The role of leguminous plants in the N cycle and N inputs/outputs in a Mediterranean shrubland ecosystem

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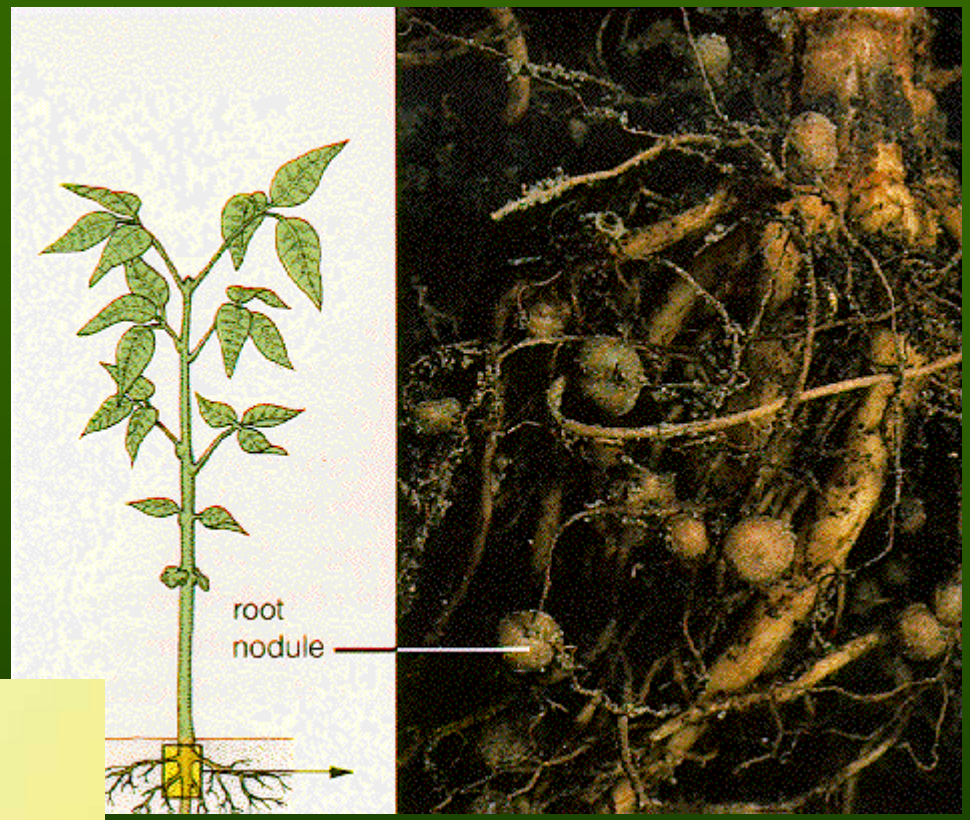
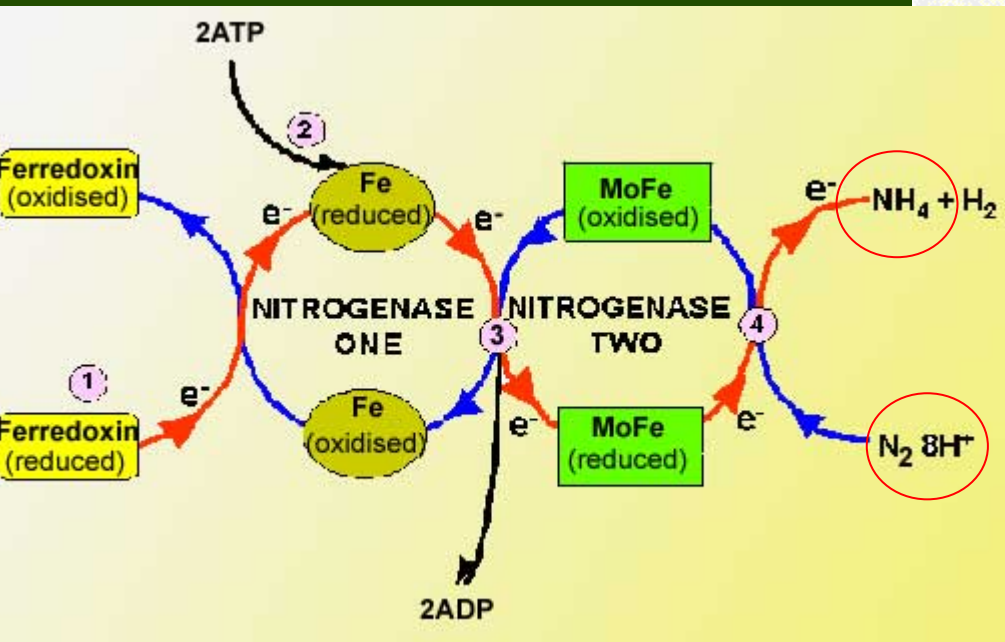
Biological Nitrogen fixation

Fabaceae (Leguminosae)

Caesalpinioideae and Mimosoidae: mainly consist of woody shrubs and trees (mainly tropical and subtropical regions)
Papilionoideae: woody shrubs, trees, and perennial and annual herbs.





97% of the Papilionoideae
90% of the Mimosoideae
23% of the Caesalpinoideae
have been found to nodulate

Most common leguminous plants present in the Mediterranean macchia

Spartium junceum

shrub

leguminous non fixer

Medicago

Melilotus

herbaceous

leguminous N_2 fixer

Herbaceous plants dominate open spaces in macchia following a disturbance event: fire, cut, cut and grazing

Which is the role of N_2 fixing plants in Mediterranean ecosystems ?

Do they enrich the system with Nitrogen?

Are N losses from the system higher below the leguminous cover?

Experimental steps carried on in the experimental site:

- Which are the leguminous present in the maquia area of study? Characterization of the herbaceous species present at site (n° of individuals, species, cover, biomass)

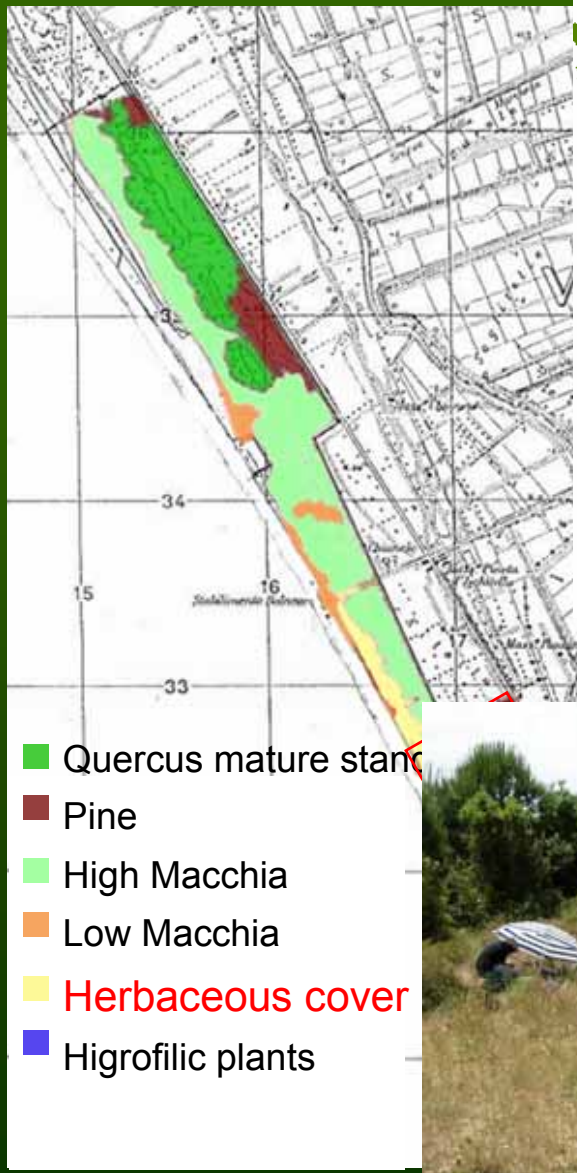
- How much N_2 enters in the system via leguminous input? Determination of the amount of N_2 fixed by the leguminous plants by two techniques: "N difference technique" and "Ndfa natural isotopic abundance"

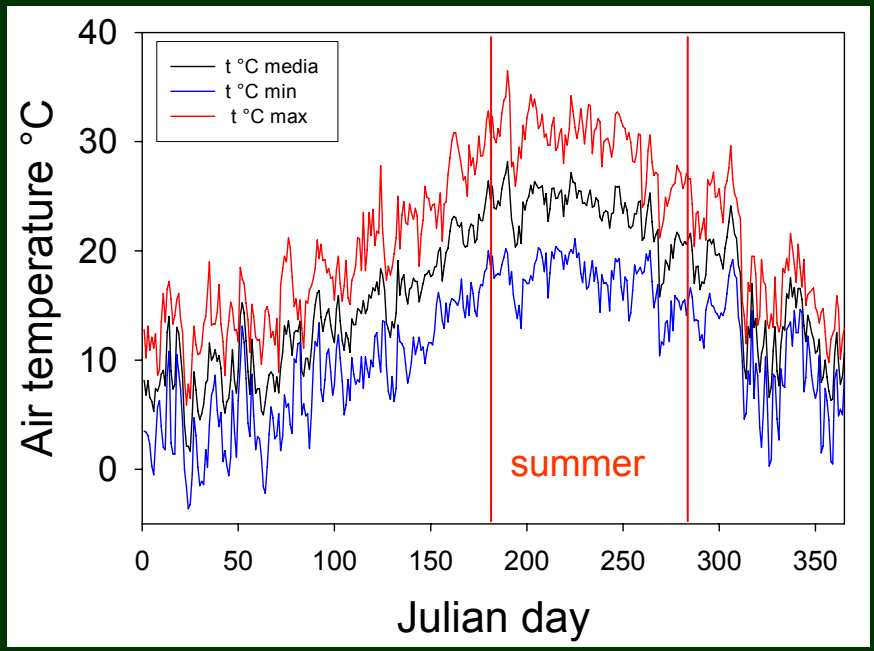
- How much Nitrogen flows, is produced and can be lost fom the system? Modellization of N cycle in the studied site by using different cover types and scenarios to estimate N losses and gains

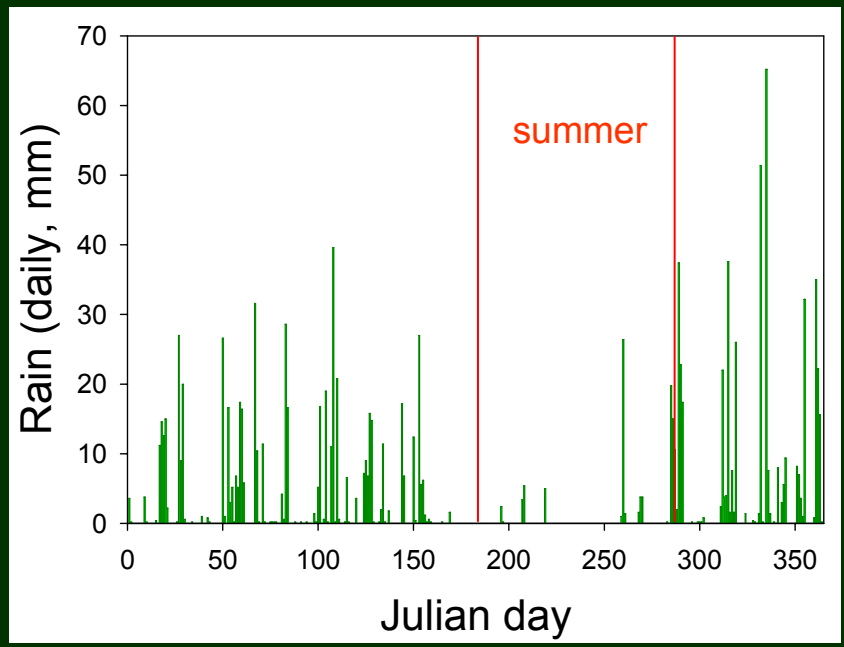
STUDY SITE

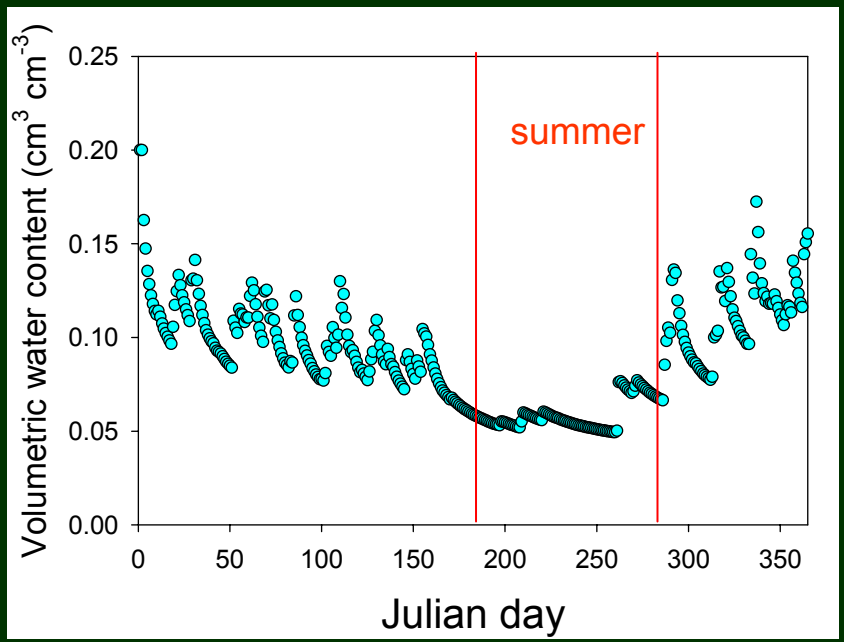
NATURAL RESERVE OF CASTEL VOLTURNO

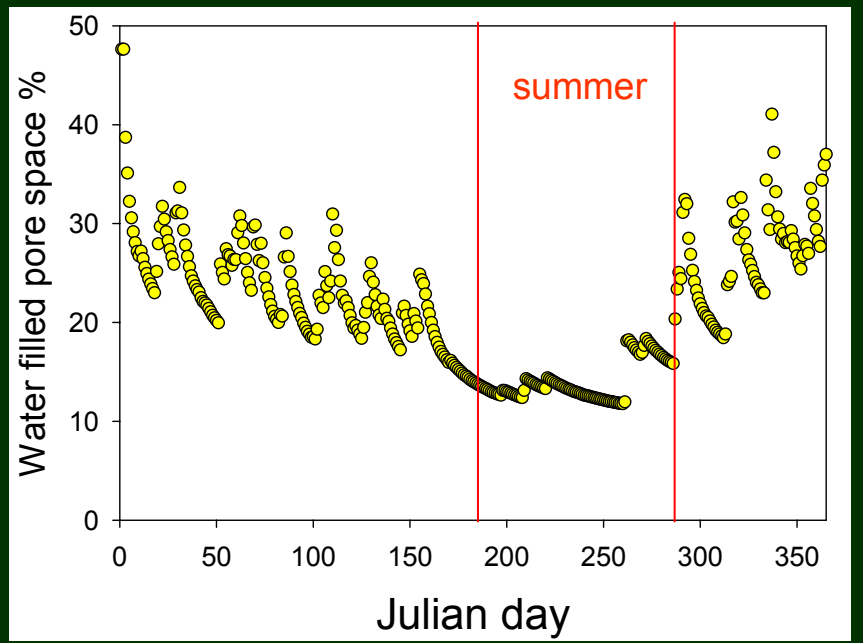
NITROEUROPE SITE




t °C media
t °C min
t °C max
summer
Air temperature °C
Julian day


summer
Rain (daily, mm)
Julian day


summer
Volumetric water content (cm3 cm-3)
Julian day


summer
Water filled pore space %
Julian day

Estimate of % N2 fixation

N-DIFFERENCE technique

Leguminosa
(Leg)

Reference non leguminous
(Ref)

$$\text{Ndfa \%} = [(N_{tot}\ \text{mass}^{-1}\ \text{Leg}) - (N_{tot}\ \text{mass}^{-1}\ \text{Ref})] \times 100$$

Estimate of % N_2 fixation (%Ndfa) by using the natural abundance technique

$$\%Ndfa = 100 \times \frac{\delta^{15}N \text{ (reference plant)} - \delta^{15}N \text{ (legume)}}{\delta^{15}N \text{ (reference plant)} - B}$$

Mass	Natural Abundance %
^{14}N	99.634
^{15}N	0.366
^{13}N	unstable

$$\delta^{15}N = \frac{R(spl) - R(std)}{R(std)} \times 1000$$

Atmospheric N_2 is considered to have a $\delta^{15}N = 0$ ‰

In ecosystems compartmentsl $\delta^{15}N$ varies between –10

and +15 ‰

$$R = \frac{^{15}N}{^{14}N}$$

Variations of ^{15}N natural abundance in the different components of the biosphere are the result of isotopic discrimination.

Leguminosae

Melilotus neapolitana

Medicago minima

Reference plants

Phleum subulatum

Petrorhagia velutina

Plant sampling

- 10 plots
- In each plot → 5 areas of 10x10cm
- in each area → 5 individuals/ specie

Samples in each plot are then bulked

Sample preparation and analyses

seeds

above ground biomass

roots

drying in oven at 70°C for 48h

powderization

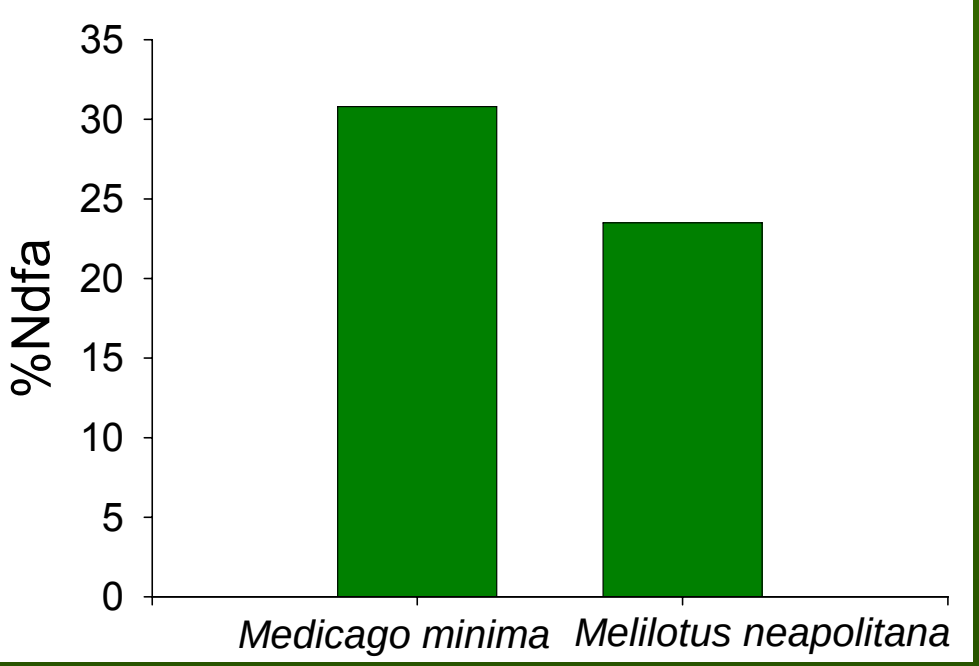
tin capsules

C.N.S analyser

C% and N% in tissue

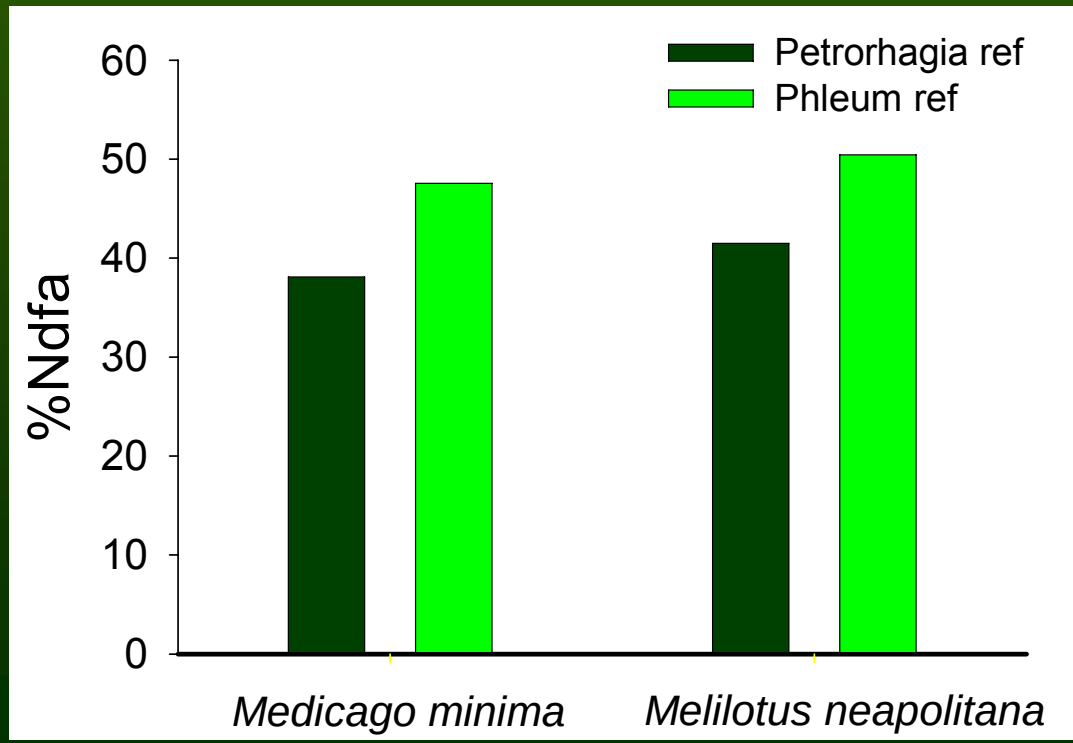
ISOTOPE RATIO MASS SPECTROMETER

$\delta^{15}N$ of N present in analysed tissue

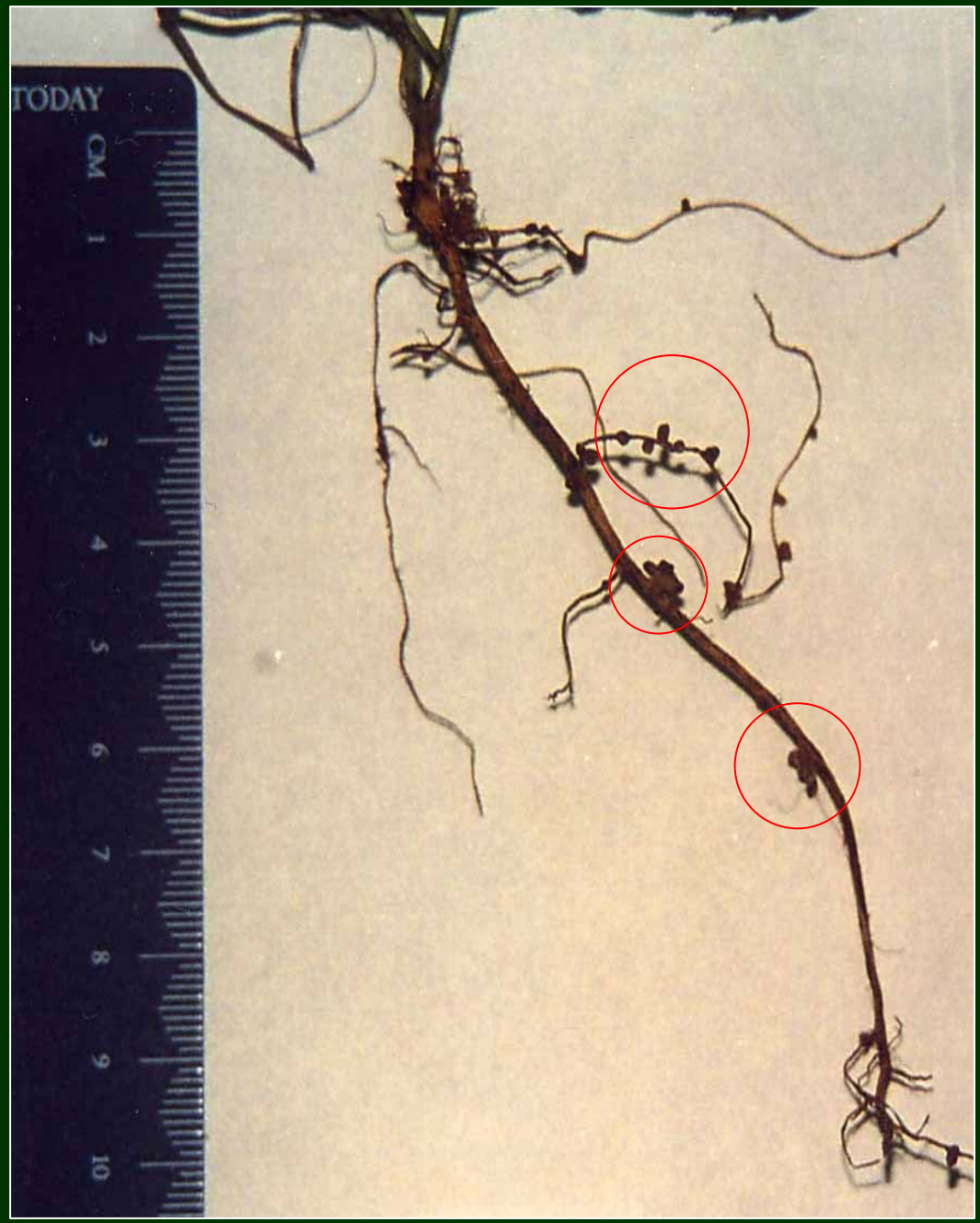


% of N_2 fixed (Ndfa) by the leguminous plants determined by using the N-difference technique

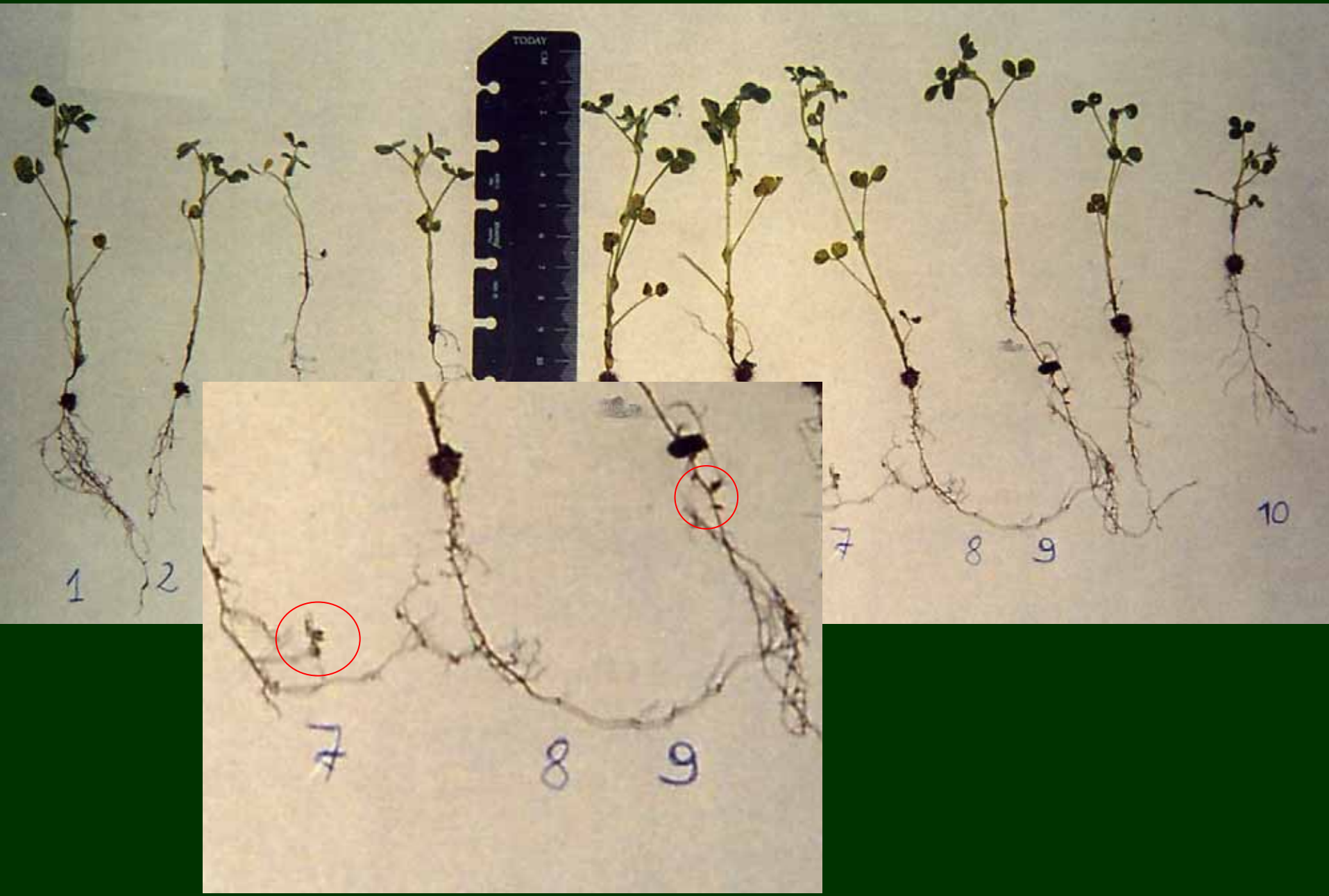
% of N_2 fixed (Ndfa) by the leguminous plants determined by using the ^{15}N natural abundance technique



Lathyrus clymenum

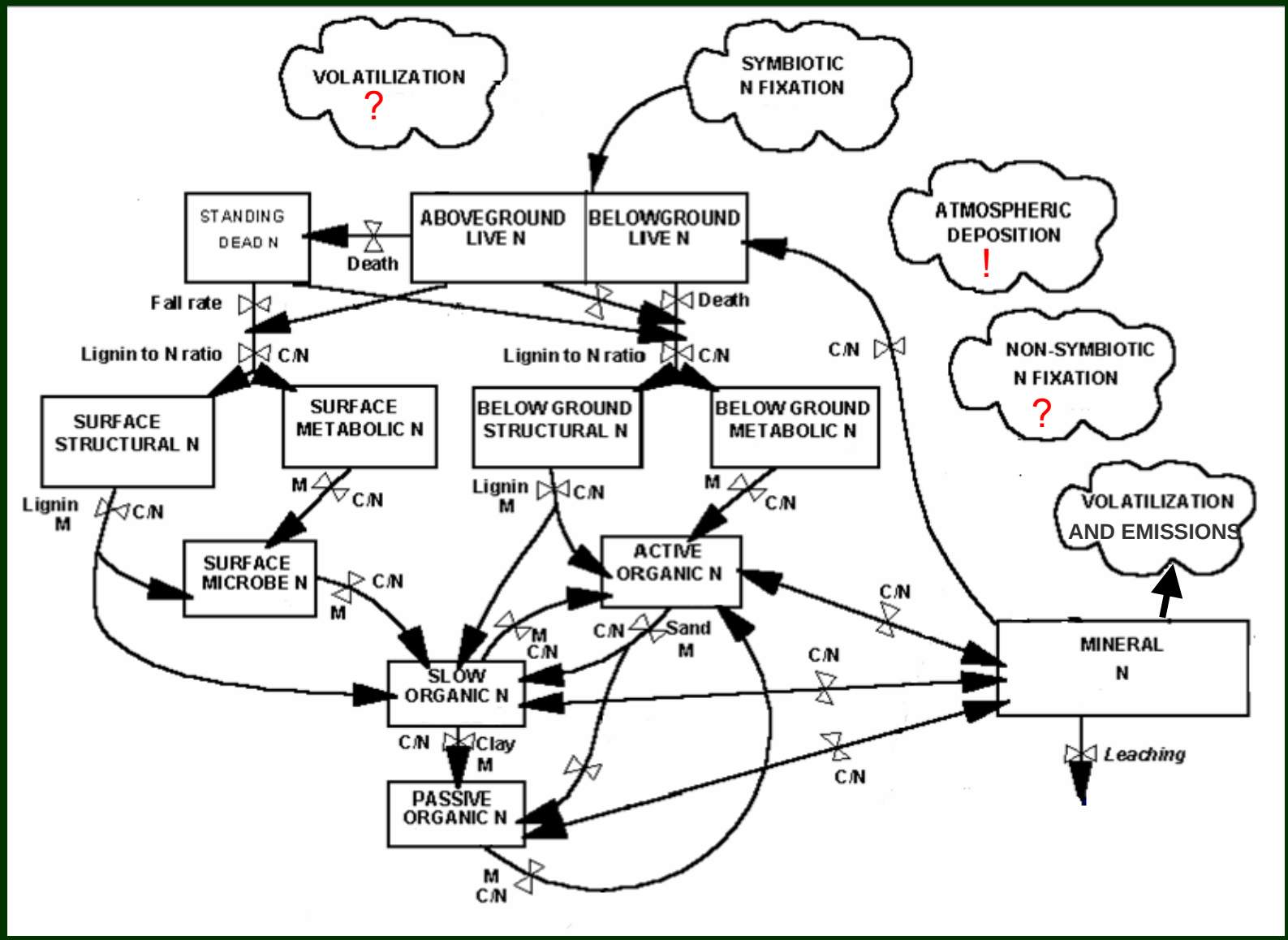


Medicago minima



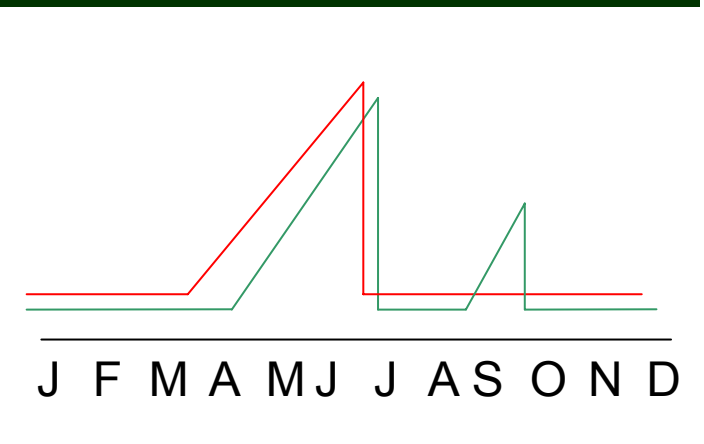
Modellization of N cycle in the studied site by using different cover types (N_2 fixing and non fixing plants) to estimate N losses and gains

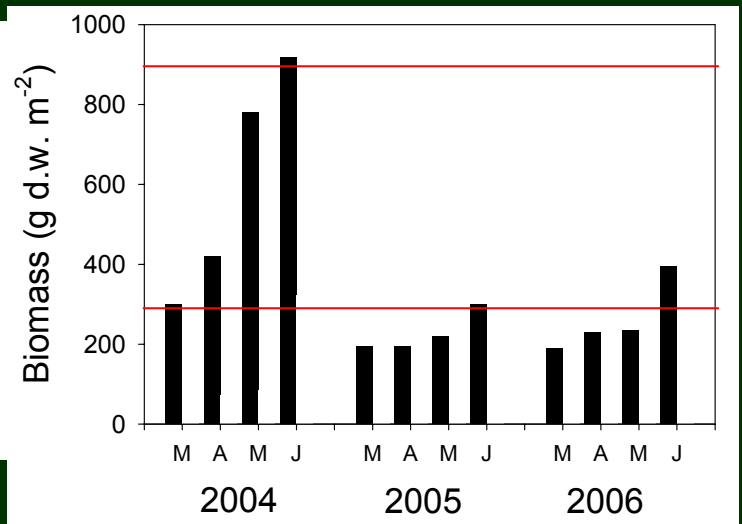
MODELLIZATION OF C AND N USING THE BASIC CENTURY MODEL IMPLEMENTED WITH SIMPLE ALGORITHMS FOR LEACHING AND N GASEOUS EMISSIONS



0 - 54% herbaceous leguminous cover

>90% herbaceous leguminous cover





max value of biomass 900 g m^{-2}

min value of biomass 250 g m^{-2}

SIMULATED SCENARIOS

Scenario 1 Leguminous fixing - 30%Ndfa - max value of total plant biomass

Scenario 2 Leguminous fixing - 30%Ndfa - min value of total plant biomass

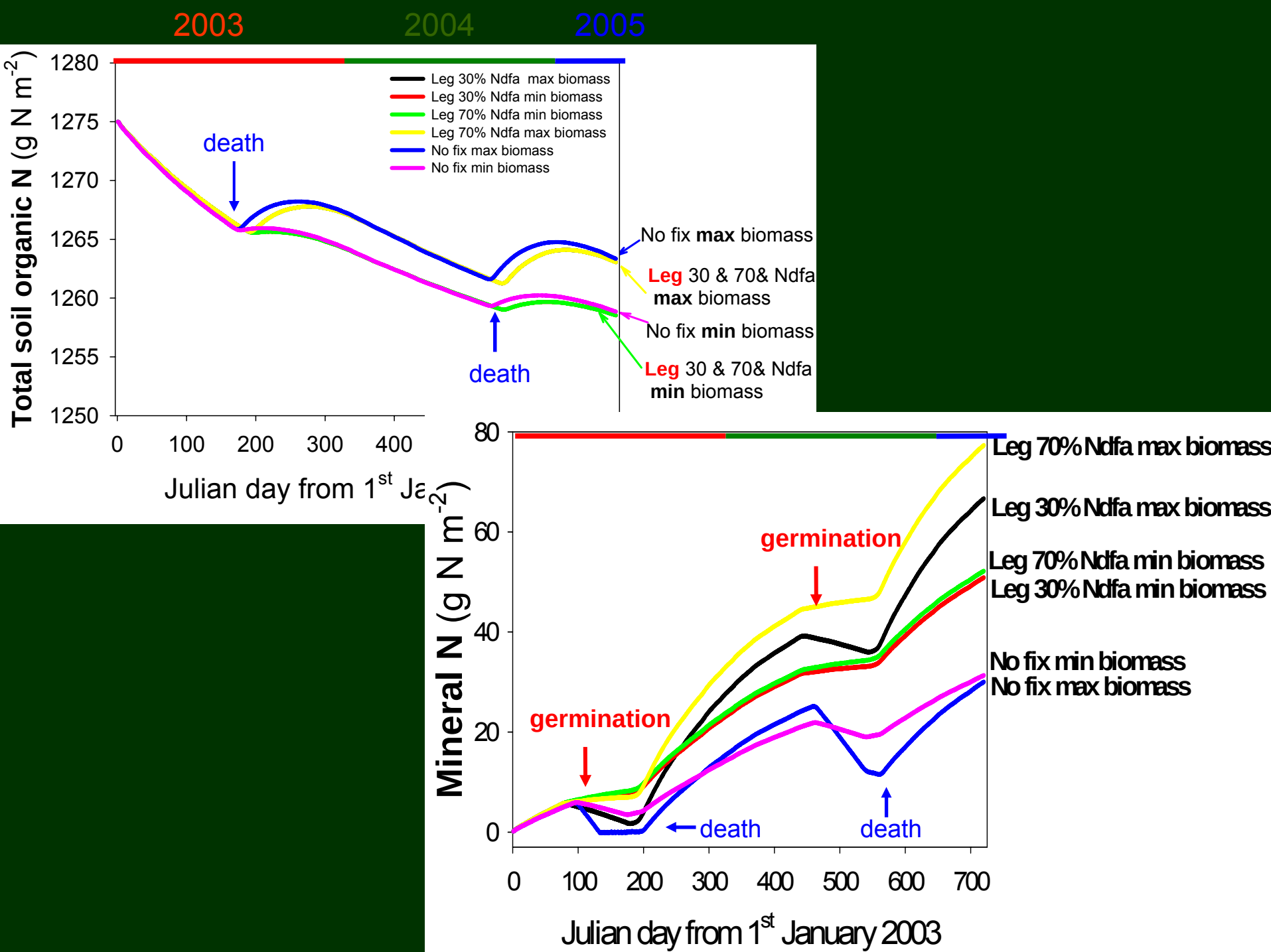
Scenario 3 Leguminous fixing - 70%Ndfa - min value of total plant biomass

Scenario 4 Leguminous fixing - 70%Ndfa - max value of total plant biomass

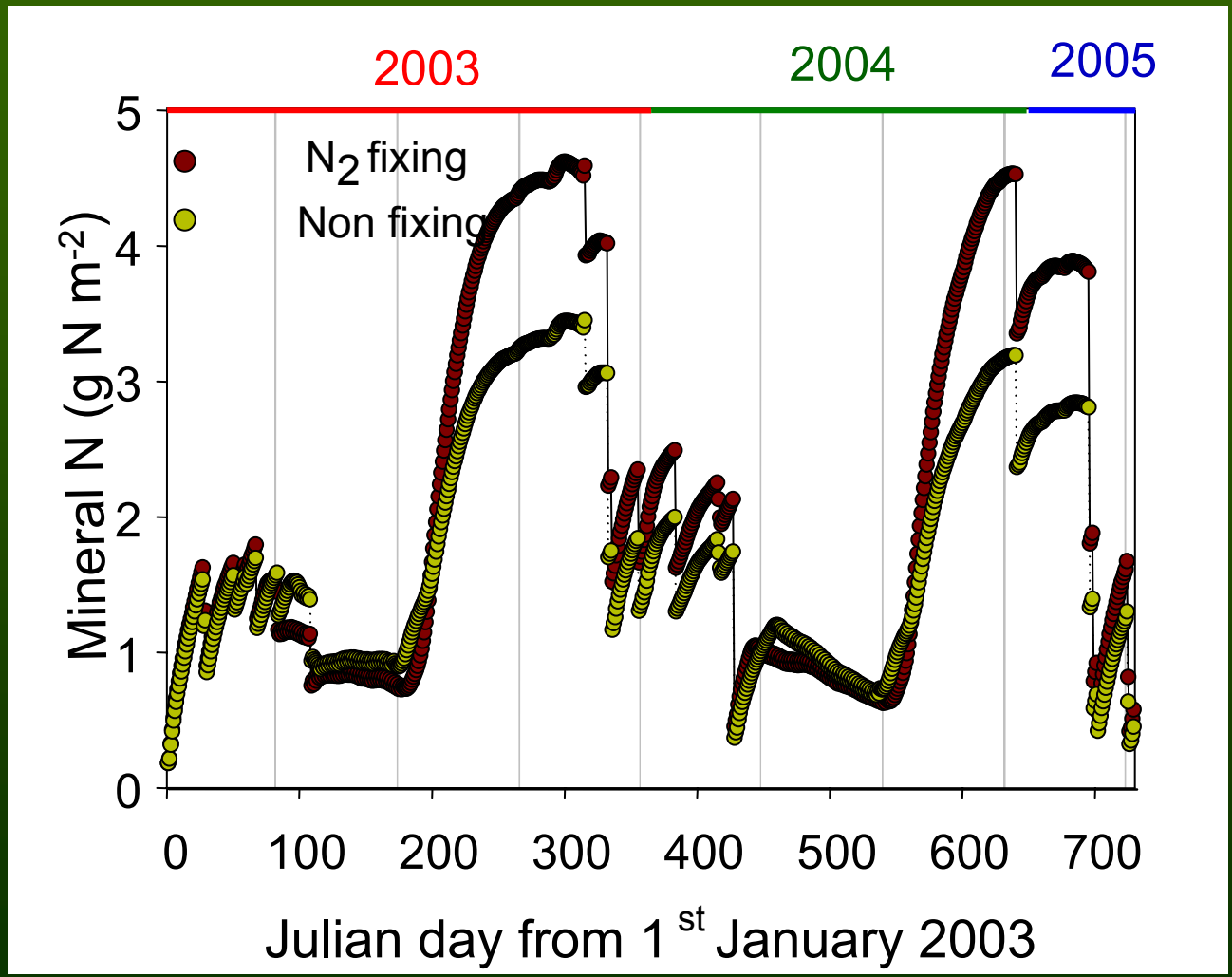
Scenario 5 Herbaceous - no fix - max value of total plant biomass

Scenario 6 Herbaceous - no fix - min value of total plant biomass

Results of simulated scenarios from 1st January 2003 to February 2005

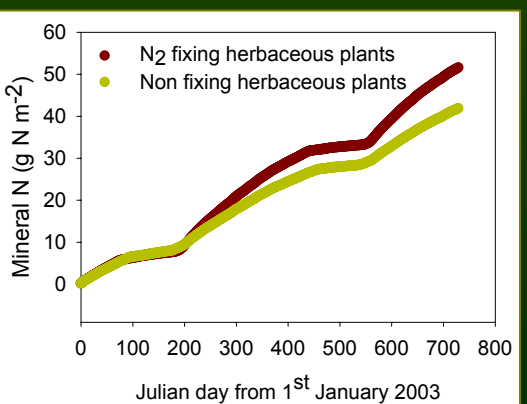

2003
2004
2005
Total soil organic N (g N m-2)
1280
1275
1270
1265
1260
1255
1250
0
100
200
300
400
Julian day from 1st Ja
Leg 30% Ndfa max biomass
Leg 30% Ndfa min biomass
Leg 70% Ndfa min biomass
Leg 70% Ndfa max biomass
No fix max biomass
No fix min biomass
death
death
No fix max biomass
Leg 30 & 70& Ndfa max biomass
No fix min biomass
Leg 30 & 70& Ndfa min biomass
Mineral N (g N m-2)
80
60
40
20
0
0
100
200
300
400
500
600
700
Julian day from 1st January 2003
germination
germination
death
death
Leg 70% Ndfa max biomass
Leg 30% Ndfa max biomass
Leg 70% Ndfa min biomass
Leg 30% Ndfa min biomass
No fix min biomass
No fix max biomass

Nitrogen present in the mineral N pool of the soil

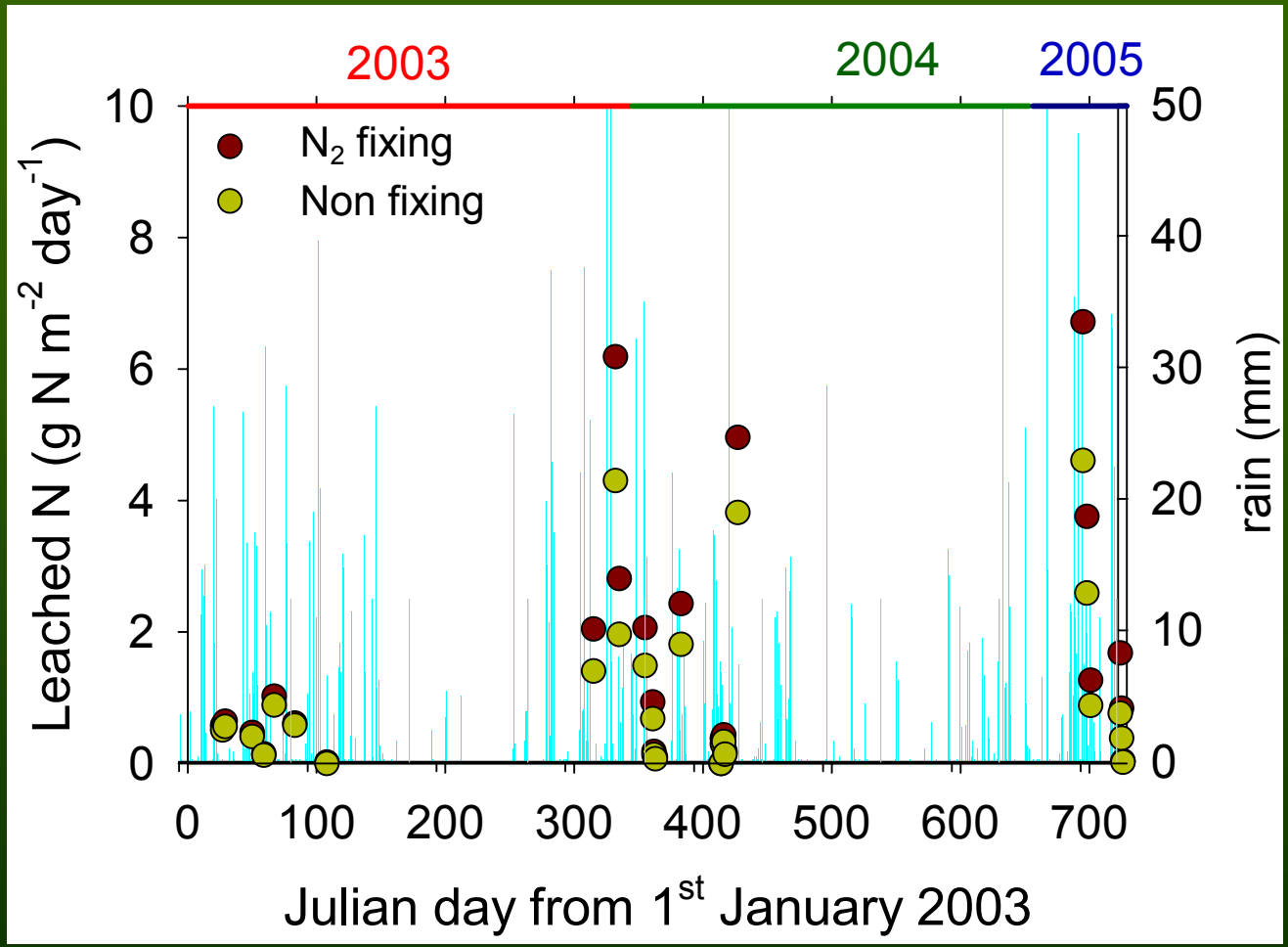


Leguminous 30% Ndfa min biomass

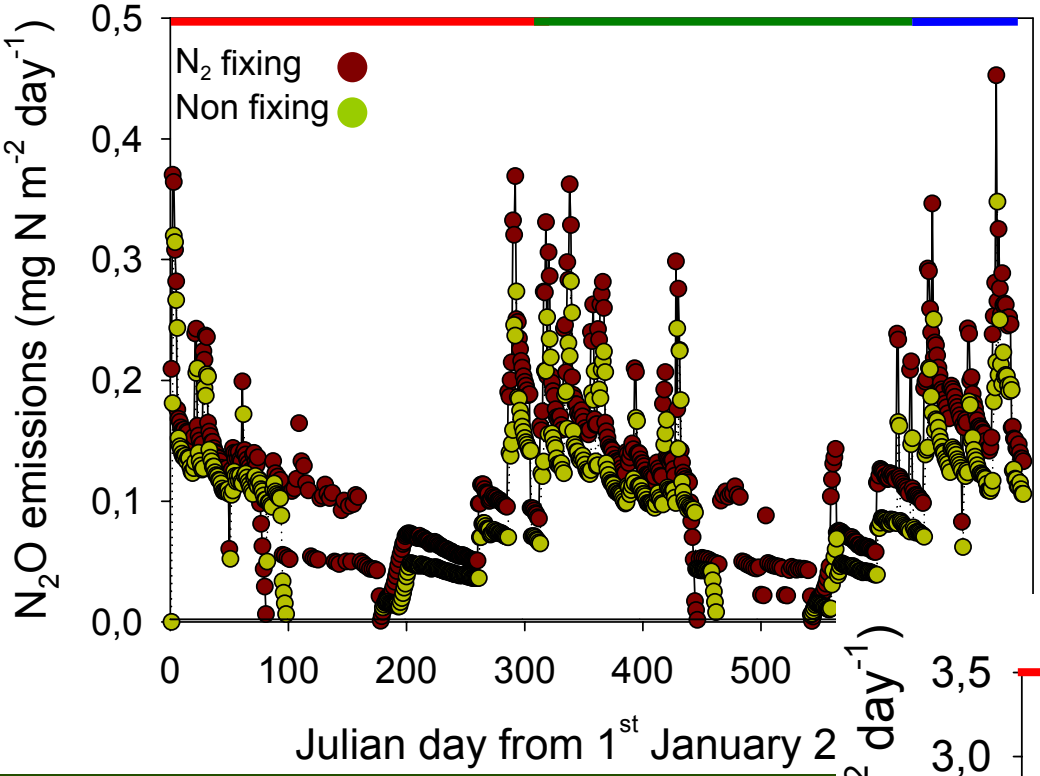
Non fixing plant min biomass



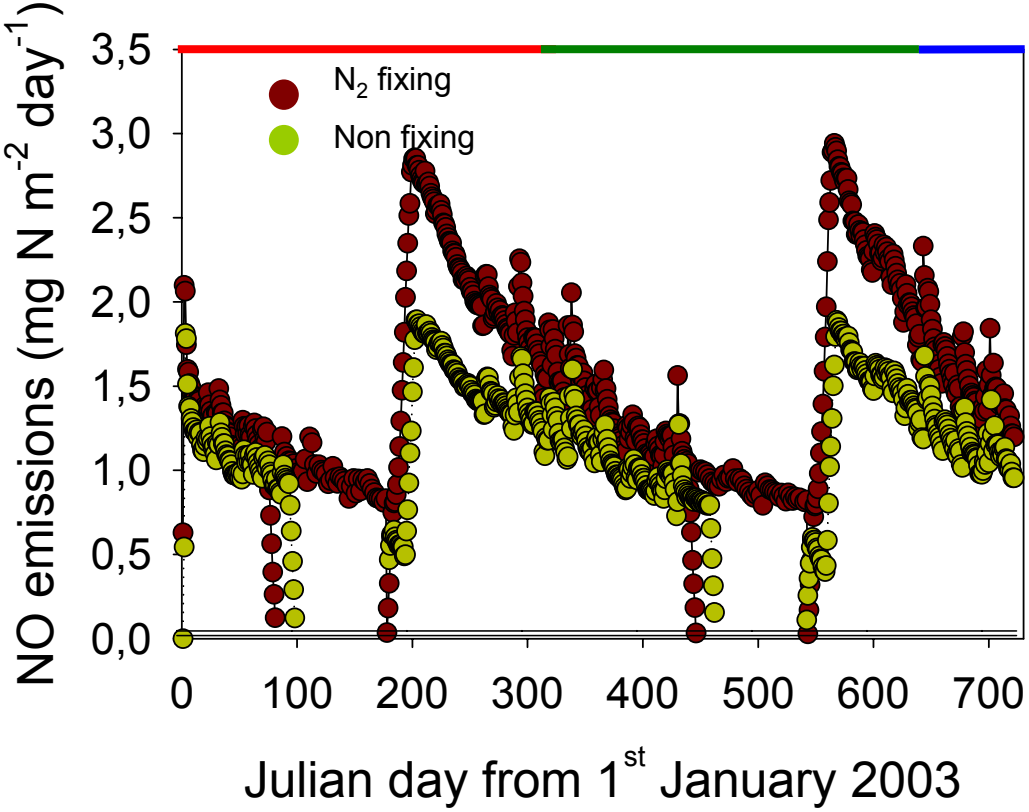
LEACHED MINERAL NITROGEN



N_2O emissions



NO emissions



Losses of N in different forms calculated for the 6 scenarios over one year

	NH_3 g m^{-2}	NO g m^{-2}	N_2O g m^{-2}	N leached g m^{-2}	Total N loss g m^{-2}		Biomass	%Ndfa
Scenario 1	2.6	0.7	0.05	27.1	30.4		Max	30
Scenario 2	2.1	0.5	0.03	17.8	20.4		Min	30
Scenario 3	2.1	0.5	0.03	17.8	20.6		Min	70
Scenario 4	3.0	0.7	0.05	27.1	30.9		Max	70
Scenario 5	1.5	0.5	0.03	17.7	19.8		Max	-
Scenario 6	1.3	0.3	0.02	13.1	14.8		Min	-

CONCLUSIONS

Leguminous herbaceous plants are present in the open macchia areas with a cover density which can go from 0 to >90% and a total mass which can vary more than 300% over different years.

The most abundant leguminous plants *Medicago minima* and *Melilotus neapolitana* derive only around 30% of the N present in their tissue from the atmosphere. Hence they compete for the remaining 70% with non fixing plants. However fixation of atmospheric N can go up to 70% in some species.

Below a critical mass, N input with plant tissue cannot balance N organic loss during the remaining part of the year. This means that only in exceptional years there will be an accumulation of organic N in the system.

The N richer tissue of leguminous does not result in higher organic N accumulated compared with non fixing plants, but is results in higher levels of mineral N available in the system.

In case this higher availability of mineral N would not be paired with adequate uptake by other plants (non fixers herbaceous, shrubs) the extra N derived from atmosphere (Ndfa) would result in higher losses, the higher is the Ndfa%.