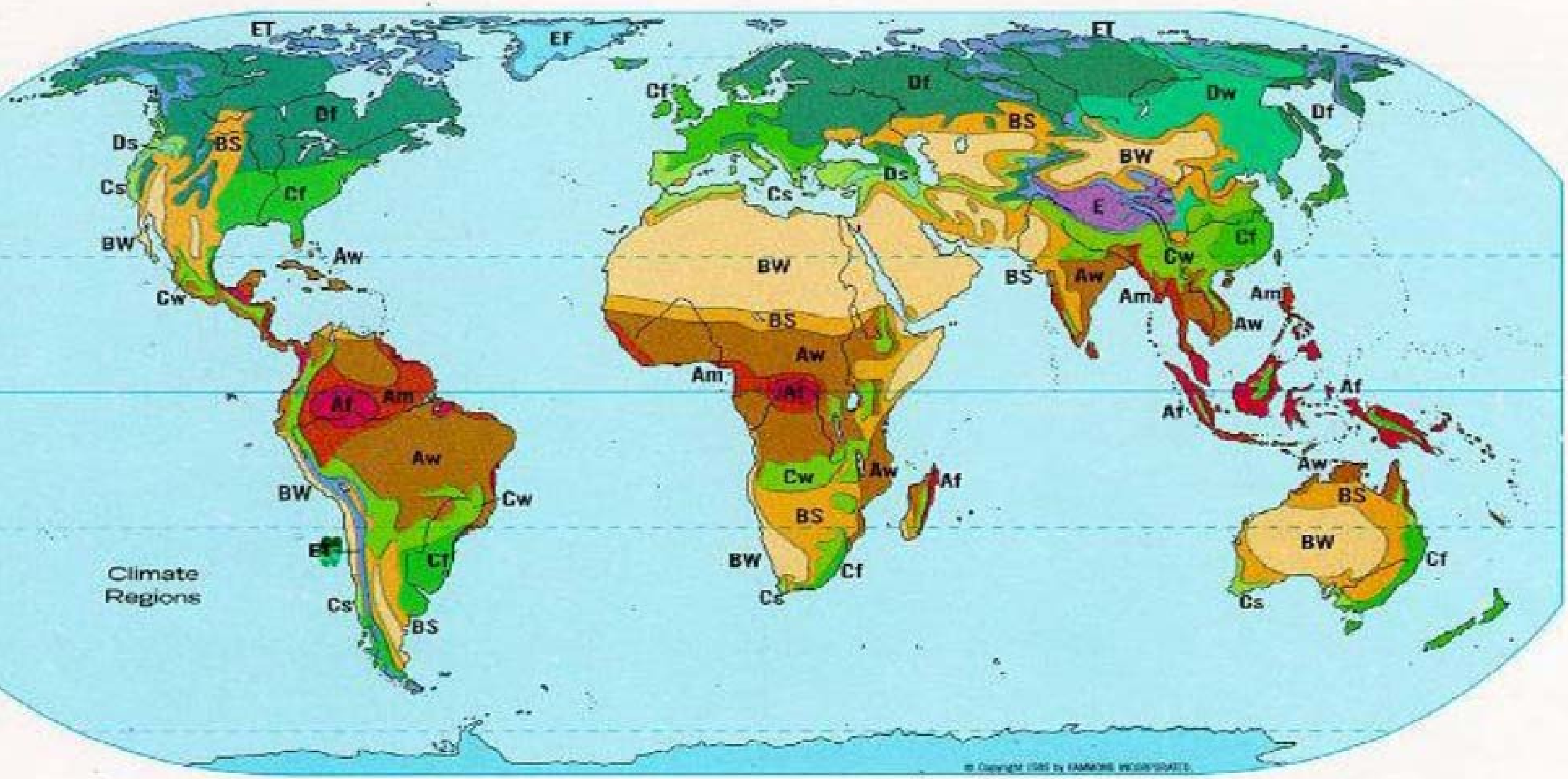
Mediterranean ecosystems



WORLD-CLIMATE



A HUMID TROPICAL CLIMATE

- **Af** No Dry Season
- **Am** Short Dry Season
- **Aw** Dry Winter

B DRY CLIMATE

- **BS** Semiarid
- **BW** Arid

C HUMID WARM CLIMATE

- **Cf** No Dry Season
- **Cw** Dry Winter
- **Cs** Dry Summer

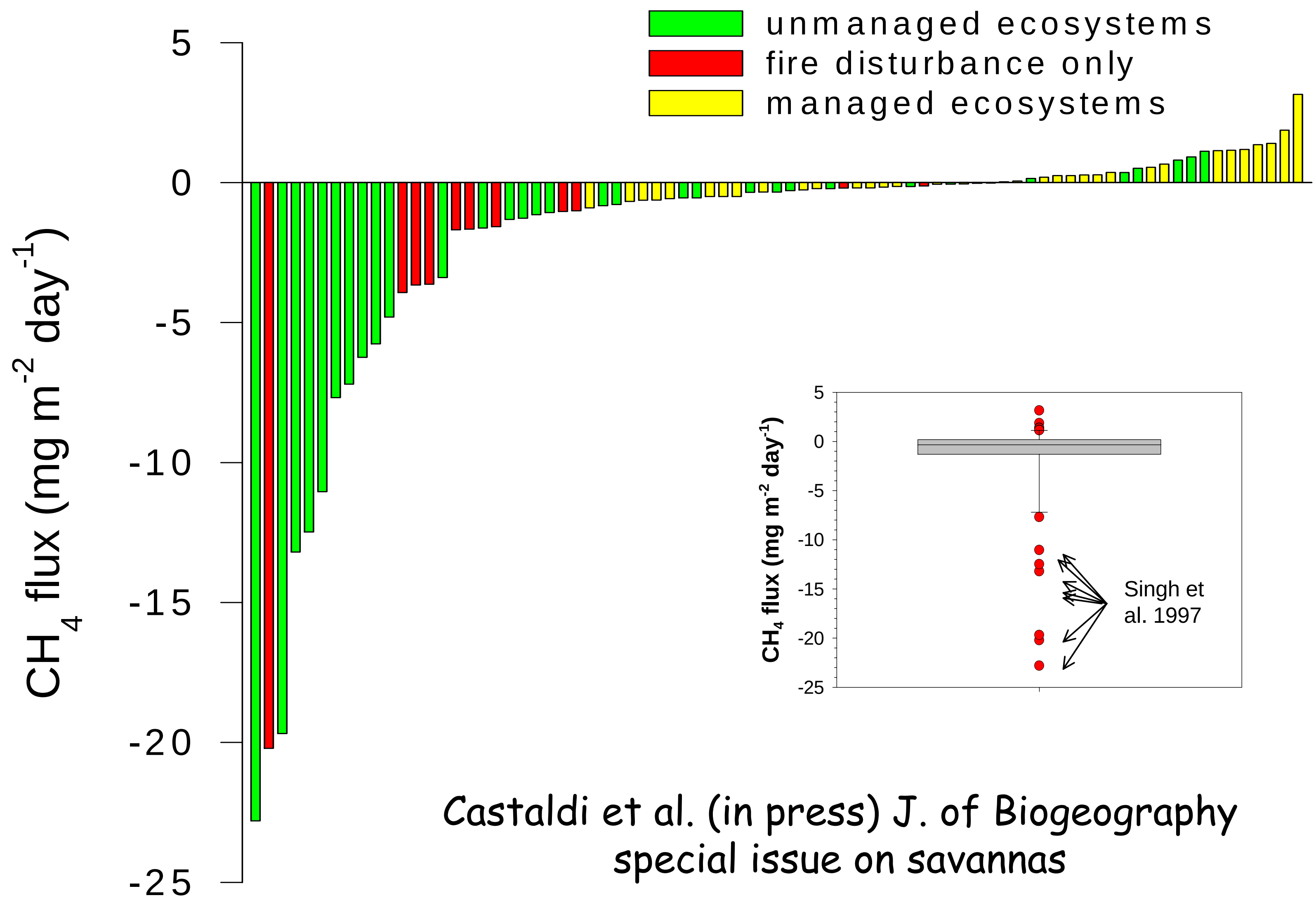
D HUMID COLD CLIMATE

- **Df** No Dry Season
- **Dw** Dry Winter
- **Ds** Dry Summer

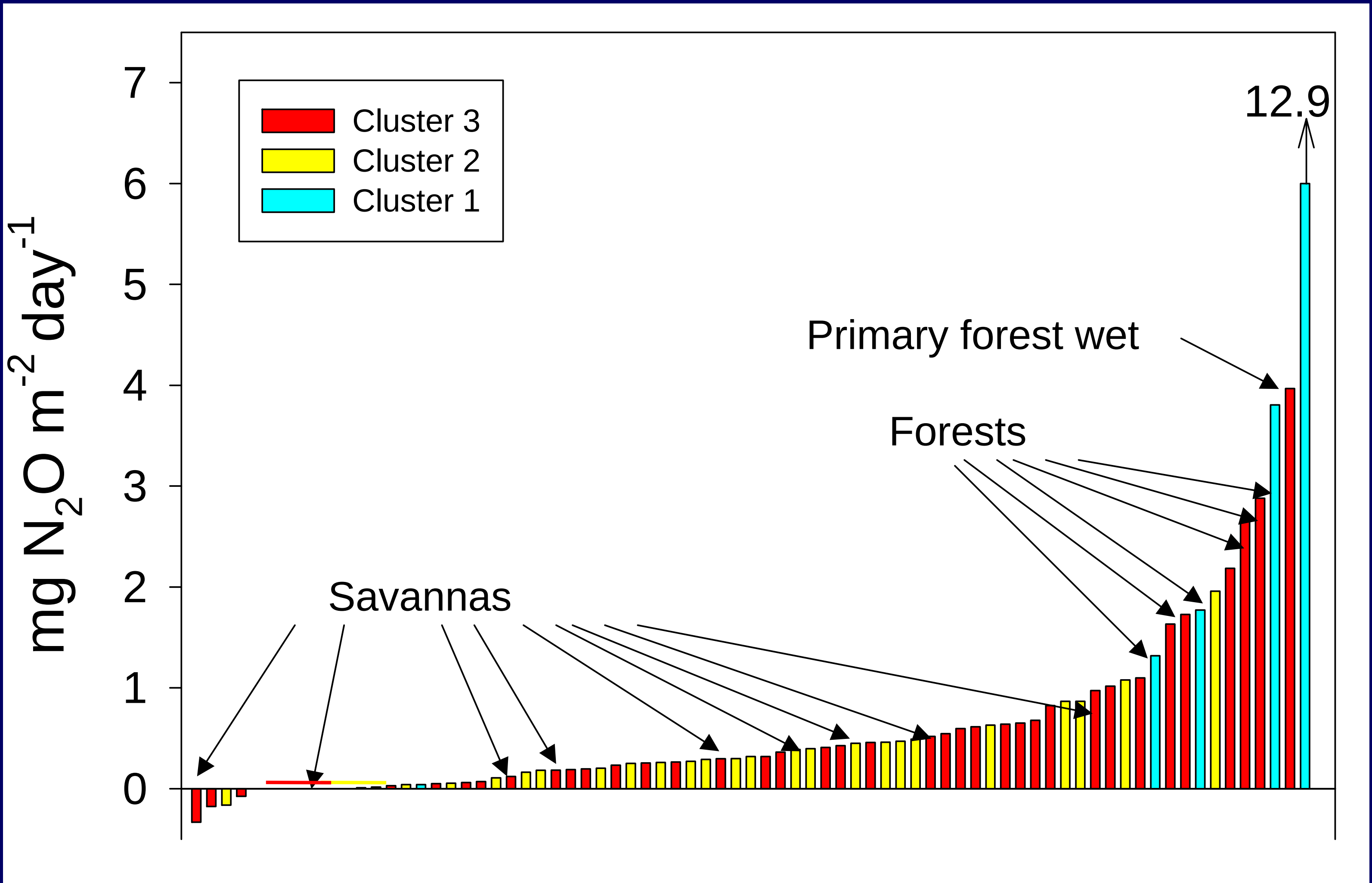
E COLD POLAR CLIMATE

- **ET** Short Cool Summer, Long Cold Winter
- **EF** Perpetual Frost
- **E** Cold and Unclassified Highlands

CH_4 flux rates from single studies from both dry and wet seasons



Castaldi et al. (in press) J. of Biogeography special issue on savannas



Castaldi et al. (in press) J. of Biogeography
special issue on savannas

In **NATURAL UNDISTURBED CONDITIONS** we might expect that

- Mediterranean shrubland ecosystems are good sinks for CH_4
- Mediterranean shrubland ecosystems are poor sources of N_2O

Overall relatively low impact on global warming

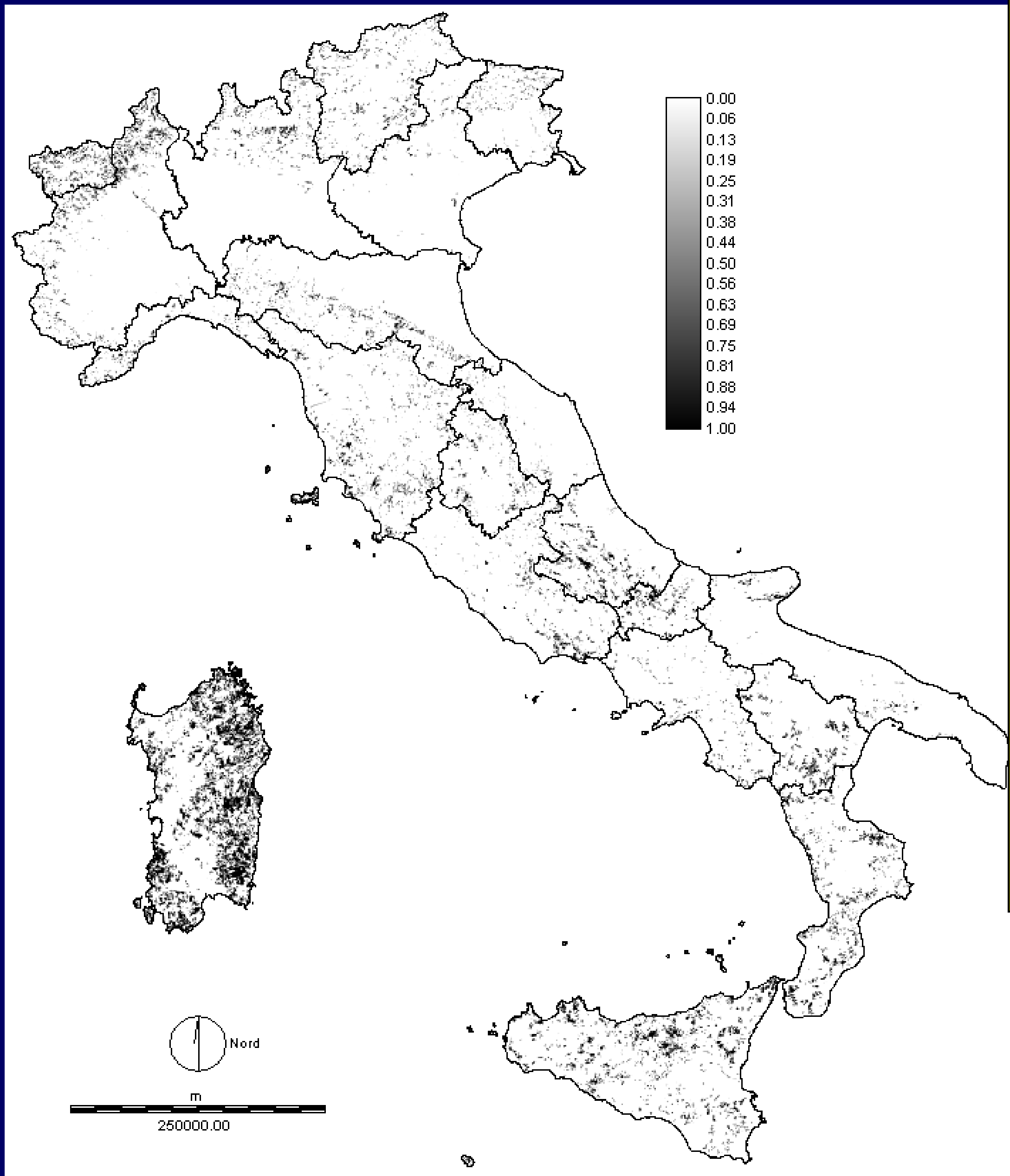
Global change might vary the contribution of these ecosystems to atmospheric greenhouse gas concentration?

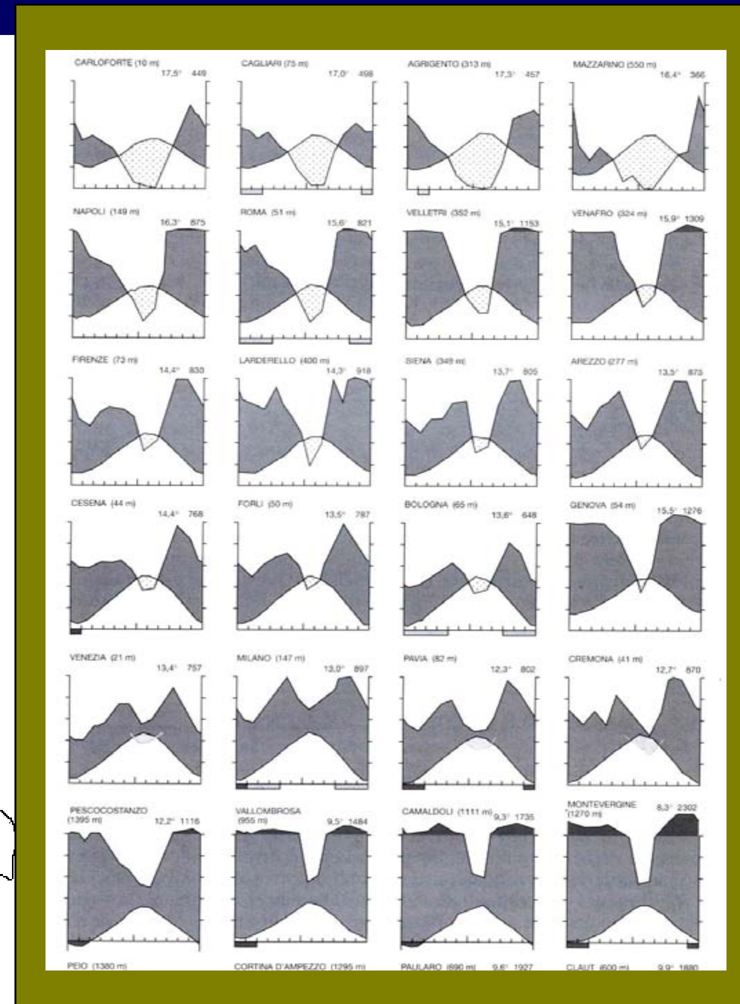
In which case?

At which extent?

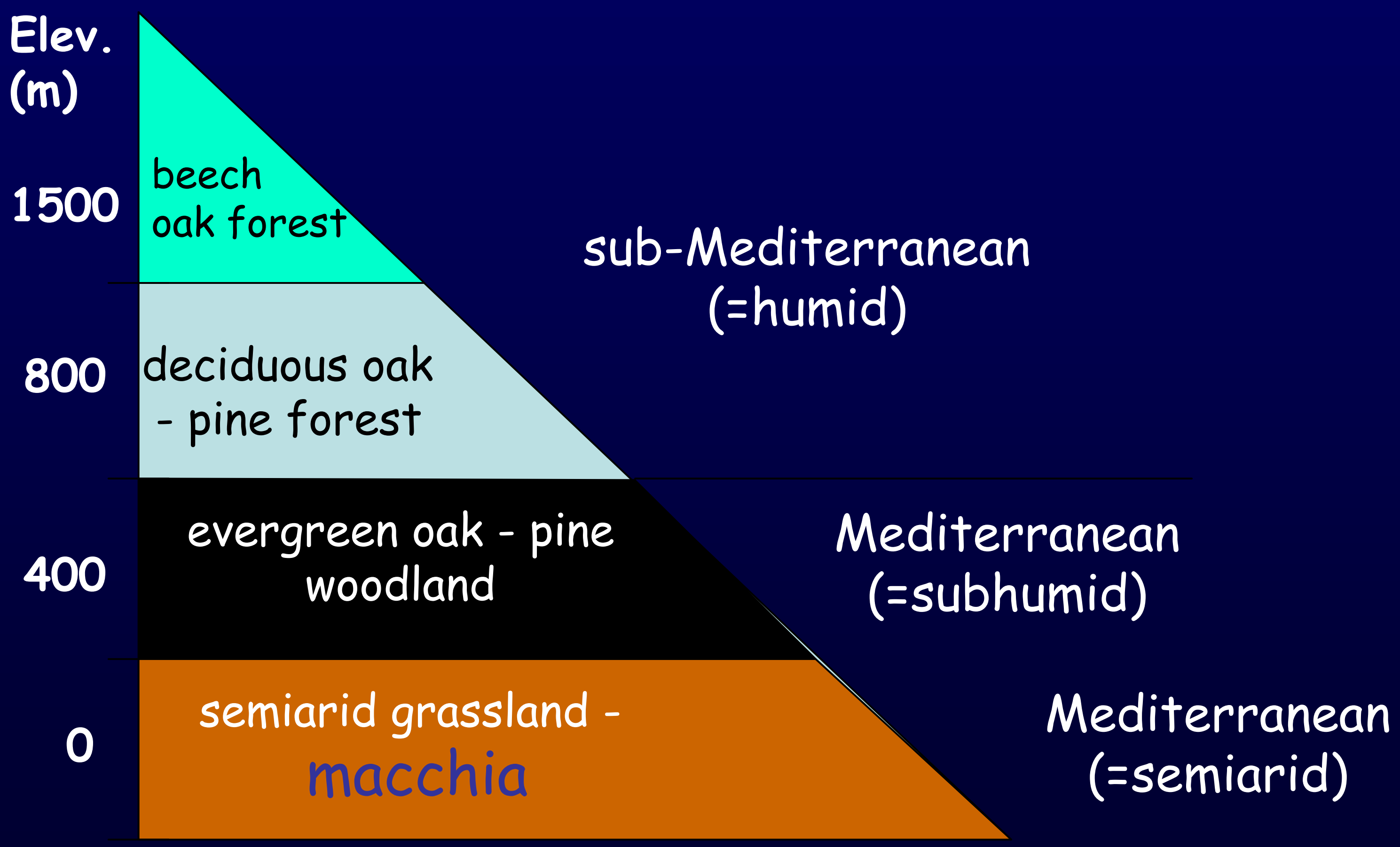
How much do we know on greenhouse gas fluxes from Mediterranean shrubland ecosystems?

Distribution of shrubland ecosystems





Elevation - vegetation relations in southern Italy



TWO MEDITERRANEAN SHRUBLANDS

TOLFA ⟷ comparison ⟷ CASTEL VOLTURNO

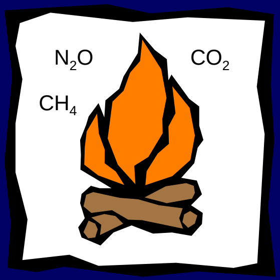
GLOBAL CHANGE IMPACT

IMPACT OF CHANGING RAINFALL INPUT ON TRACE GAS FLUXES

MIND

2003 - 2005

IMPACT OF FIRE ON TRACE GAS FLUXES



2000 - 2002

HIGH MACCHIA:

Arbutus unedo

LOW MACCHIA:

Quercus ilex. L.,

Fillirea angustifolia L.,

Cistus sp. Pl.,

Mirtus communis L.,

Pistacia lentiscus L.,

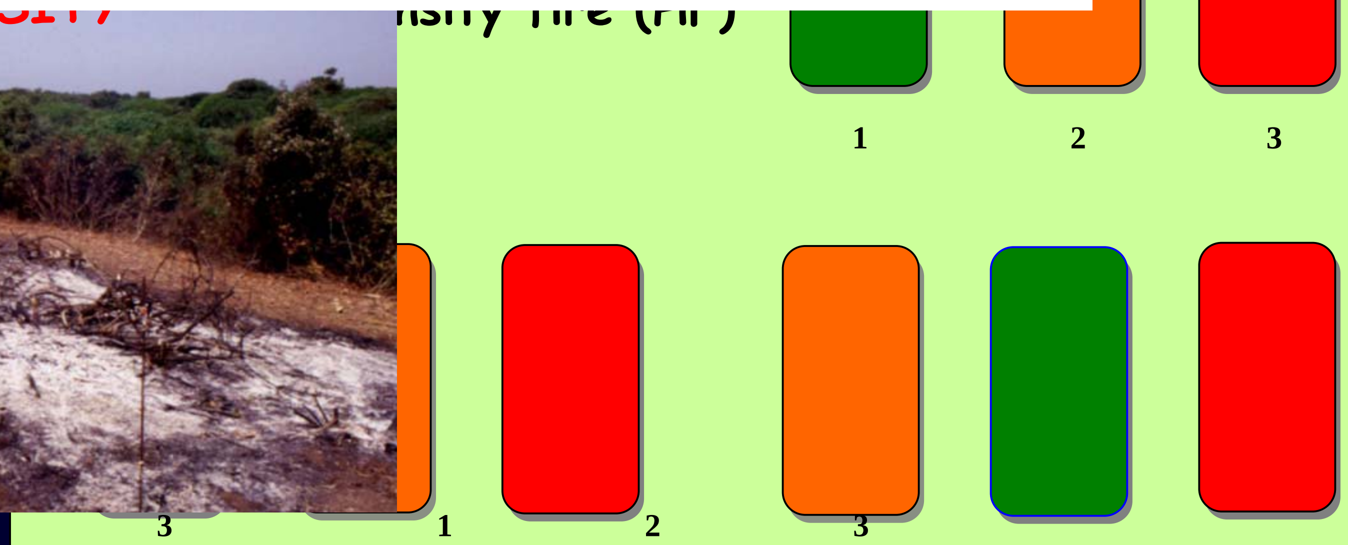
Rosmarinus officinalis L.

Some soil characteristic measured over the top 10 cm of soil in the two macchia sites

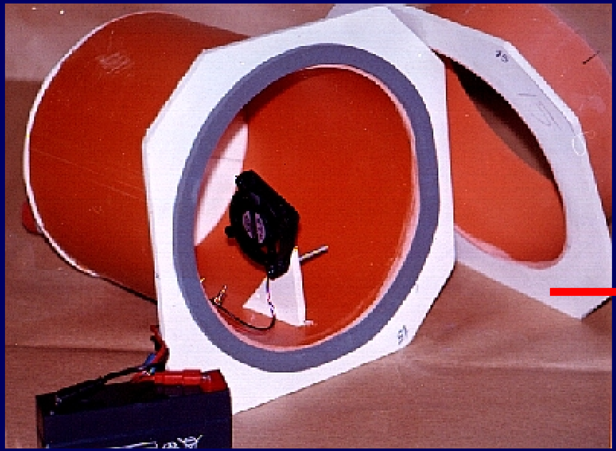
	Sand %	Silt %	Clay %	Bulk density g cm^{-3}	Soil organic C %	Soil Total N %	Water holding capacity m^3 m^{-3}	pH
CASTEL VOLTURNO	97.1	1.2	1.6	1.00	2	0.5	0.25	7.6

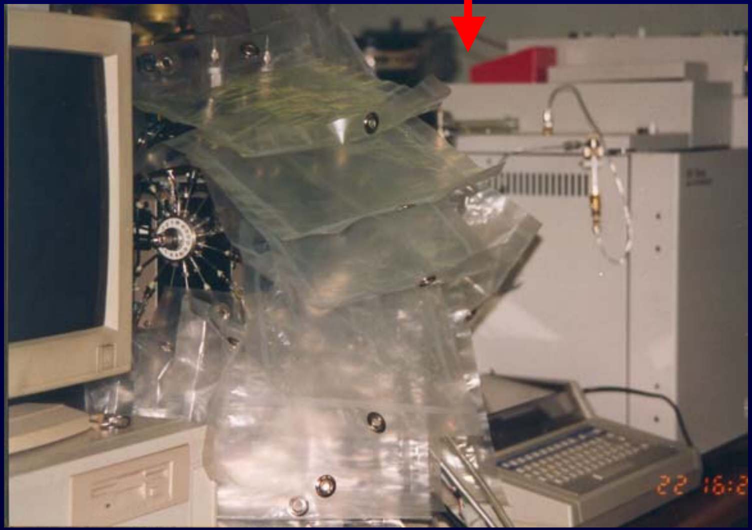
	Sand %	Silt %	Clay %	Bulk density g cm^{-3}	Soil organic C %	Soil Total N %	Water holding capacity m^3 m^{-3}	pH
TOLFA	45.6	48.7	6.3	0.75	15	0.8	0.35	4.3

CASTEL VOLTURNO FIRE EXPERIMENT 2000-2002



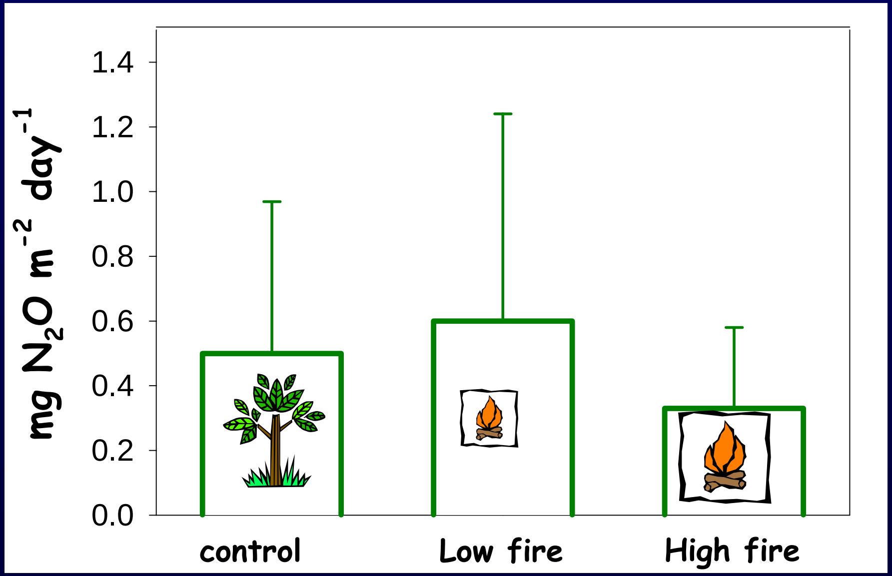
BURNING EVENT 7TH JULY 2000





AVERAGE ANNUAL TRACE GAS FLUXES IN CONTROL AND BURNED MACCHIA

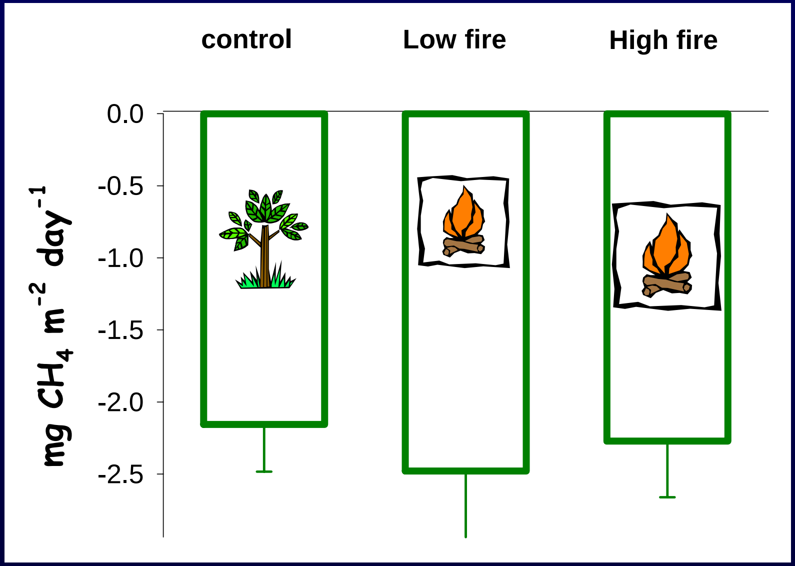
N_2O FLUX



Quite low rates

No significant difference between control and burned plots

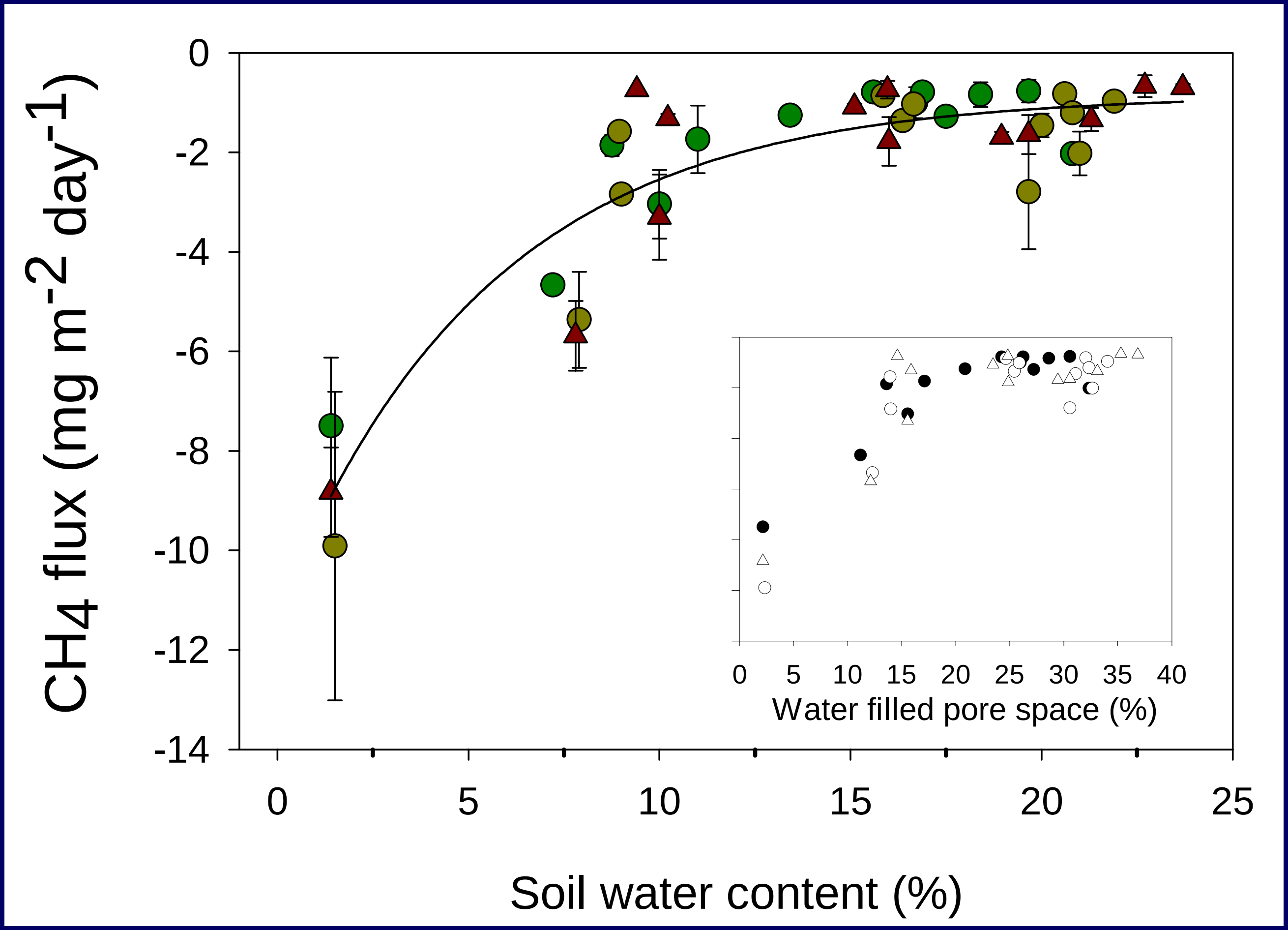
CH_4 FLUX



Quite high rates

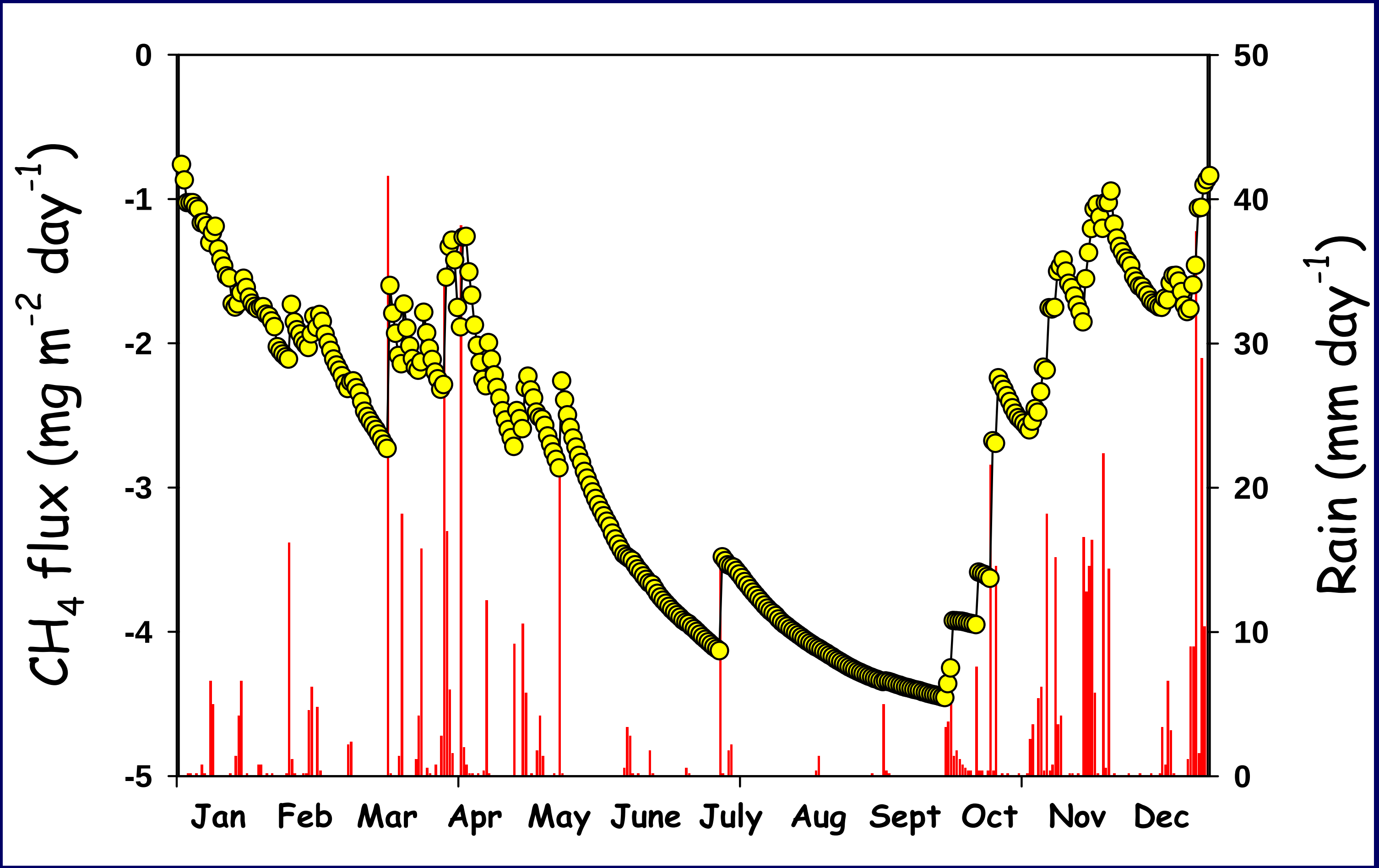
No significant difference between control and burned plots

Relationship between CH_4 fluxes and gravimetric soil water content in the Castel Volturno ecosystem



$$y = -9,9 + 9,2\,(1 - e^{-0.2\,x})$$

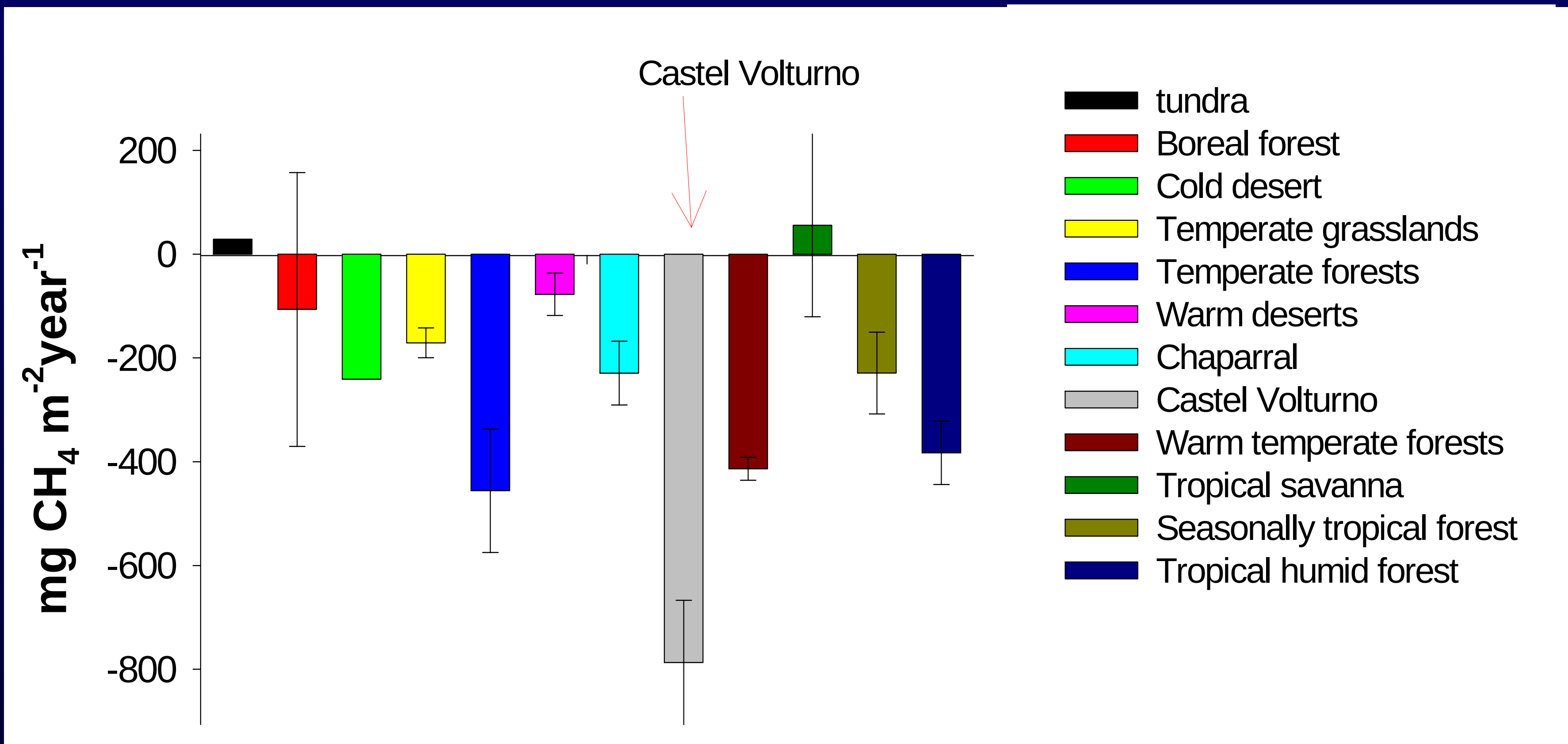
Simulation of daily CH_4 uptake rates in the Castel Volturno site for the year 2000



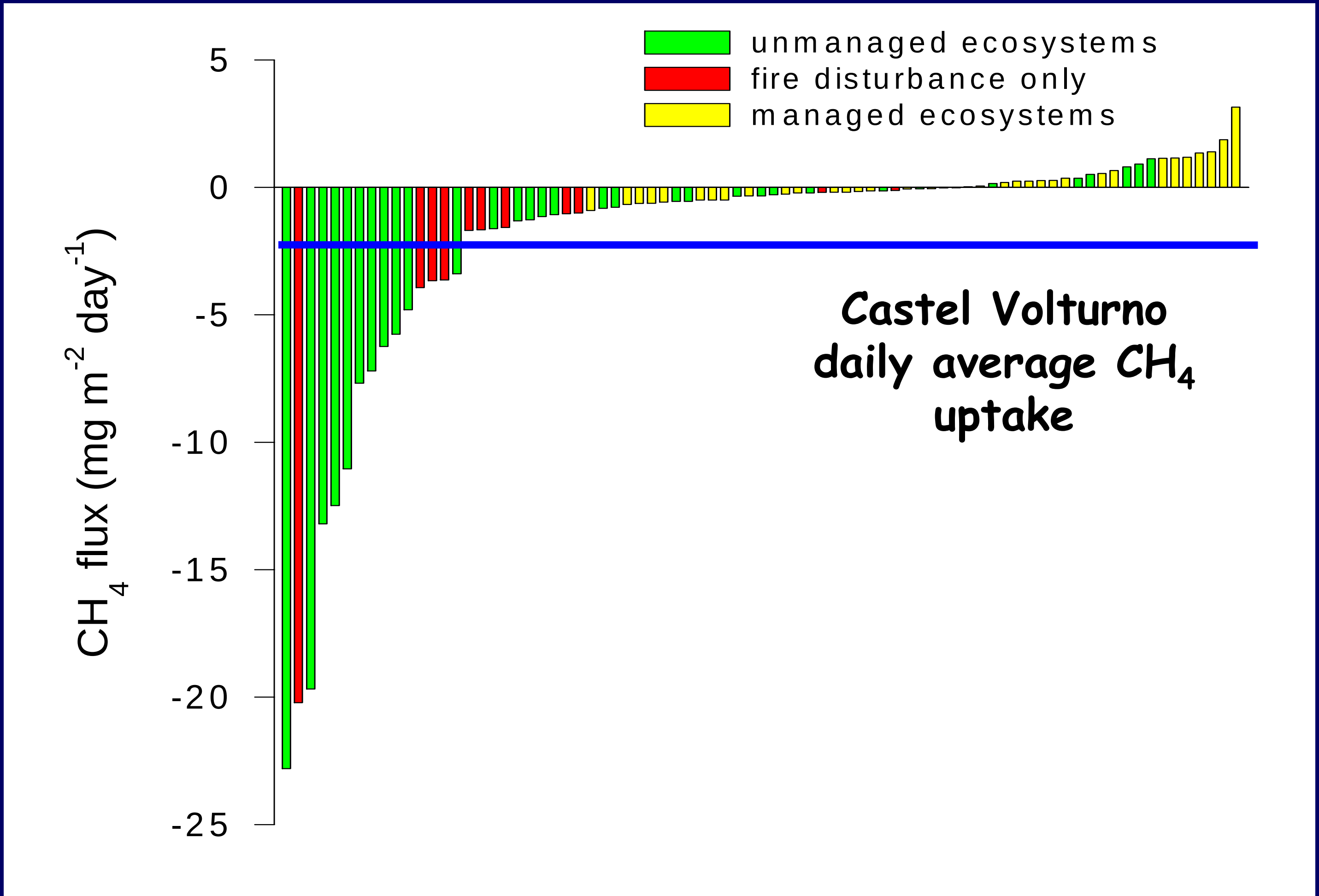
Total annual uptake = 990.9 mg CH_4 m^{-2}

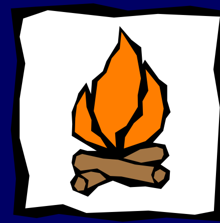
Annual average daily flux = -2.70 ± 1.08 mg CH_4 m^{-2} day^{-1}

Comparison of CH_4 uptake rates measured at Castel Volturno with rates from other ecosystems



Comparison of CH_4 uptake rates measured at Castel Volturno with rates from tropical seasonally-dry ecosystems (Castaldi et al. (in press))





Direct detrimental effect of fire on methanotropic bacteria

Increase of soil NH_4^+

Competition by ammonia-oxidizing bacteria

(Steudler 1996; King 1997)

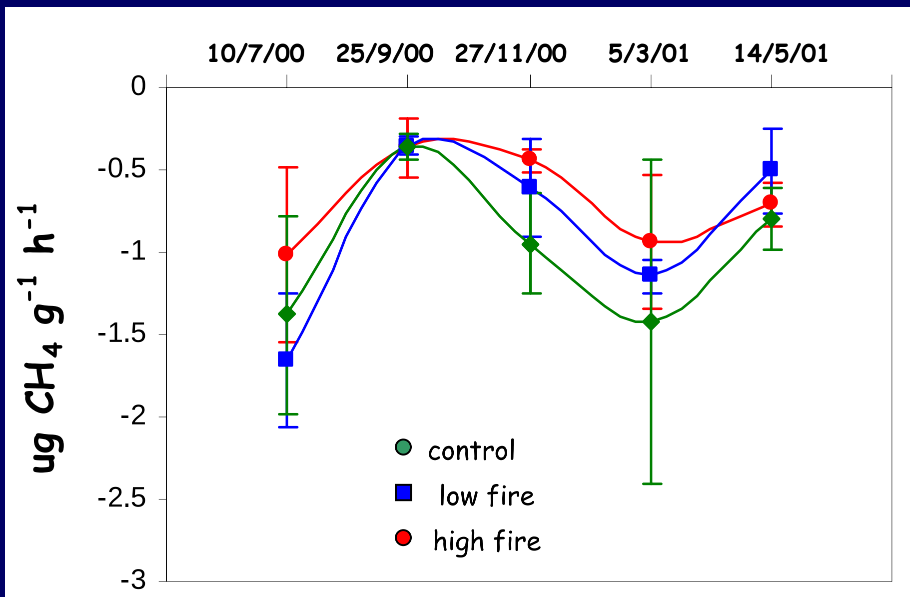
Competitive inhibition of methane monooxygenase by ammonia

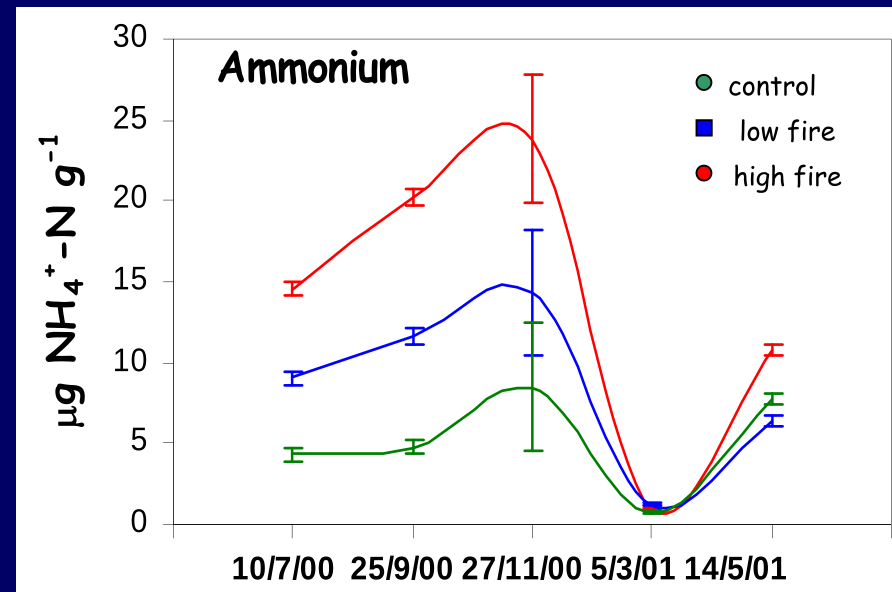
(Bédard and Knowles, 1989)

Reduction of methane oxidizing capacity of soil

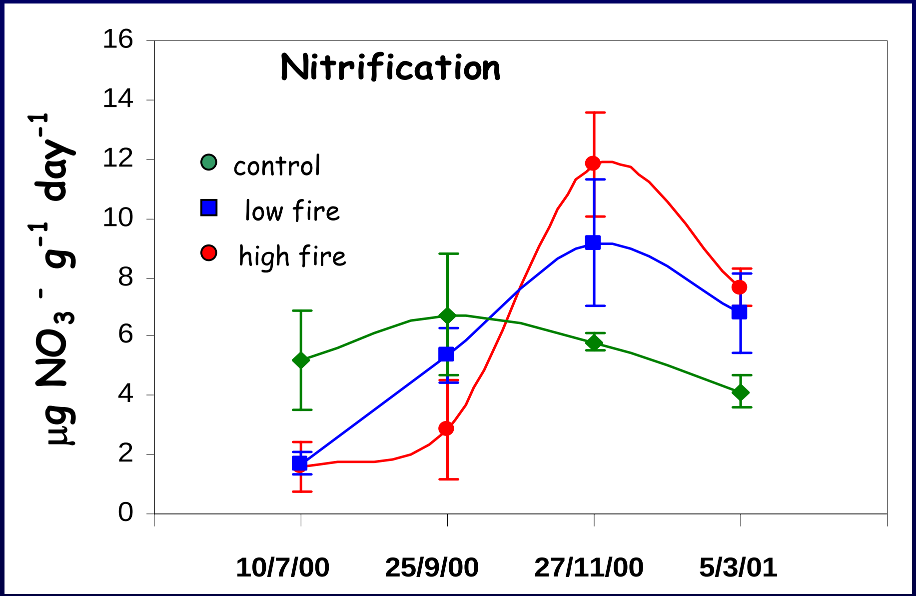
(Smith K.A. et al., 2000)

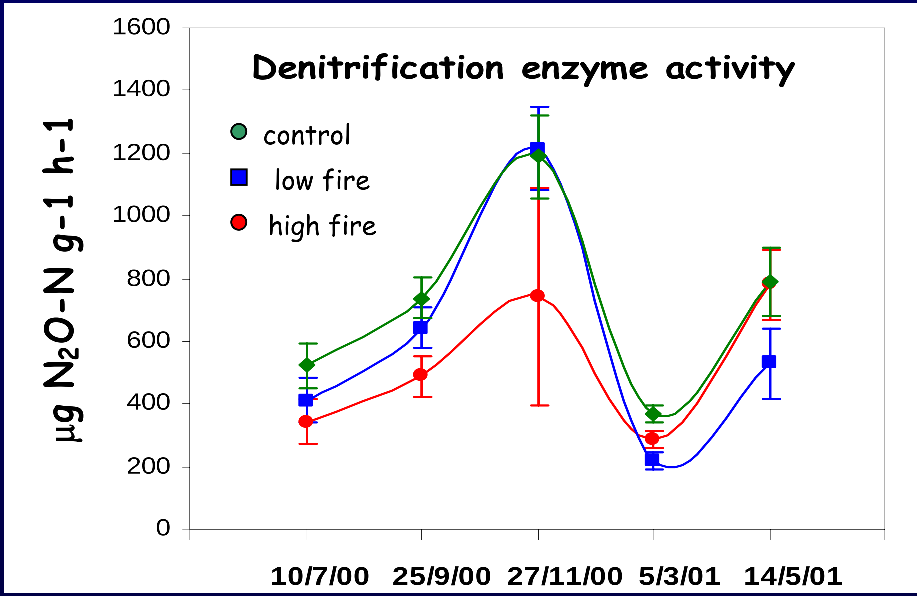
Laboratory CH4 uptake rates measured on Castel Volturno soil under fire experiment





Nitrification and denitrification measured in Castel Volturno soil under fire experiment





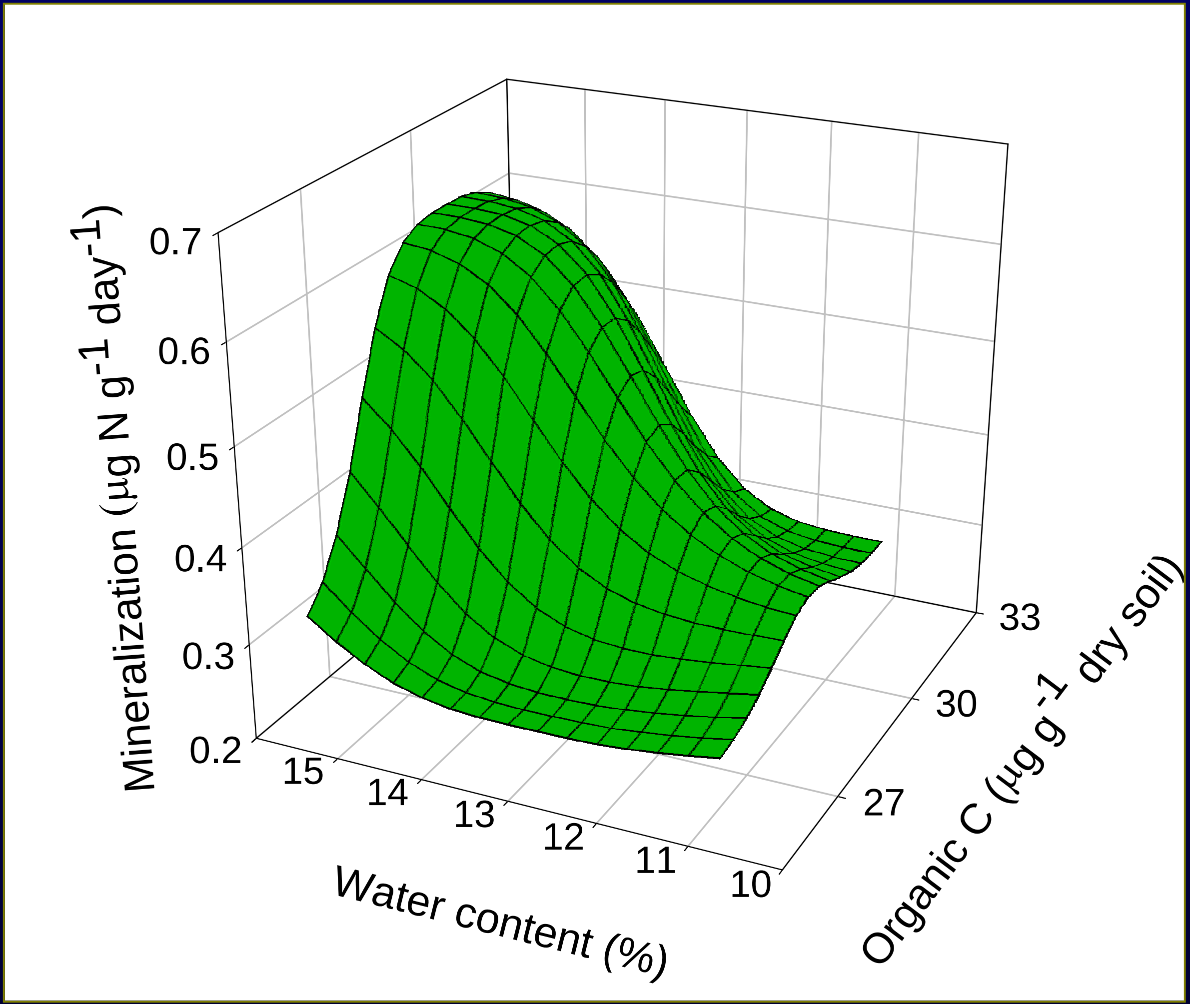
Nitrification is strongly reduced immediately after fire

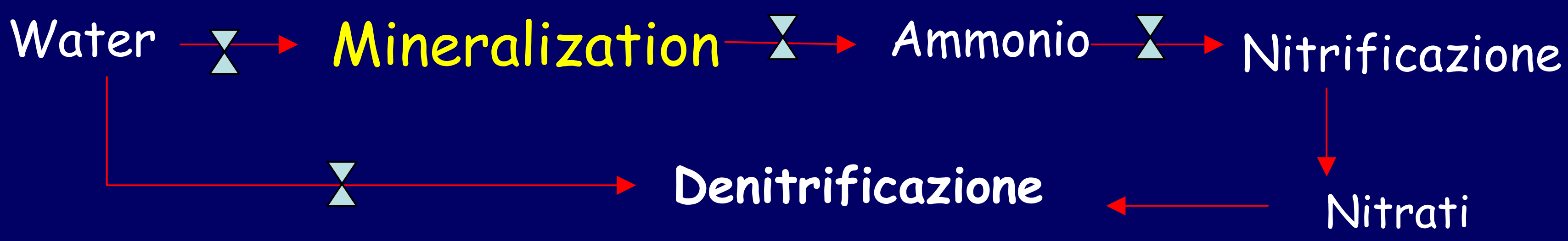
Denitrification is slightly reduced immediately after fire

It is then stimulated compared to the control

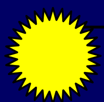
It is then enhanced compared to the control

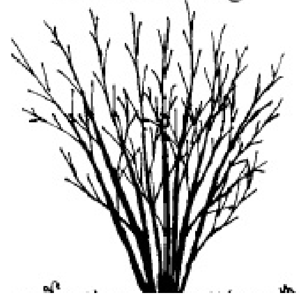
Mineralization is limited by water and organic input




Water
Mineralization
Ammonio
Nitrificazione
Denitrificazione
Nitrati

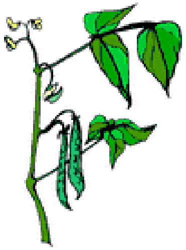
Main driving factors of denitrification activity in Castel Volturno site

Sampling	Variables	R^2	P
	Denitrification vs. nitrification	0.67	0.007
	Denitrification vs. nitrification	0.72	0.004
	Denitrification vs. wc%	0.78	0.002
	Denitrification vs. NH_4^+-N	0.71	0.004
	Denitrification vs. NH_4^+-N	0.68	0.006
	Denitrification vs. NO_3^--N	0.83	0.005
	Denitrification vs. nitrification	0.85	0.004
	Denitrification vs. organic C%	0.83	0.006



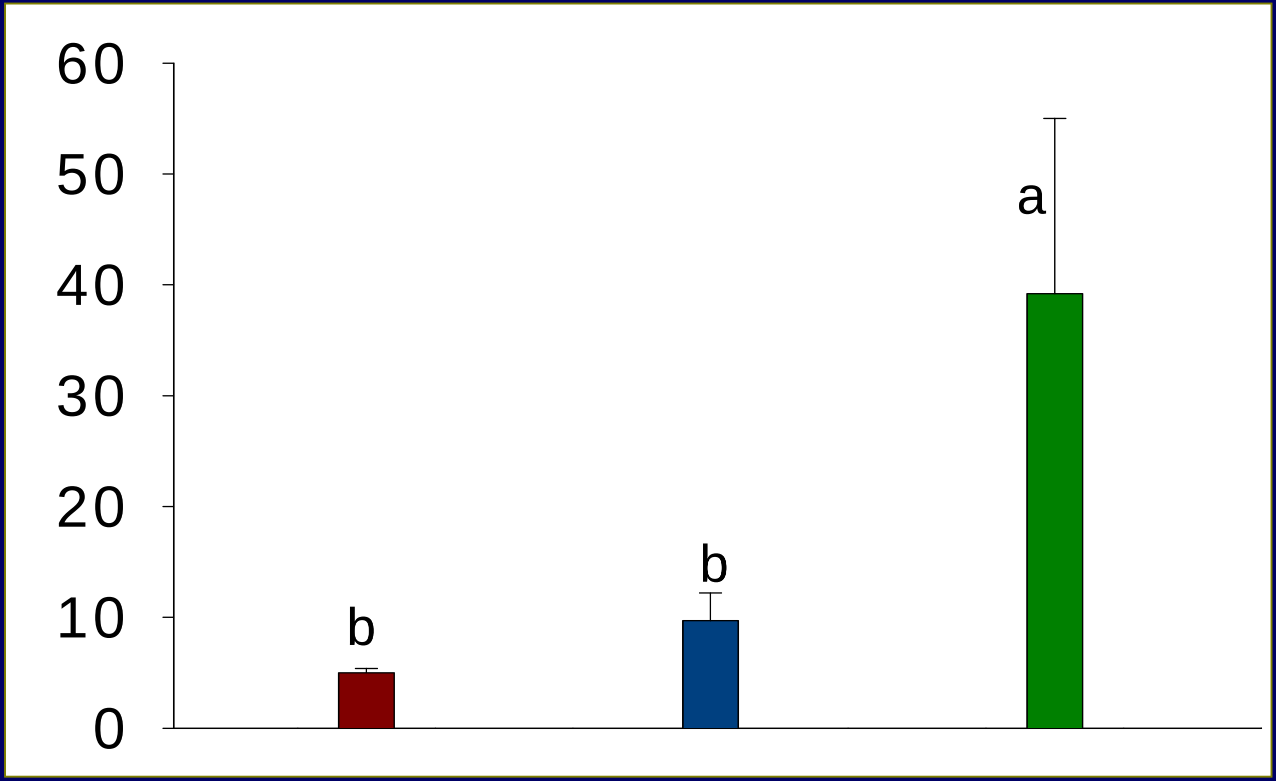
shrubs

non fixer
herbaceous

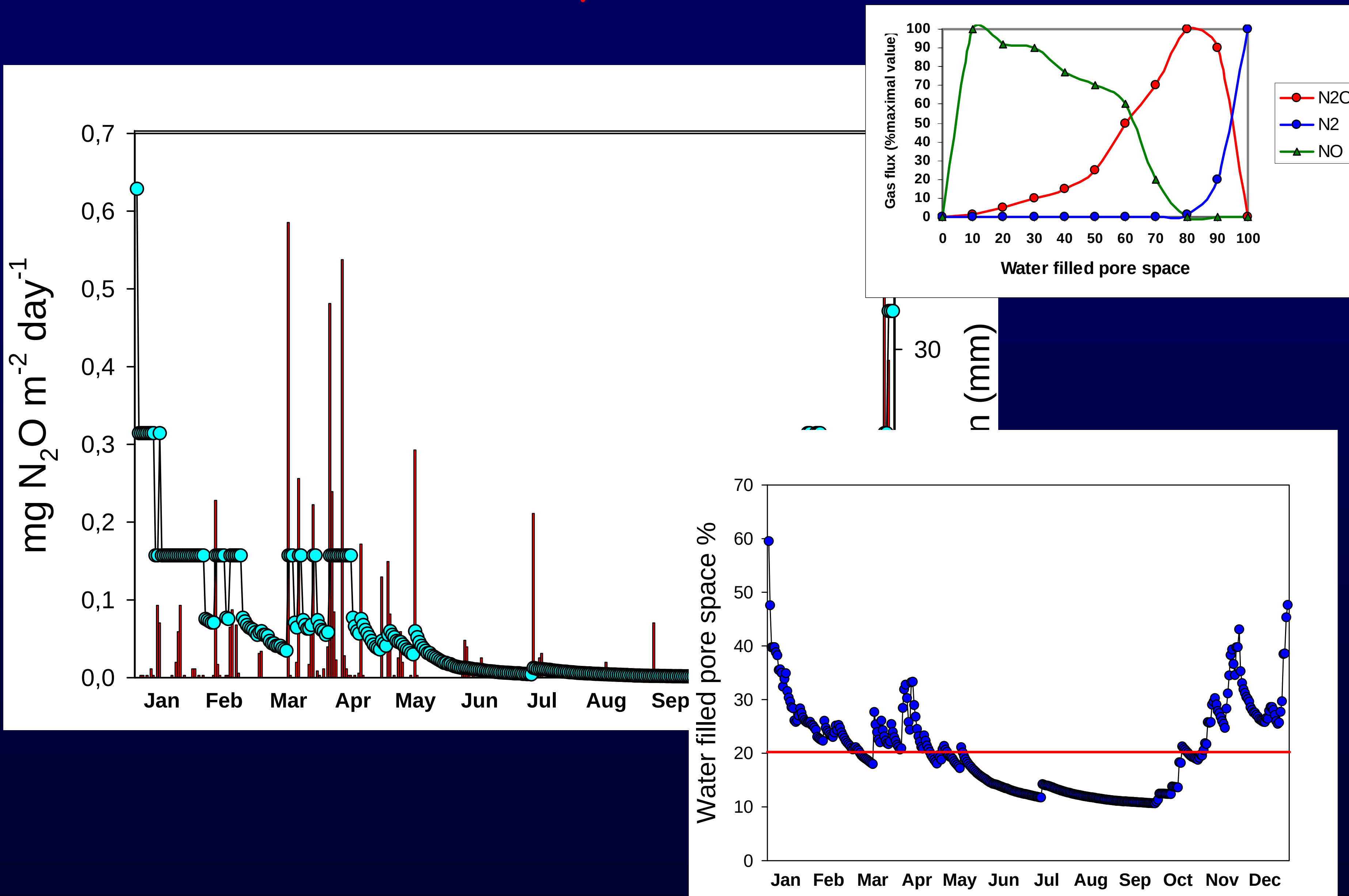


leguminous

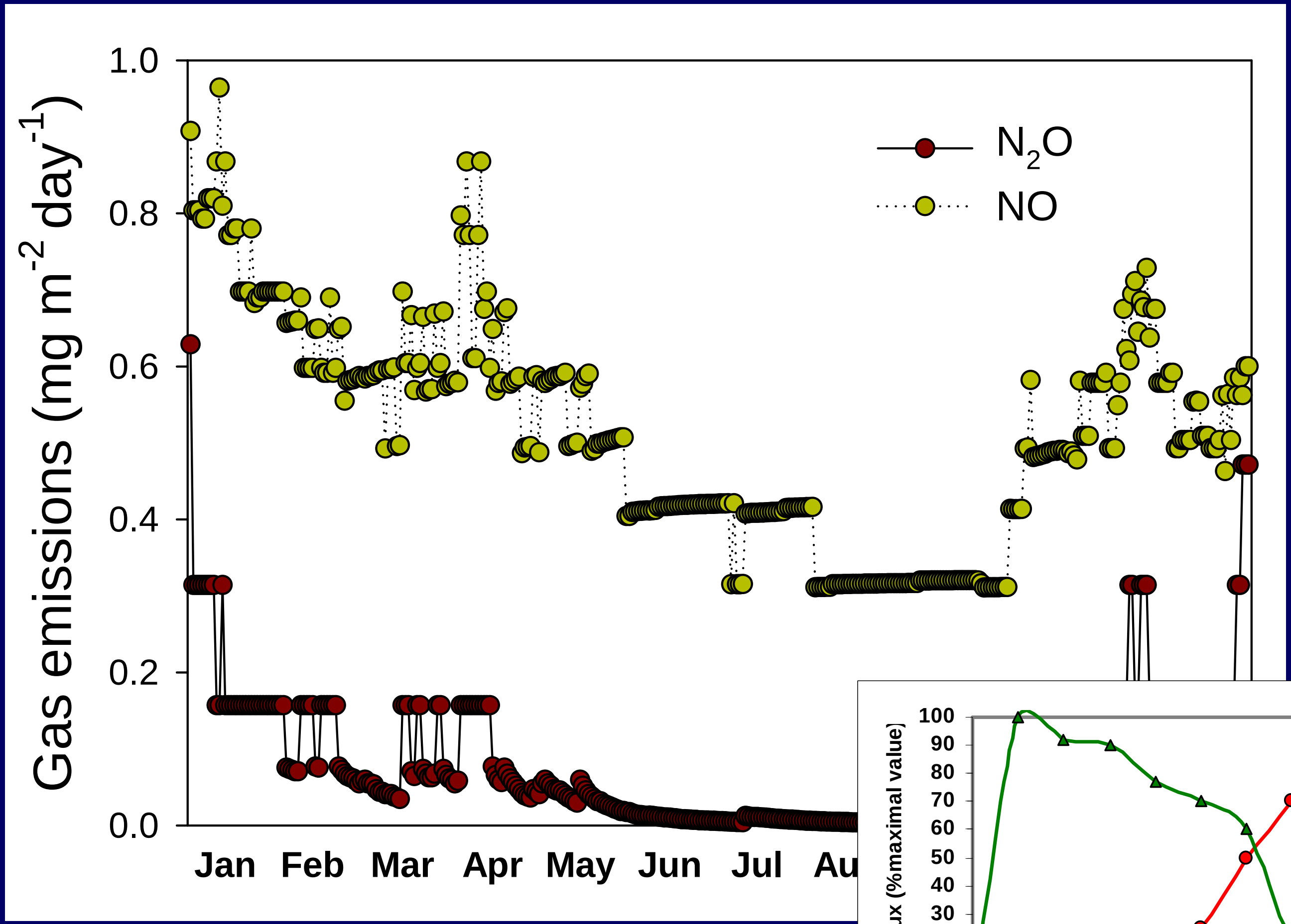
Denitrificazione
ng $N\text{-}N_2O$ g^{-1} h^{-1}

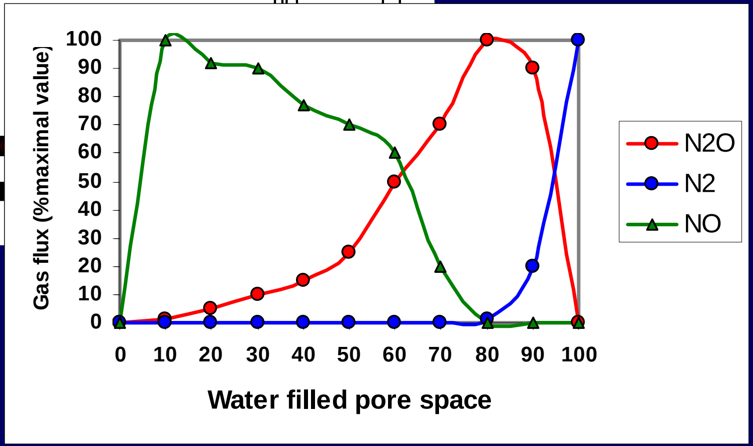


N_2O fluxes simulated during the whole year 2000 using Daycent model

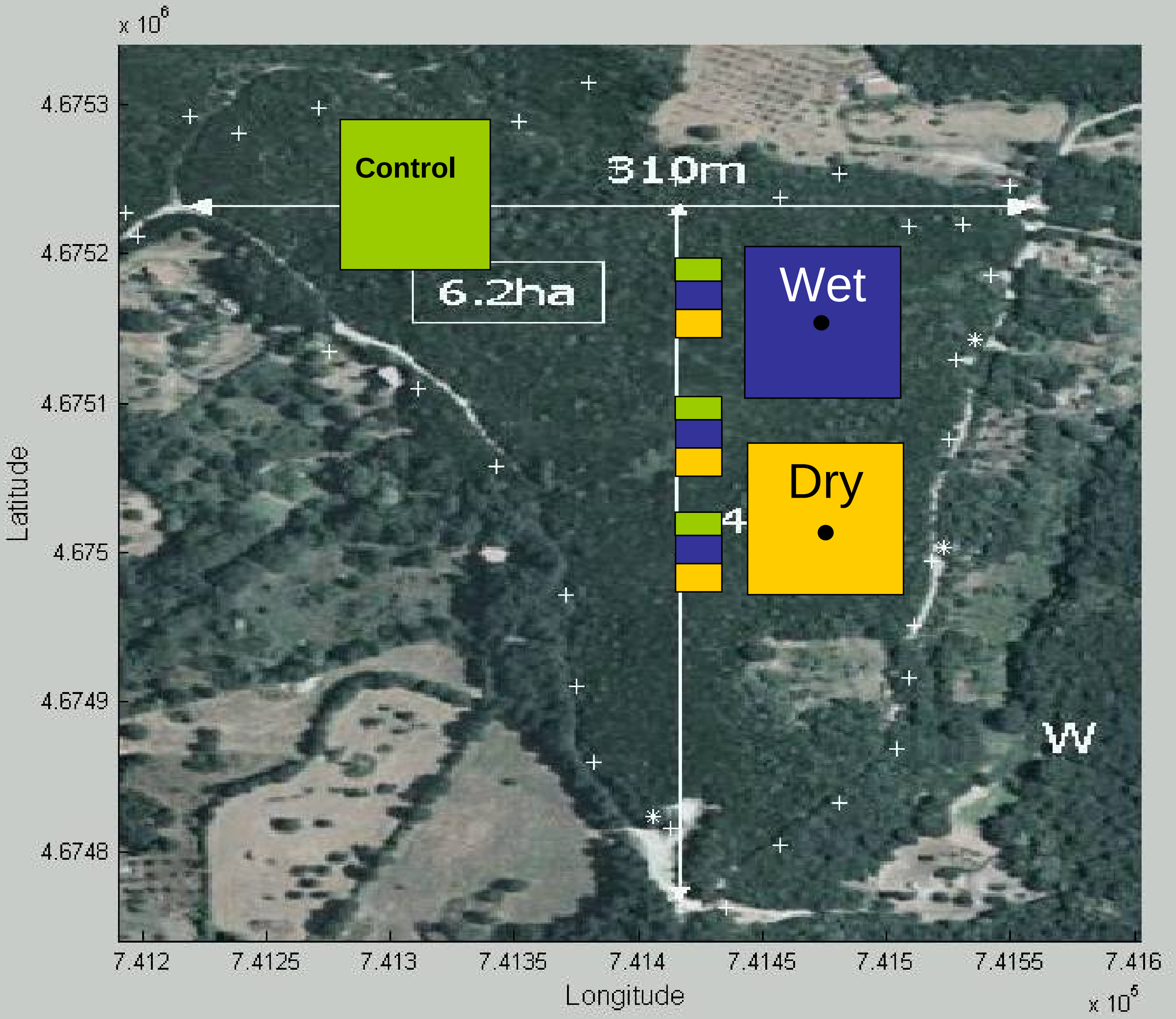


NO and N_2O fluxes simulated during the whole year 2000 using Daycent model





TOLFA


x 10^6
4.6753
4.6752
4.6751
4.675
4.6749
4.6748
Latitude
Control
310m
6.2ha
Wet
Dry
4
W
7.412
7.4125
7.413
7.4135
7.414
7.4145
7.415
7.4155
7.416
Longitude
x 10^5

DRY TREATMENT

20% RAIN INTERCEPTED BY DRAINS

WET TREATMENT

IRRIGATION SYSTEM

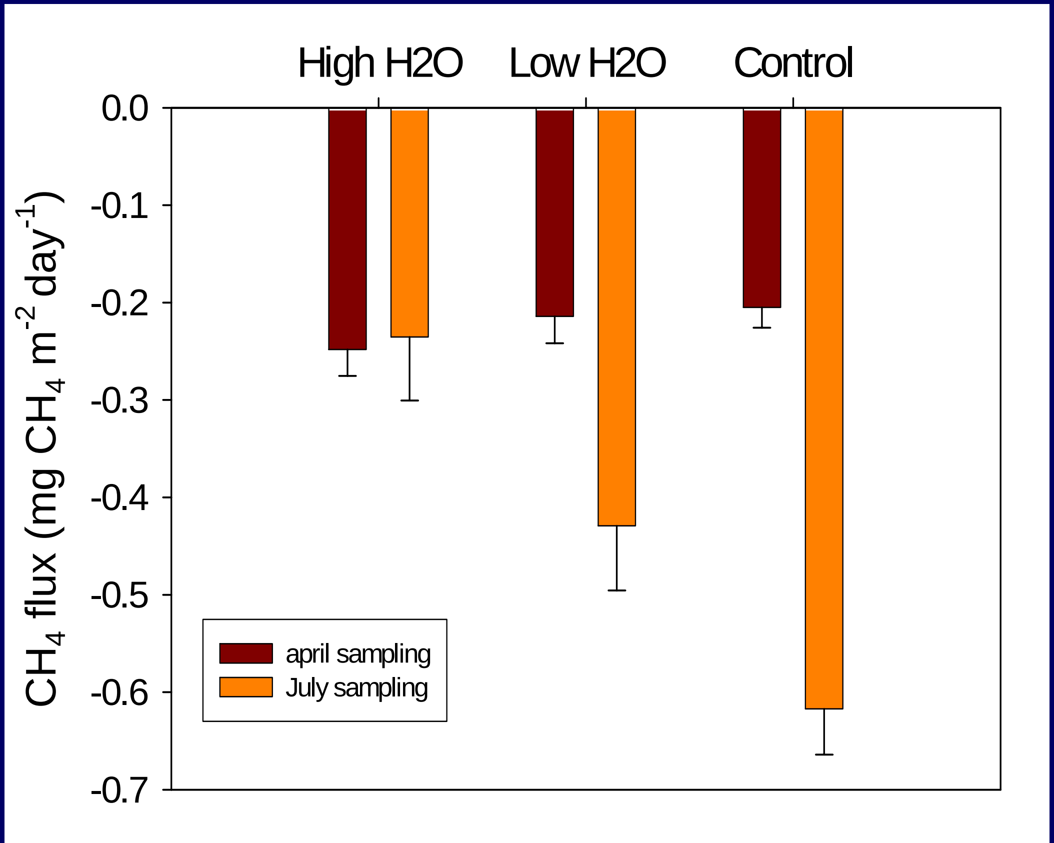
~ + 20% water input

Measurements of N_2O and CH_4 at the Tolfa site

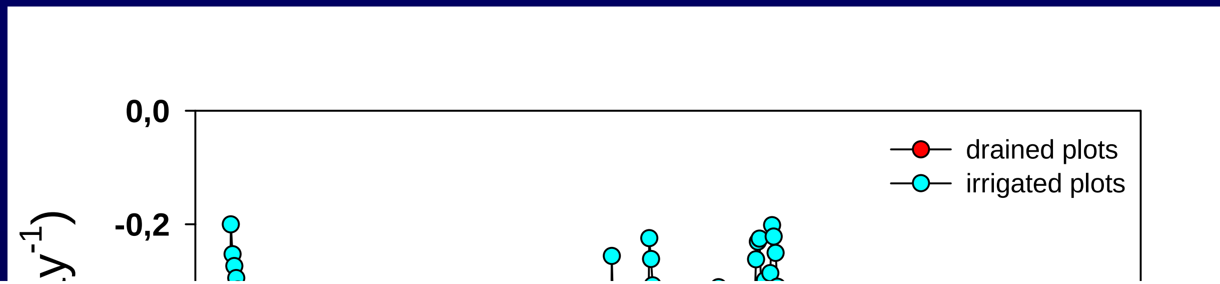
- N_2O FLUXES WERE ALWAYS BELOW DETECTION LIMIT !

Methane fluxes average by treatment ± 1 st. error (n=9).

- NO TREATMENT STATISTIC EFFECT
- SIGNIFICANT SEASONAL EFFECT



CH4 fluxes in wet and dry plots simulated using the diffusional model by Potter et al. 1993 during the year 2004-2005



Budget over the period September 2004 – August 2005

WET TREATMENT

Tot annual uptake = **253,6** mg CH_4 m^{-2}

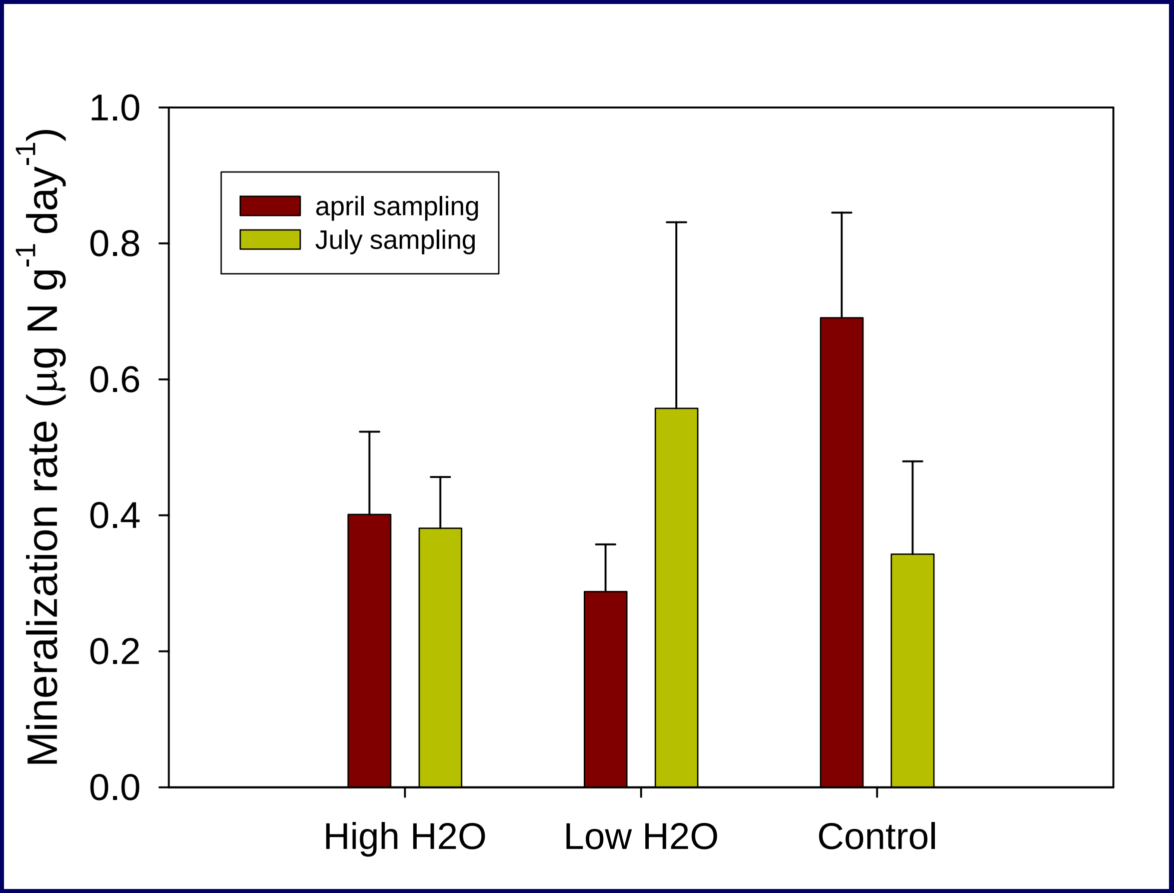
Annual average daily flux = - 0.92 ± 0.18 mg CH_4 m^{-2} day^{-1}

DRY TREATMENT

Tot annual uptake = **302,3** mg CH_4 m^{-2}

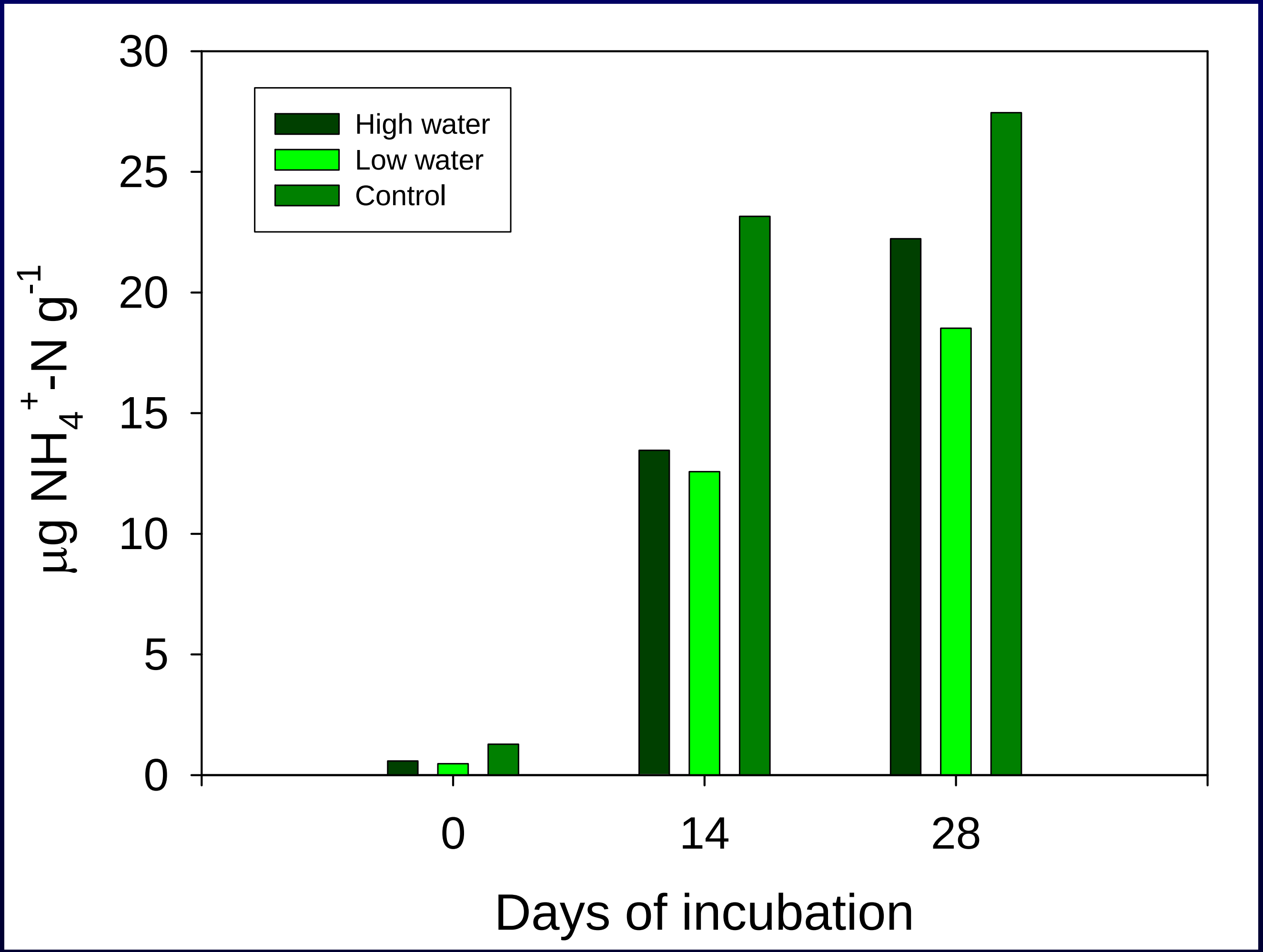
Annual average daily flux = - 0.83 ± 0.15 mg CH4 m^{-2} day^{-1}

N mineralization rates ± 1 st. error (n=9).



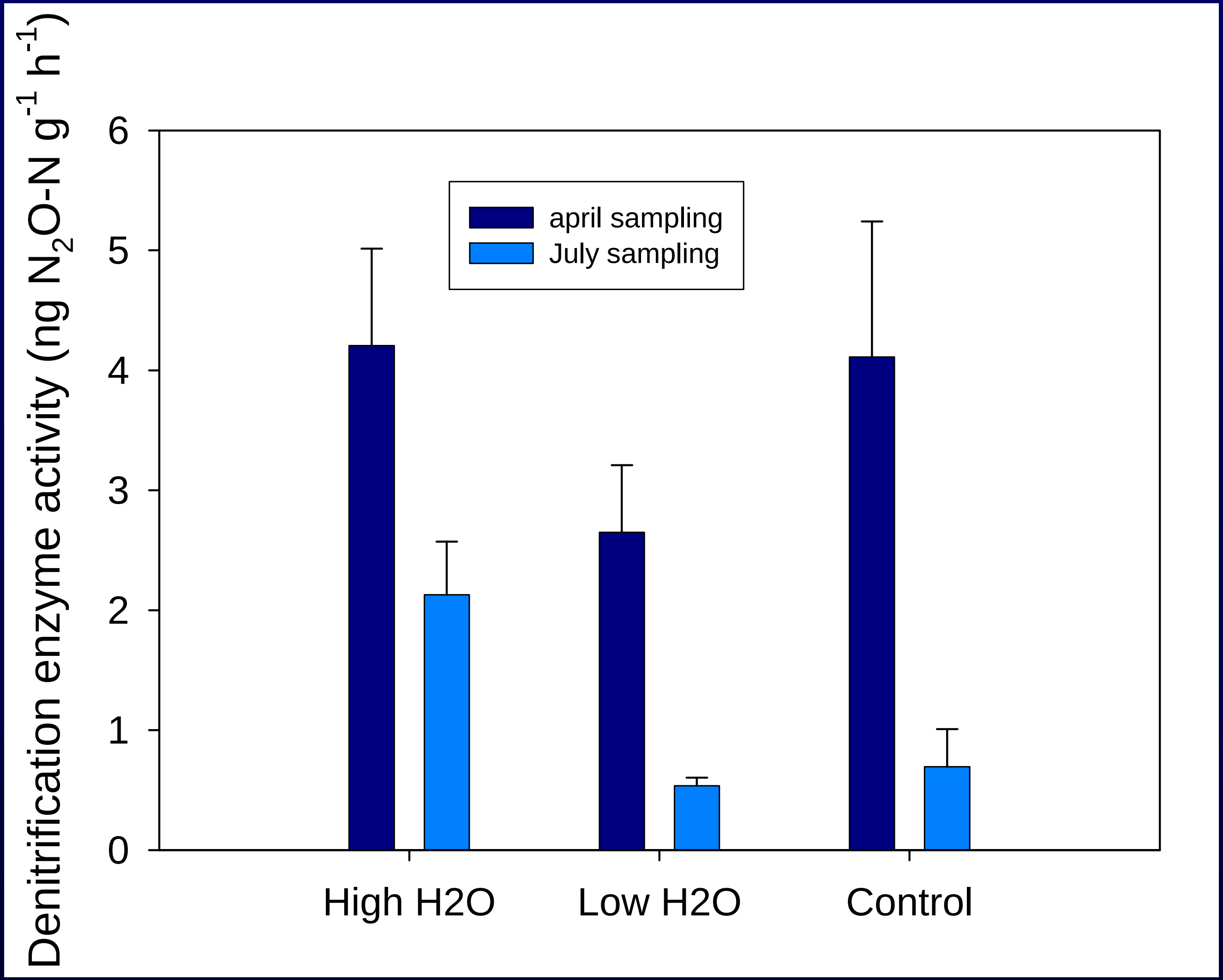
NITRIFICATION

No autotrophic nitrification was detected in the Tolfa soil !



NH_4^+ accumulates, no NO_3^- is formed in the Tolfa soil

DENITRIFICATION



Denitrification enzymes, despite the low levels of NO_3^-, are however present

Some questions which rise from the results

- In the system no autotrophic nitrification occurs.
- Which process forms NO_3^- which should act as substrate for the present denitrification activity?
- Is heterotrophic nitrification present at this site?
- Do denitrifiers use mineral NO3- or organic N ?
- Why is nitrification blocked?
- Is it due to low pH? Or allelophatic effects?
- How can we model properly N cycle and N2O fluxes in this ecosystem?

INHIBITORY EFFECT OF LOW pH

Tolfa soil was limed with **CaCO3**

Soil pH 4.7 ⇒ 6.1

Tolfa soil is incubated for 14 days at 25°C

Table - Nitrification rates measured over 14 days in limed and unlimed soil from Tolfa

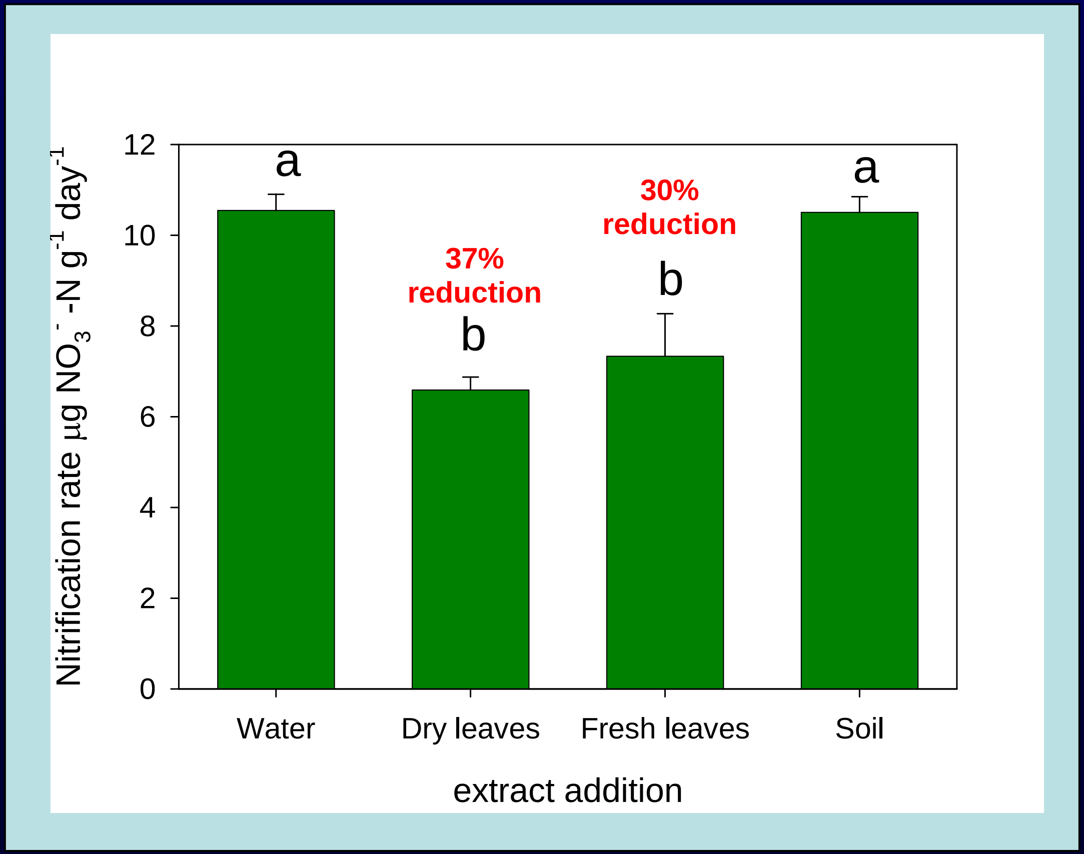
	Nitrification rate $\mu g\ NO_3^-\text{-}N\ g^{-1}\ day^{-1}$	Soil pH
Tolfa soil	0.00	4.7
Limed Tolfa soil	0.006 ± 0.007	6.1

No positive effect of pH rise over 14 days was observed

POSSIBLE ALLELOPHATIC EFFECTS

Extracts (2 hours in water) of:

- fresh leaves of Arbutus unedo
- Dry intact leaves from litter of Arbutus unedo
- Soil underneath Arbutus unedo



Nitrification Test on soil from: Mediterranean maquis of Castelvolturno

Incubation for 14 days at 25°C

CONCLUSIONS

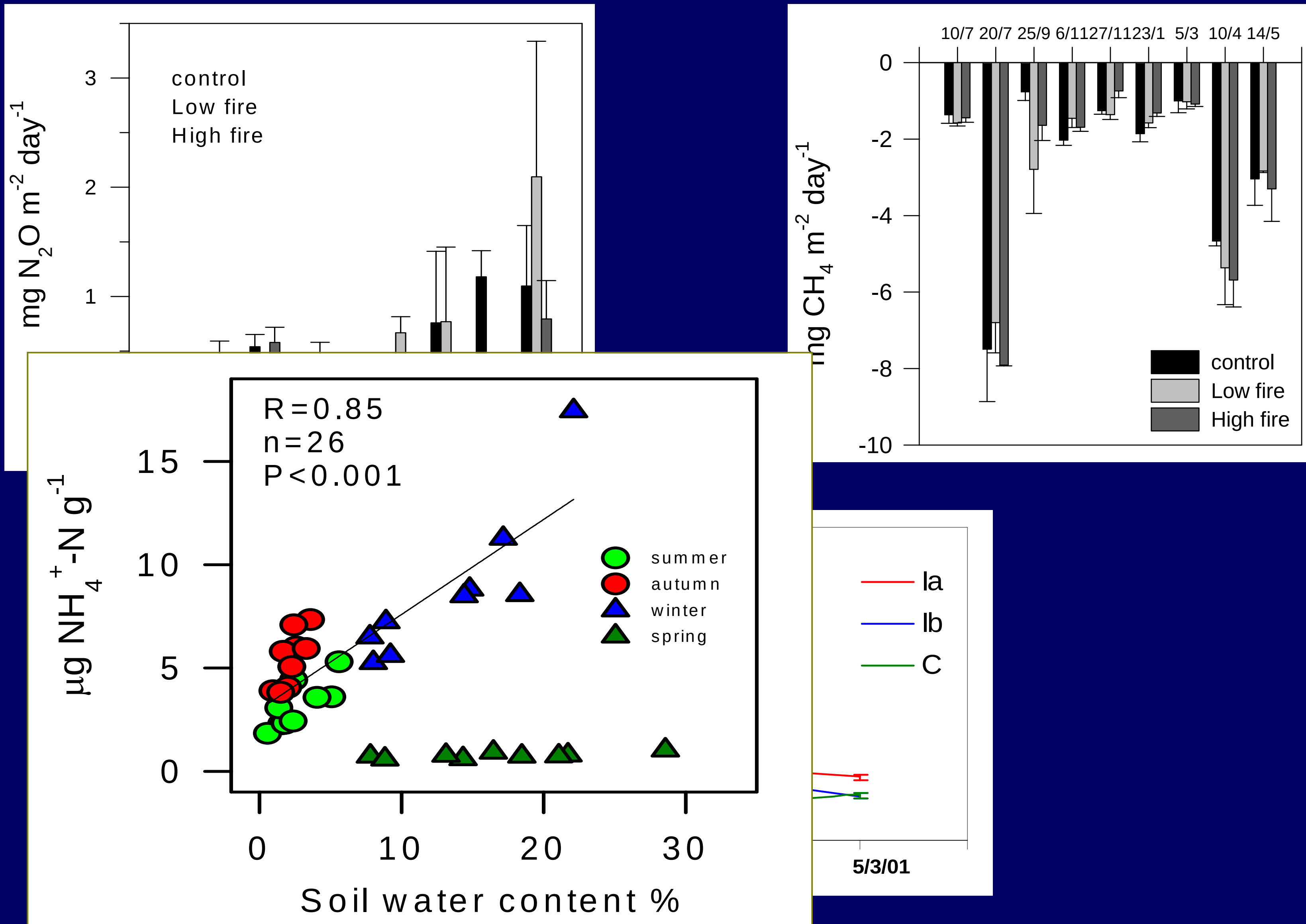
Despite a similar climate and type of vegetation, the two macchia sites have shown very different N_2O and CH_4 fluxes as well as different patterns of N cycle

In both cases the measured N_2O and CH_4 fluxes did not match exactly the expected values on the base of previous reported observations.

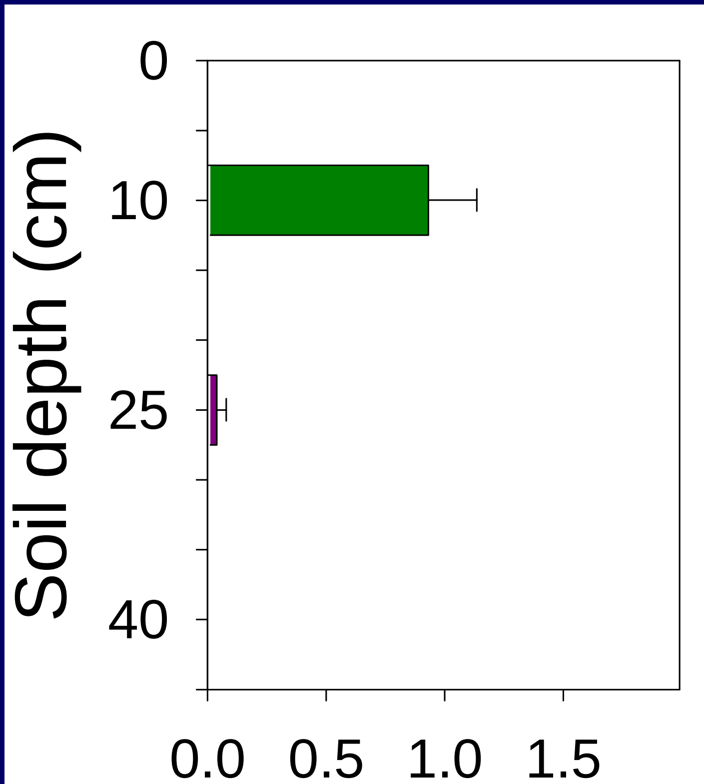
Both systems seem quite resistent and resilient to changes induced by external events such as fire or variations of climatic regime

More research is needed in these ecosystems in order to scale up N_2O and CH_4 fluxes over the entire Mediterranean region

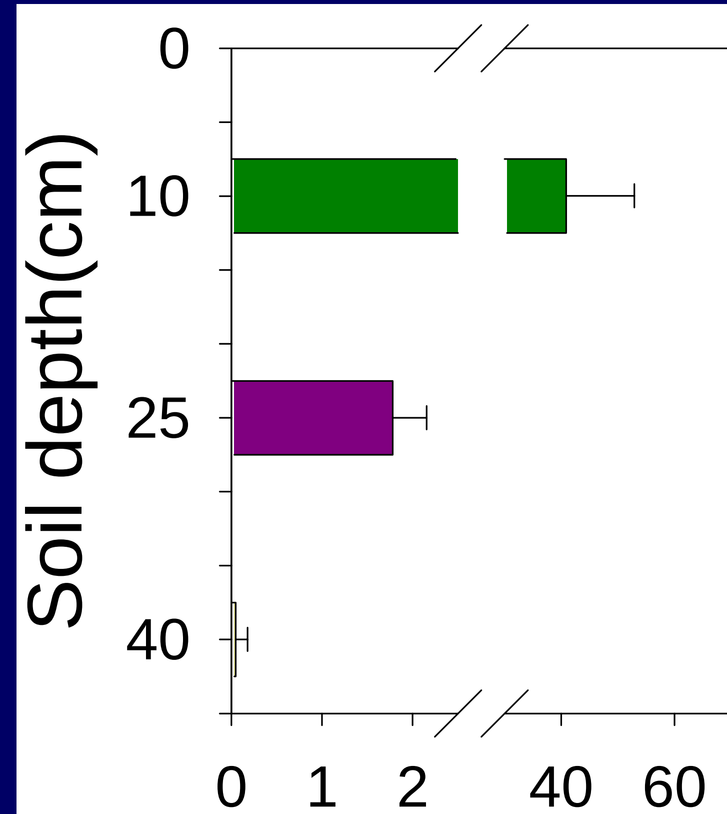

thank you



mg N$_2$O m^{-2} day^{-1}
3
2
1
control
Low fire
High fire
mg CH$_4$ m^{-2} day^{-1}
10/7 20/7 25/9 6/11 27/11 23/1 5/3 10/4 14/5
0
-2
-4
-6
-8
-10
control
Low fire
High fire
Ia
Ib
C
5/3/01
R=0.85
n=26
P<0.001
µg NH$_4^+$-N g^{-1}
15
10
5
0
summer
autumn
winter
spring
0
10
20
30
Soil water content %



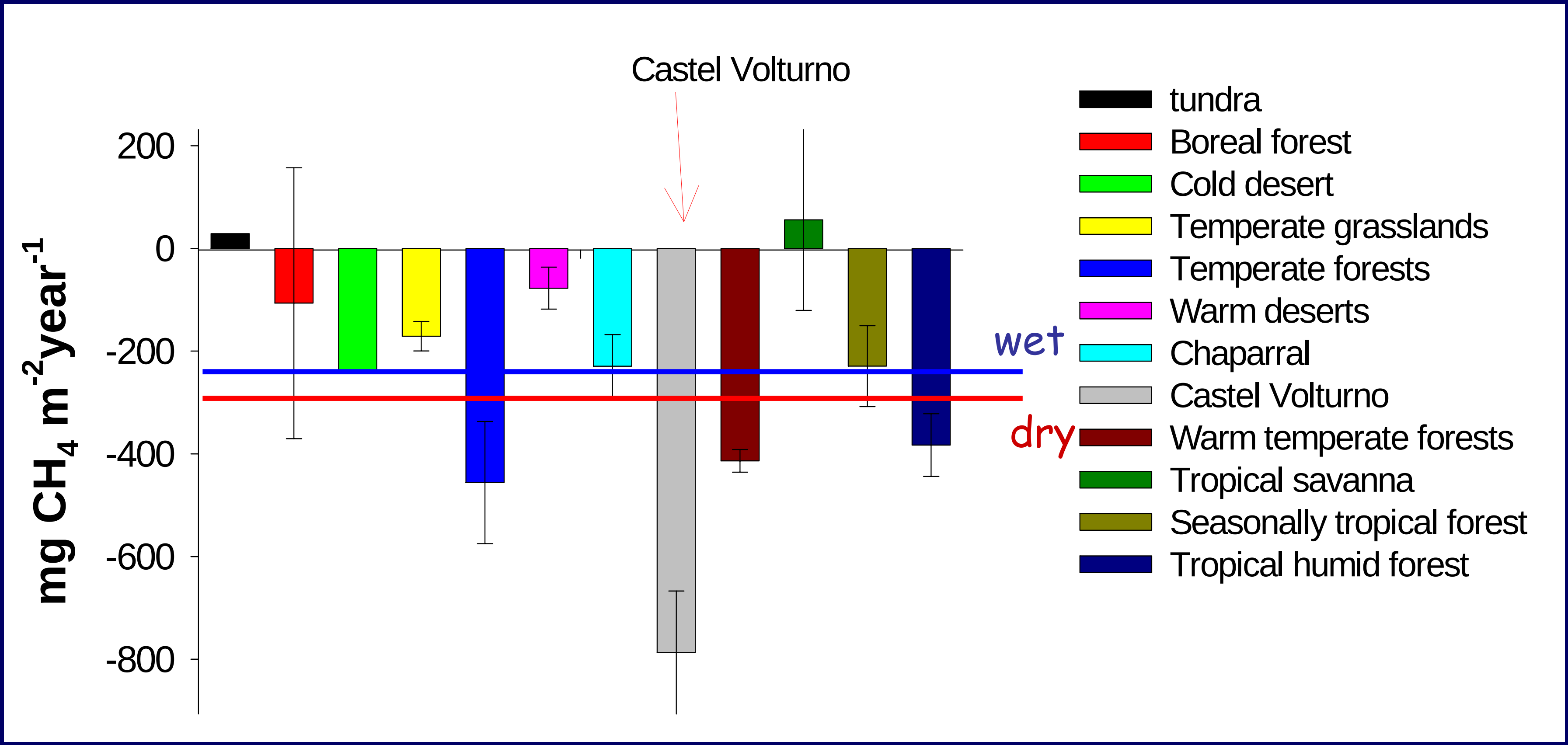
Nitrification rate (μg N-NO_3^- g^{-1} day^{-1})

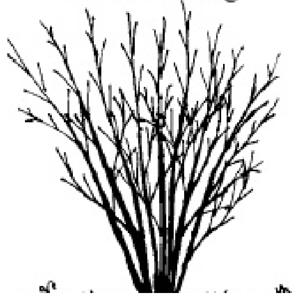


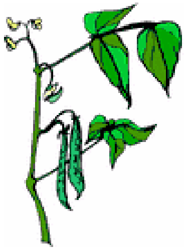
Denitrification enzyme activity

(ng N g^{-1} h^{-1})

Comparison of modeled CH_4 fluxes at Tolfa site in wet (blue line) and dry (red line) plots with other ecosystems







shrubs

non fixer herbaceous

leguminous

Mineralizzazione
μg N g^{-1} day^{-1}

Nitrificazione potenziale
μg N g^{-1} day^{-1}

Denitrificazione
ng N-N$_2$O g^{-1} h^{-1}