Efecto de las deposiciones de nitrógeno en la biodiversidad y funcionamiento de las comunicades de los brezales dominados por *Calluna vulgaris* en la Cordillera Cantábrica

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VIII Seminario: SEGUIMIENTO DE LA CALIDAD DEL AIRE EN LA RED DE PARQUES NACIONALES
24th – 26th Septiembre 2018
Valsain-Segovia

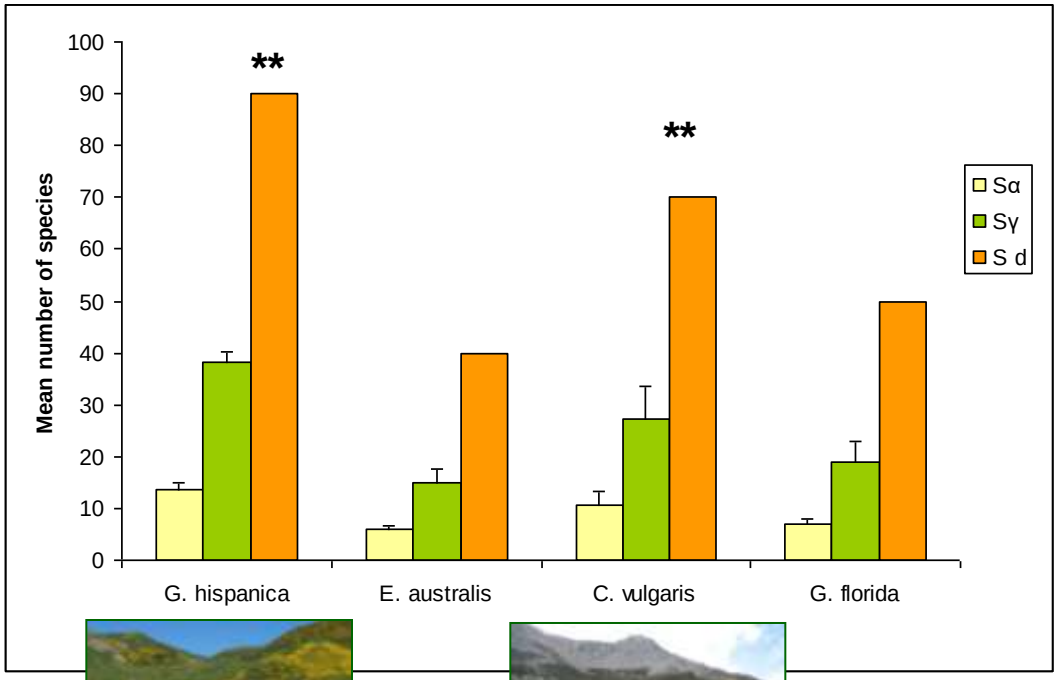
Diversidad de comunidades de matorral

Erica australis heathlands

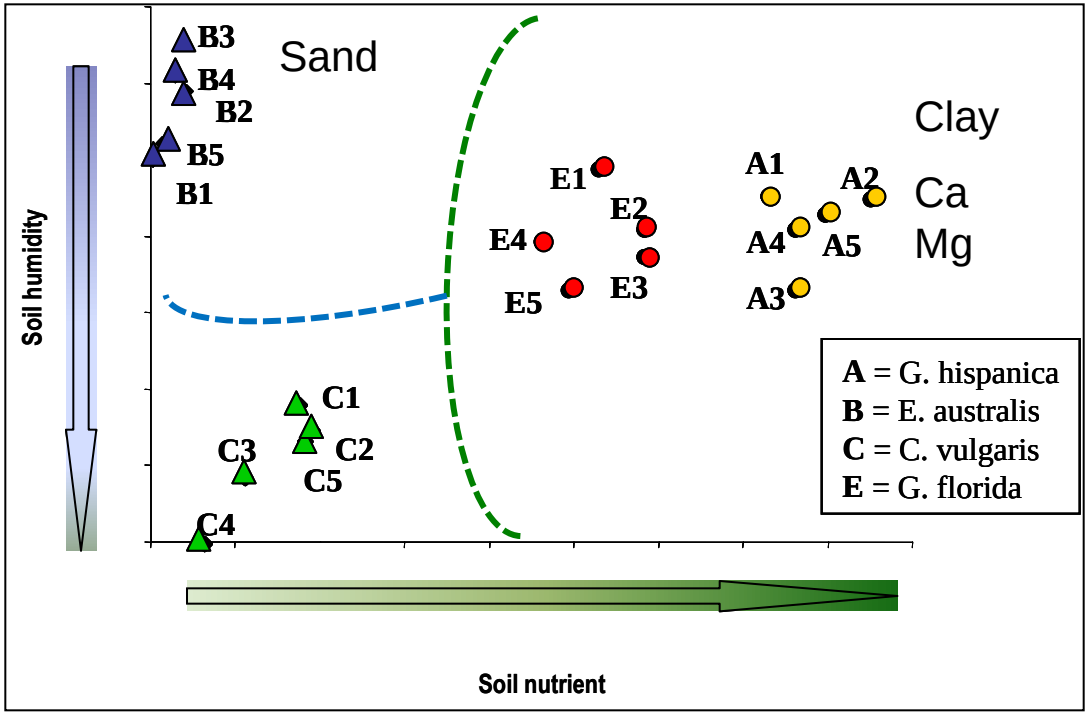
Genista hispanica shrublands

Genista spp. shrublands

Calluna vulgaris heathlands



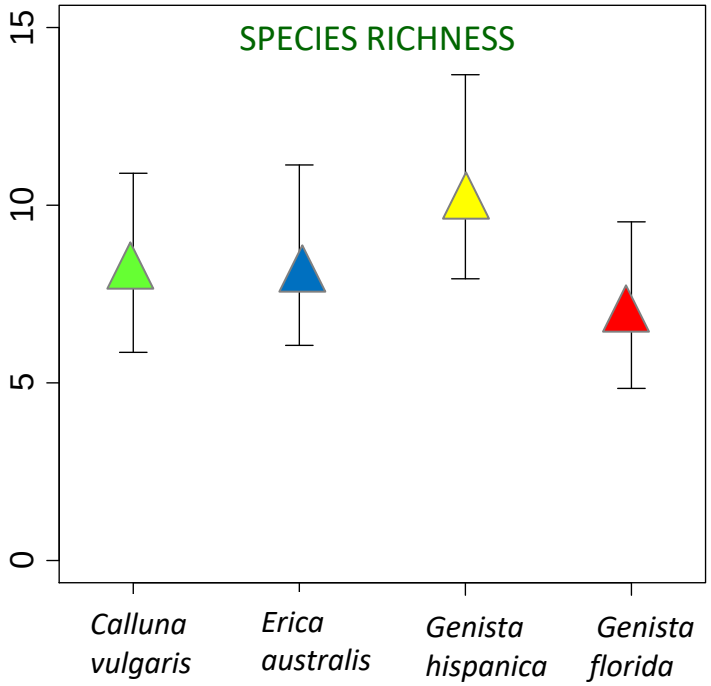
-***G hispanica*** **shrublands and *Calluna*-heathlands:** showed significantly higher plant richness



- **Heathlands:** very poor soils

- ***Genista*** **communities:** high amount of nutrients

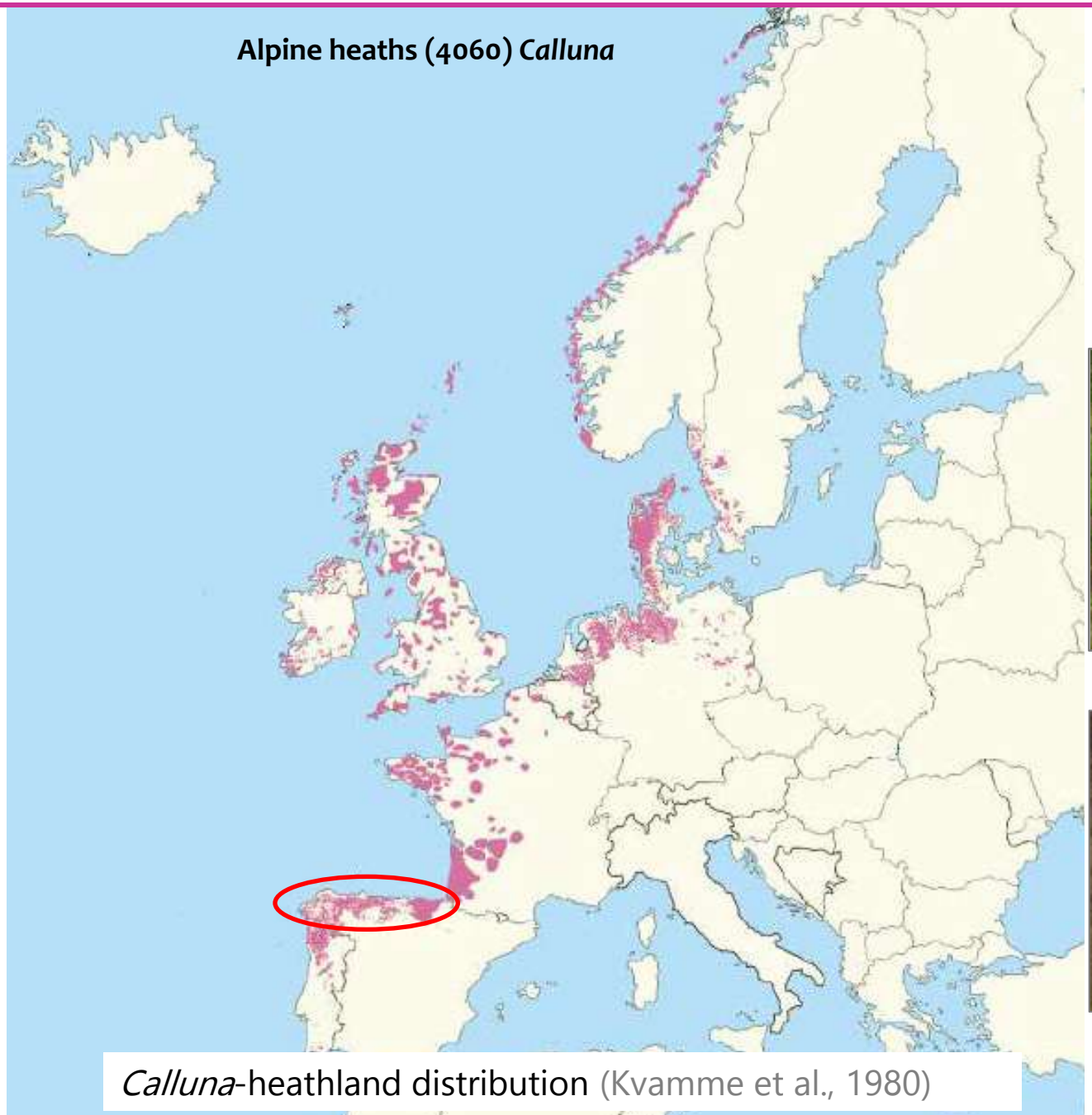
Carabid beetles communities



(*) ***Calluna*** **heathlands** showed the **highest number in endemic** species: *Cryobius cantabricus, Nebria asturiensis* and *Pterostichus cantaber*

Cryobius cantabricus

Brezales de *Calluna vulgaris*



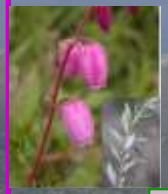
Calluna-heathland distribution (Kvamme et al., 1980)

Importancia de los Brezales de *Calluna vulgaris*

Habitats Directive 92/43/EEC (Natura 2000 Network)

Dactylorhiza cantabrica

CULTURAL



Cultural heritage
Protection of biodiversity
Recreation, ecotourism

Cicindela sylvatica

REGULATING

Prevention of soil erosion
Water purification

Carbon sequestration

PROVISIONING

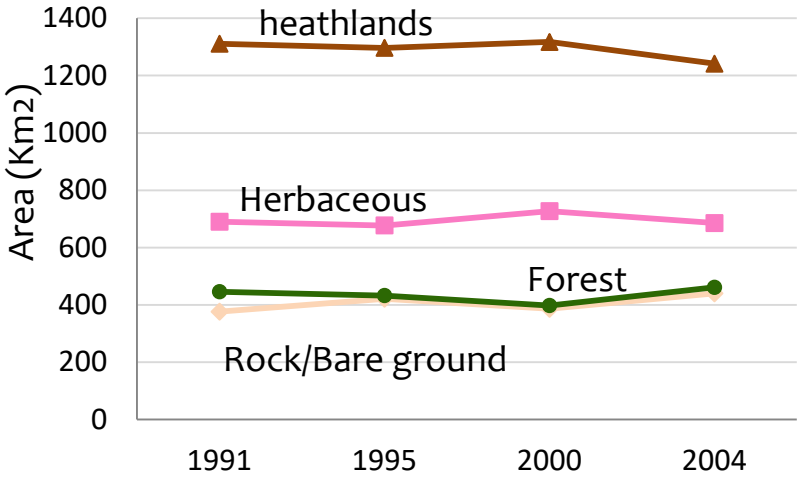
Goods: honey, meat, wool, etc.
Grazing
Game

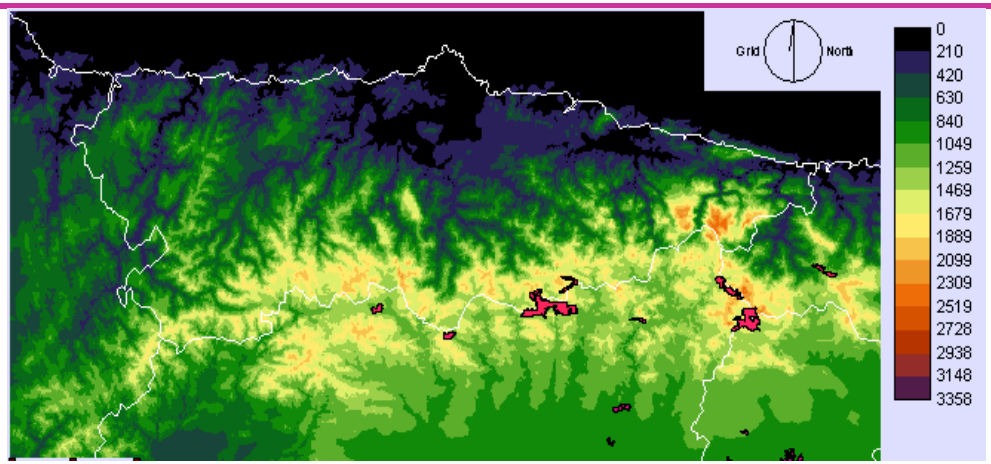
Medicines
Gentiana lutea

Provisioning of Habitat
Preserving genetic biodiversity

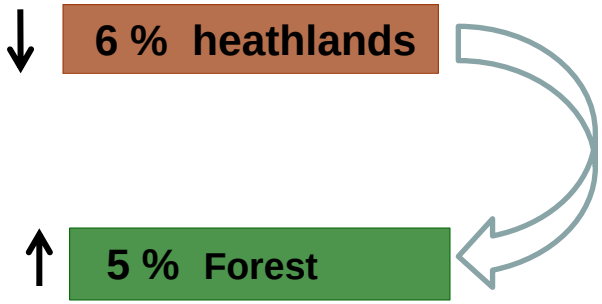
Ecosystem services provided by these socio-ecological systems

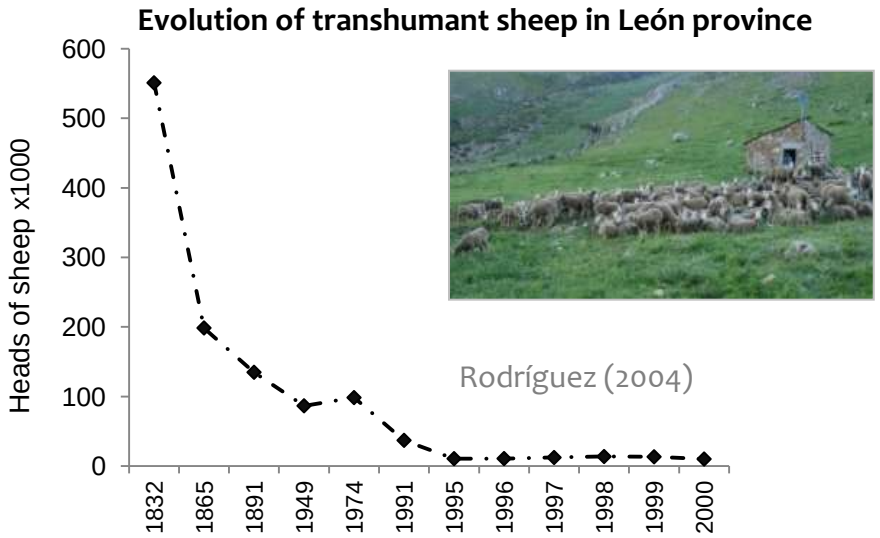
Problemas de los brezales húmedos de Calluna vugaris (I)





Heathland dominated by *Calluna vulgaris* in the Cantabrian Mountain (Red colour). Source: Cartography Habitat Directive 92/43/CEE (1:50000) Ministerio de Medio Ambiente

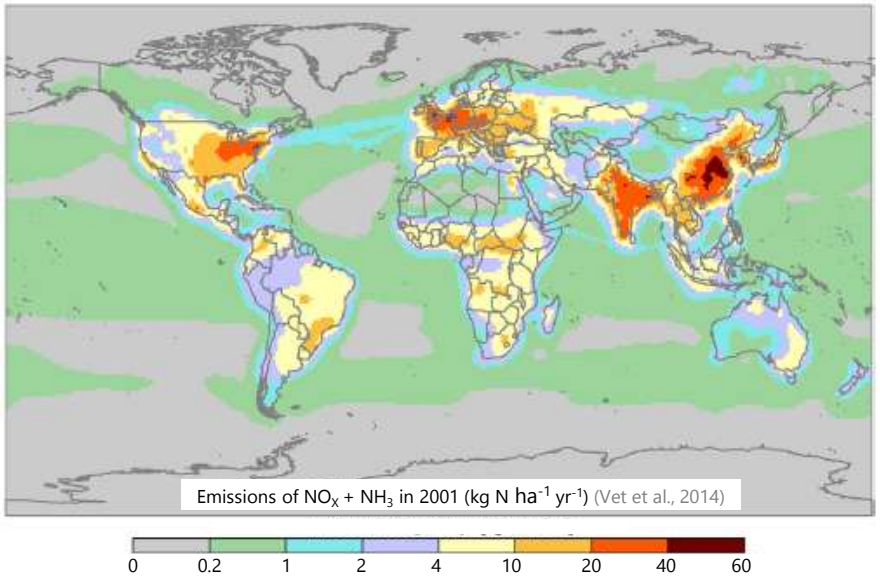




Abandonment of traditional uses (pastures) ----- succession process

Problemas de los brezales húmedos de Calluna vugaris (I)

Increasing atmospheric N depositions (Calvo et al., 2007)



Changes in heathland functioning, structure and composition

Zonas experimentales de estudio

1998--- 2005---2011

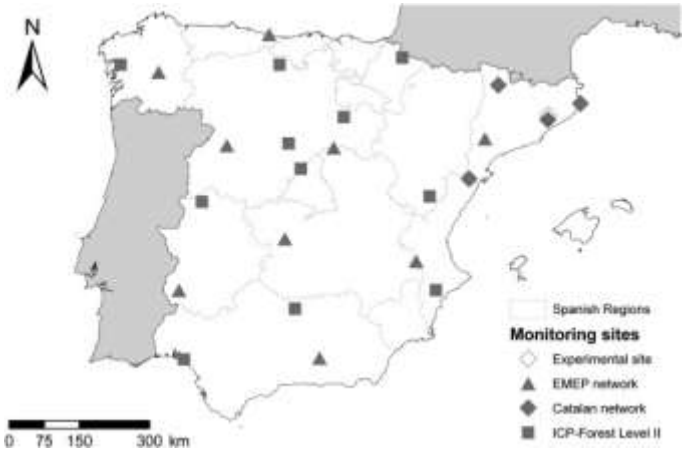
Cantabrian Mountains (NW Spain)

1.- ¿Cuánto nitrógeno está depositándose y en qué formas?

1.- Cargas teóricas: N= 28 Kg* ha * year^{-1}

Rivero Fernández, C., Rabago Juan-Aracil, I., Sousa Carrera, M., Lorente Ibañez, M., Schmid, T. (1996). Cálculo y cartografía de cargas críticas para España. Aplicación del modelo SMB. CIEMAT, Madrid.

2.- Oxidized inorganic N deposition > Reduced inorganic N deposition



1.- ¿Cuánto nitrógeno está depositándose y en qué formas?

(1st July 2011)

3 bulk collectors (500 ml; 113 cm^2; 1mm pore mesh)

1 Hellmann rain gauge (200 cm^2)

Monthly : July 2011 - August 2014 (3 years)

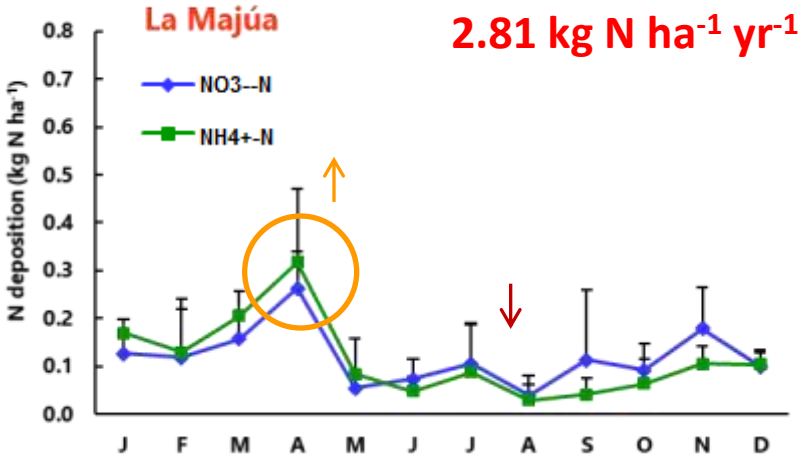
Analytical procedure

Ammonium (NH_4^+) concentration (Reardon et al., 1966)

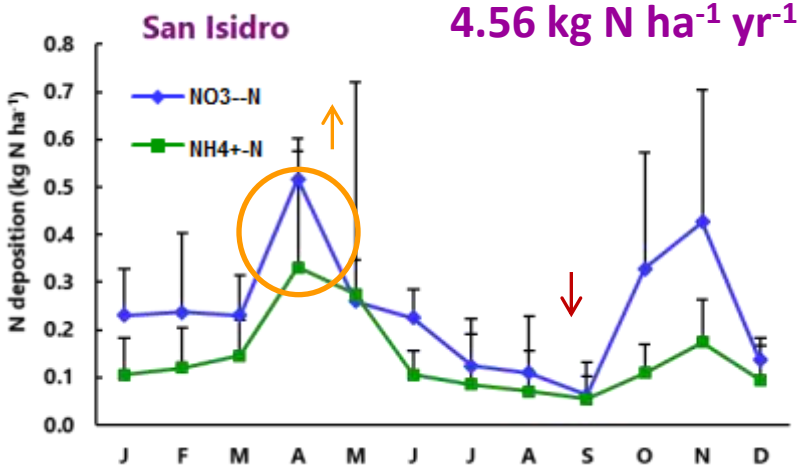
Nitrate (NO_3^-) concentration (Tabatabai and Dick, 1983)

Calvo-Fernández, J., Marcos, E., Calvo, L., 2017. Bulk deposition of atmospheric inorganic nitrogen in mountainous heathland ecosystems in North-Western Spain. Atmospheric Research 183, 237-244.

Bulk NO_3^--N and NH_4^+-N depositions



2.81 kg N ha^{-1} yr^{-1}



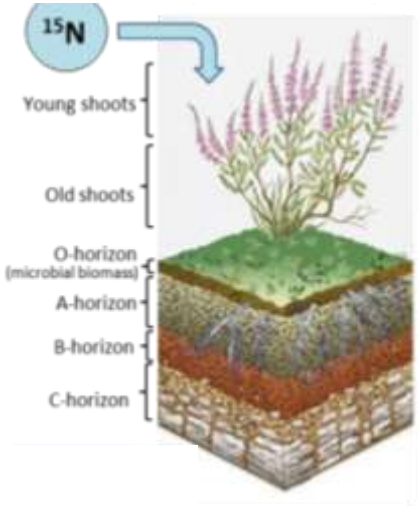
4.56 kg N ha^{-1} yr^{-1}

La Majúa: NH_4^+-N / NO_3^--N = **0.98: Agricultural**

San Isidro: NH_4^+-N / NO_3^--N = **0.58: Industrialized**

2.- ¿Dónde se almacena en el ecosistema?

July 2011: ^{15}N tracer addition



- Current year's *Calluna* shoots (new shoots)
- 1-2 year old *Calluna* shoots (old shoots)
- Soil horizons (O-, A- and B-horizons)
- Soil microbial biomass
- ^{15}N leaching losses

Calvo-Fernández, J., Marcos, E., Calvo, L., Härdtle, W., 2015. Allocation patterns of airborne nitrogen in mountainous heathlands - A ^{15}N tracer study in the Cantabrian Mountains (NW Spain). Ecological Engineering 84, 128-135. http://doi.org/10.1016/j.ecoleng.2015.07.027.

^{15}N tracer recovery

Compartment	November 2011				November 2012			
	^{15}Nrec (mg N m^{-2})		% ^{15}Nrec		^{15}Nrec (mg N m^{-2})		% ^{15}Nrec	
New shoots	0.21	(0.04)	0.54	(0.10)	0.12	(0.01)	0.32	(0.02)
Old shoots	0.51	(0.14)	1.31	(0.37)	0.28	(0.06)	0.73	(0.16)
O-horizon	18.03	(3.11)	46.58	(8.04)	1.04	(0.79)	2.69*	(2.04)
A-horizon	5.05	(1.95)	13.04	(5.03)	0.52	(0.84)	1.33	(2.16)
B-horizon	3.89	(1.01)	10.06	(2.61)	0.00	(0.00)	0.00	(0.00)
Soil microbial biomass	0.08	(0.01)	0.22	(0.04)	0.59	(0.13)	1.52*	(0.33)
Leaching losses $^{15}NO_3^-$	0.003		0.007		0.003		0.009	
$^{15}NH_4^+$	0.000		0.001		0.001		0.003	
Total recovery (%)			**71.54**				**5.09**	

Heathland ecosystems are still not N saturated under current N deposition loads

3.- ¿Qué efectos produce en el ecosistema en función de la escala temporal de deposición y de la edad de *Calluna*?

*N inputs at two **time scales***

Calluna ages

Young=8 years old

Short term N inputs
2 years

Long term N inputs
10 years

0

N 10 Low

N 20 Medium

N 50 High

N 56 High

0

N 10 Low

N 20 Medium

N 50 High

N 56 High

Short term N inputs
2 years

Long term N inputs
10 years

Mature >40 years old

3.- ¿Qué efectos produce en el ecosistema en función de la escala temporal de deposición y de la edad de *Calluna*?

Hypotheses Increasing N loads:

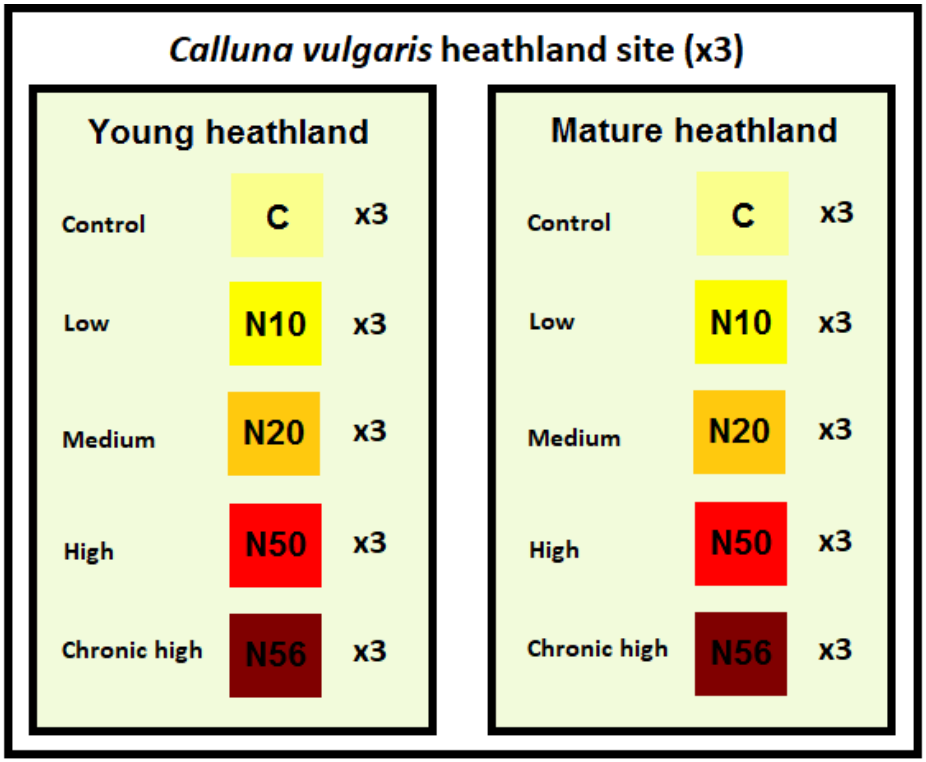
(1) Plant-litter-soil N and P contents (Southon et al., 2013)
(2) Rates of enzymatic activities (Johnson et al., 1998)
(3) Soil microbial biomass C and N contents (Power et al., 2006)
(4) Root mycorrhizal colonization (Caporn et al., 1995)

(1) Community composition (Calvo et al., 2007)
(2) Plant species richness (Maskell et al., 2010)
(3) Graminoids cover (Calvo et al., 2005)
(4) Calluna vital rates (shoot growth / flowering) (Calvo et al., 2012)

Greater impact with chronic N inputs (Phoenix et al., 2012)

Age related effects (Power et al., 2012)

3.- ¿Qué efectos produce en el ecosistema en función de la escala temporal de deposición y de la edad de *Calluna*?



Experimental design

Total 90 2 m x 2 m plots

Two heathland ages:

- Young stands: prescribed fire
- Mature stands: land abandonment

Five N treatments (NH_4NO_3 monthly basis)

- Short-term (2013-2015; 3 years)
- Long-term (2005-2015; 10 years)

3.- ¿Qué efectos produce en el ecosistema en función de la escala temporal de deposición y de la edad de *Calluna*?

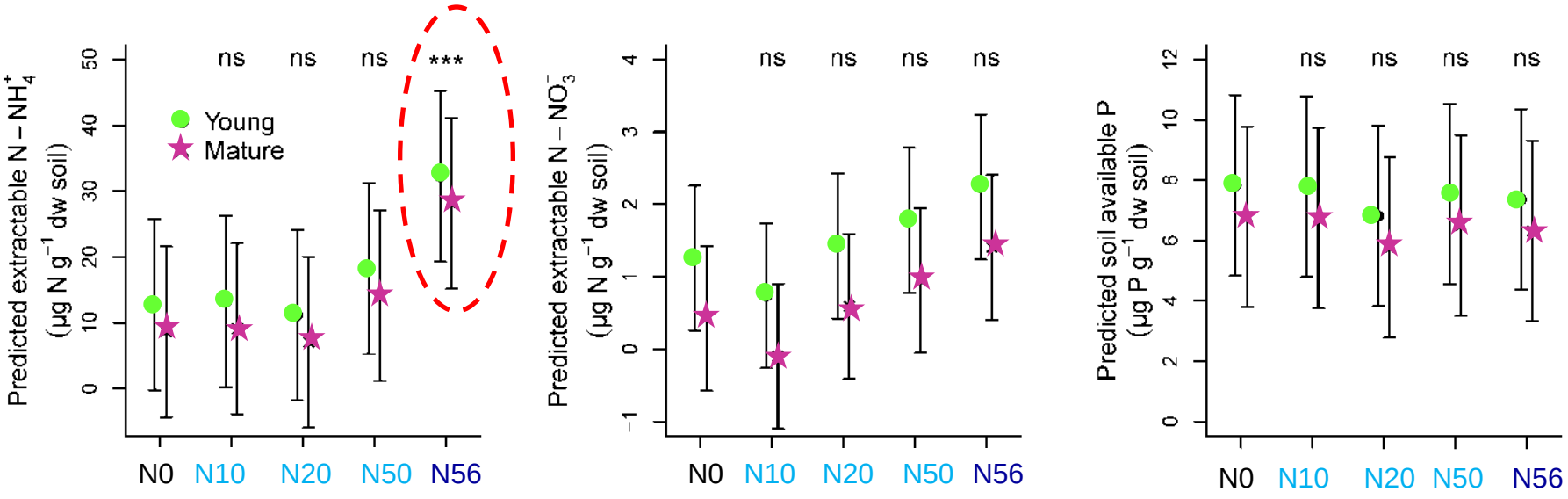
In each 1m x 1m plot

- Ten young *Calluna* shoots
- Three 5 cm x 5 cm litter layer samples
- Five-ten *Calluna* plant fine roots
- Three soil samples (topsoil, 0-5 cm)
- Five current year's *Calluna vulgaris* shoots to assess the shoot length and number of flowers per shoot
- The percentage of cover for each vascular and non-vascular species

Variables

- Soil total N, organic C, C:N ratio, and available P
- Soil extractable NH_4^+ and NO_3^-
- Acid phosphatase, β-glucosidase, and urease enzyme activities
- Soil microbial biomass N and C contents
- *Calluna* root mycorrhizal colonization
- *Calluna* shoot and litter N and P contents and N:P ratios

Soil nutrient contents



Significance levels respect to control (N0)= *** (0.001 > p), ** (0.01 > p > 0.001), * (0.05 > p > 0.01), • (0.1 > p > 0.05), and ns (p > 0.1)

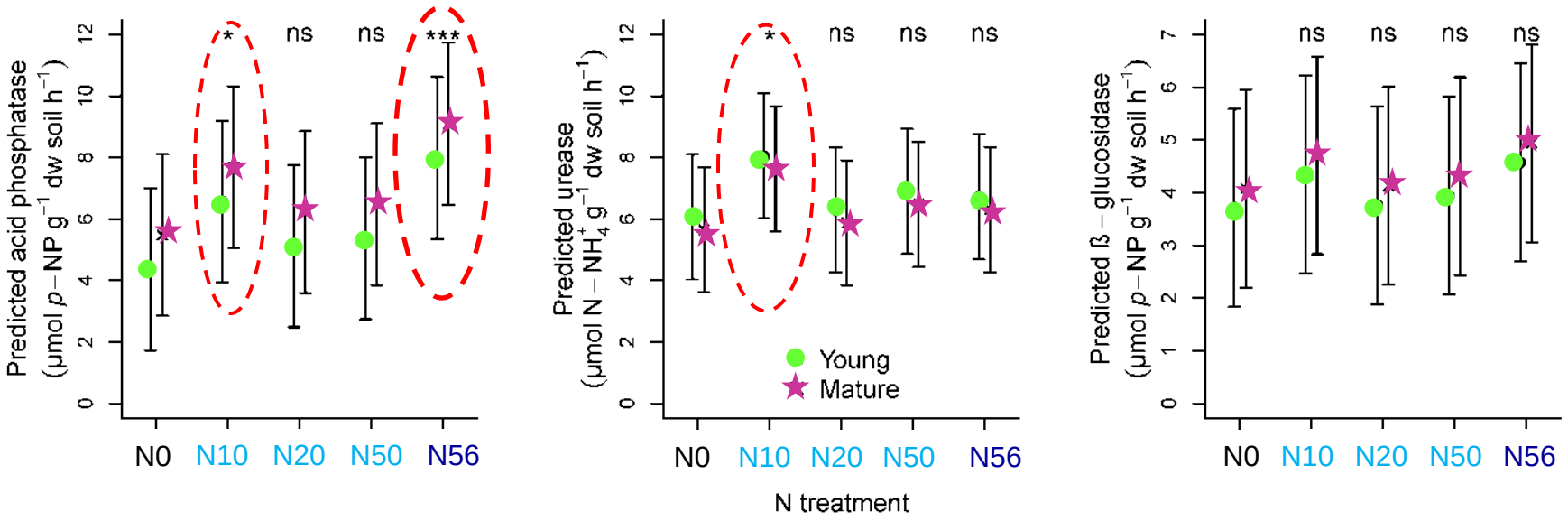
(1) <u>Soil extractable N-NH_4^+</u> increased in response to N addition-*<u>long-term high N input (N56)</u>

(2) **<u>Age-related effects:</u>**

<u>NO3</u> and **<u>Available Phosphorous</u>** <u>young</u>

Calvo-Fernández, J., Taboada, A., Fichtner, A., Härdtle, W., Calvo, L., Marcos, E., 2018. Time- and age-related effects of experimentally simulated nitrogen deposition on the functioning of montane heathland ecosystems. Science of the Total Environment 613-614, 149-159.

Soil enzymatic activities

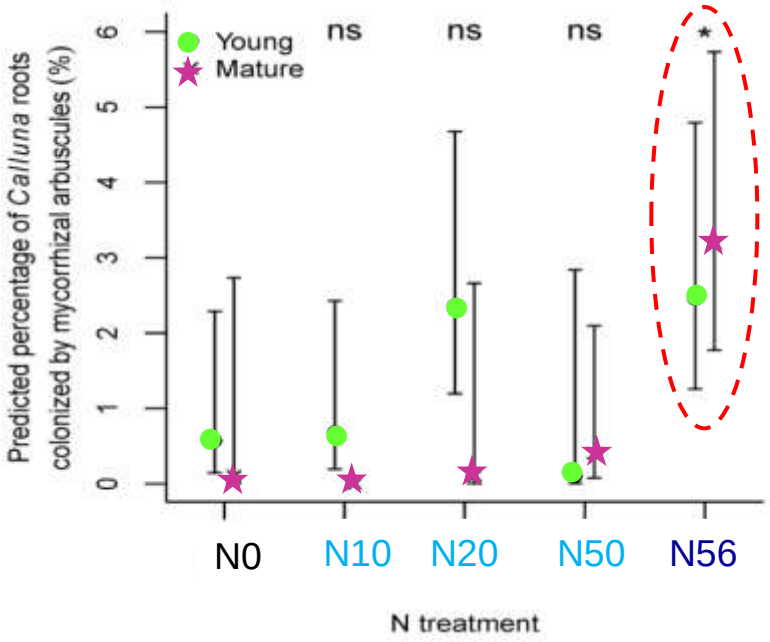


(1) **Acid phosphatase** and **urease** increased in response to N addition, particularly, the first one in the long term high N inputs (N56), and to a lesser extent both in the low N input (N10)

(2) **Age-related effects:**

No significant differences

Calluna root mycorrhizal colonization



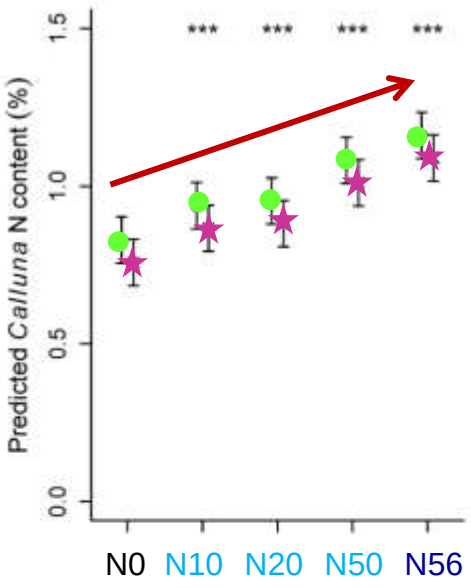
(1) There were a significant **increase** in the *Calluna* **roots colonization by mycorrhizae** under **long term high N loads** (N56).

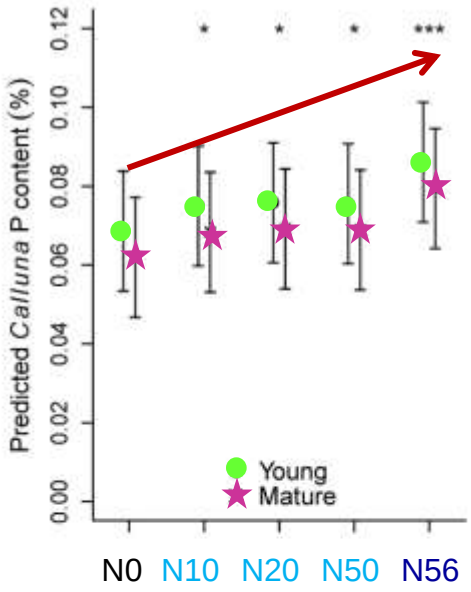
(2) **Age-related effects:**

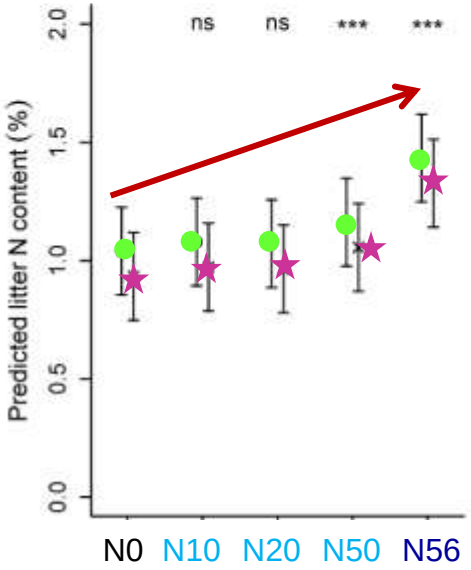
Young - Higher percentage control (N0), low (N10), medium (N20) N loads

Mature - Higher percentage high (N50) and chronic high (N56) N loads

Calluna shoot and litter nutrient contents







N inputs

⇩

Calluna shoot **N** and **P** contents

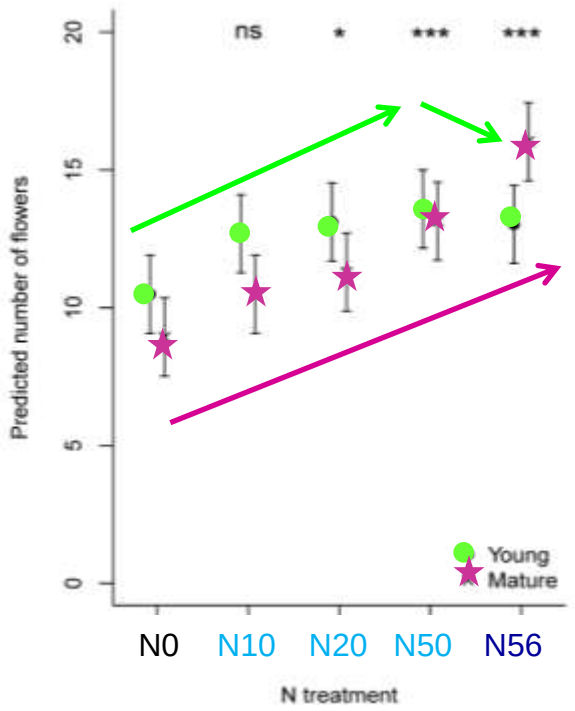
⇩

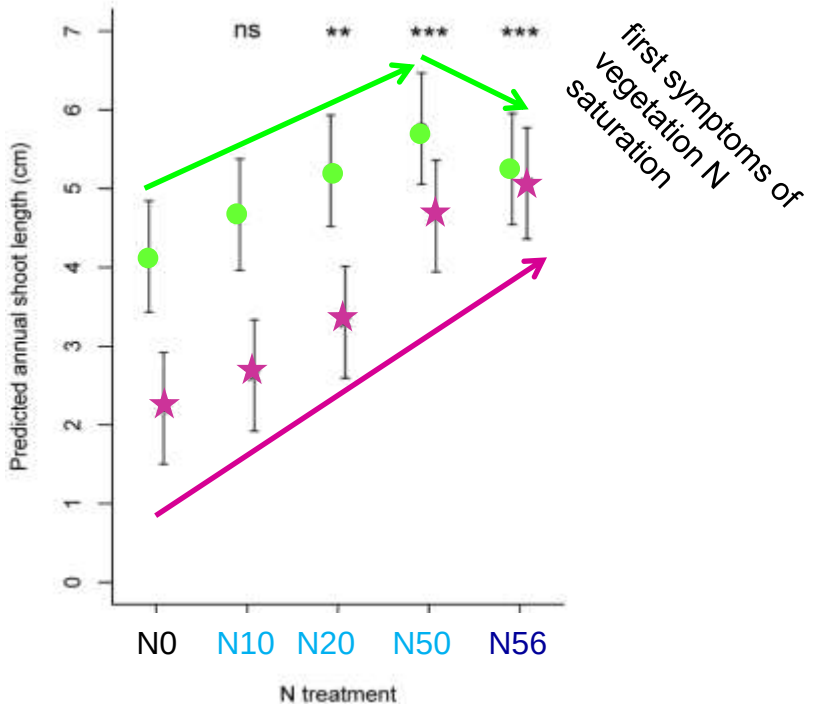
Litter **N**, P content

Age-related effects:

Young - Higher N and P content

Calluna vulgaris vital rates





(1) ***Calluna* flowering**

- Progressive increase

(2) ***Calluna* shoot length:**

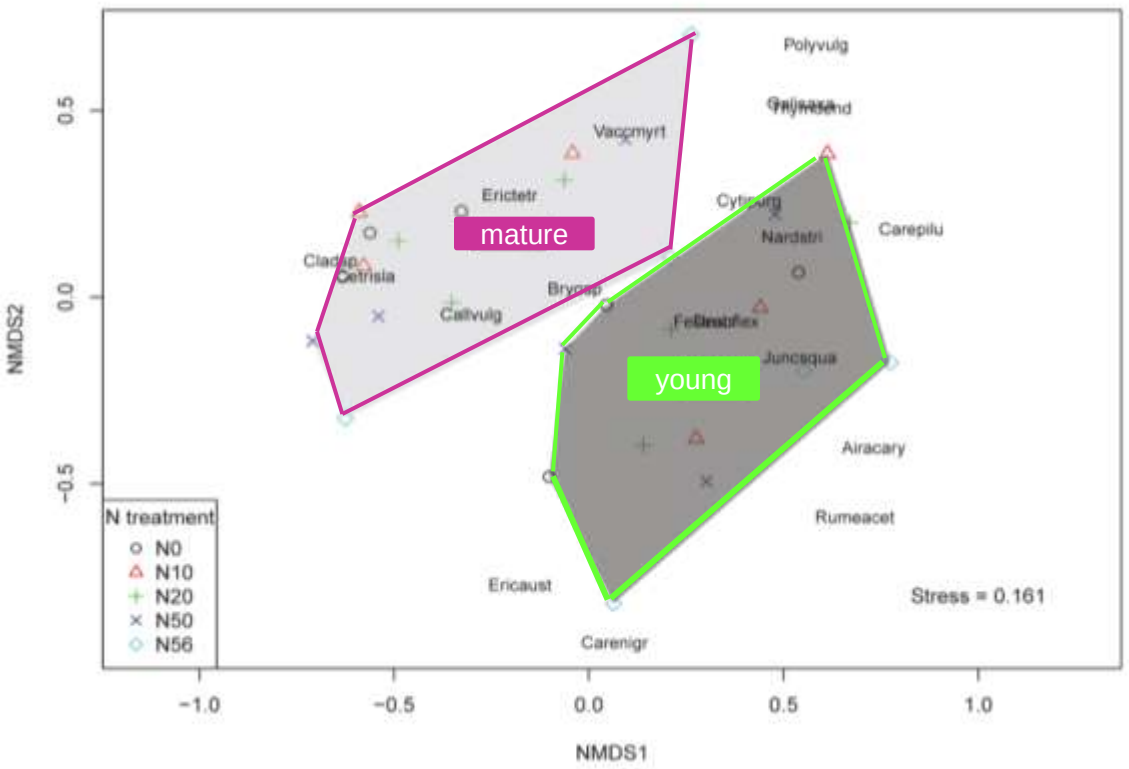
- Progressive increase

(3) Age related effects:

Young= Higher flowering and shoot length

Different behaviour **young** vs **mature**

Plant species composition



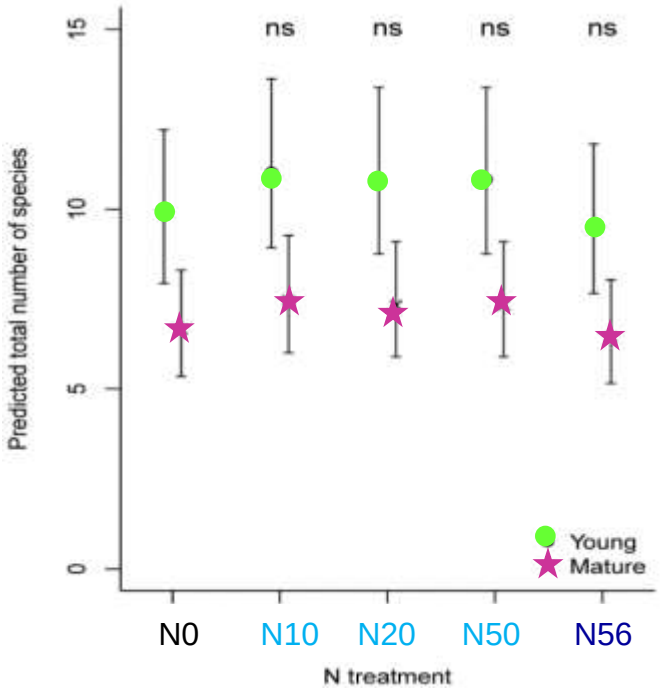
(1) **N loads** had **no effect** on plant **species composition**

(2) Age- related effects

- **Young :** higher number of graminoid and bryophytes.
- **Mature:** higher number of woody and lichens.

Angela Taboada, Javier Calvo-Fernández, Elena Marcos, Leonor Calvo. 2018. Plant and vegetation functional responses to cumulative high nitrogen deposition in rear-edge heathlands. Science of total environmental, 637-638: 980-990

Total plant species richness

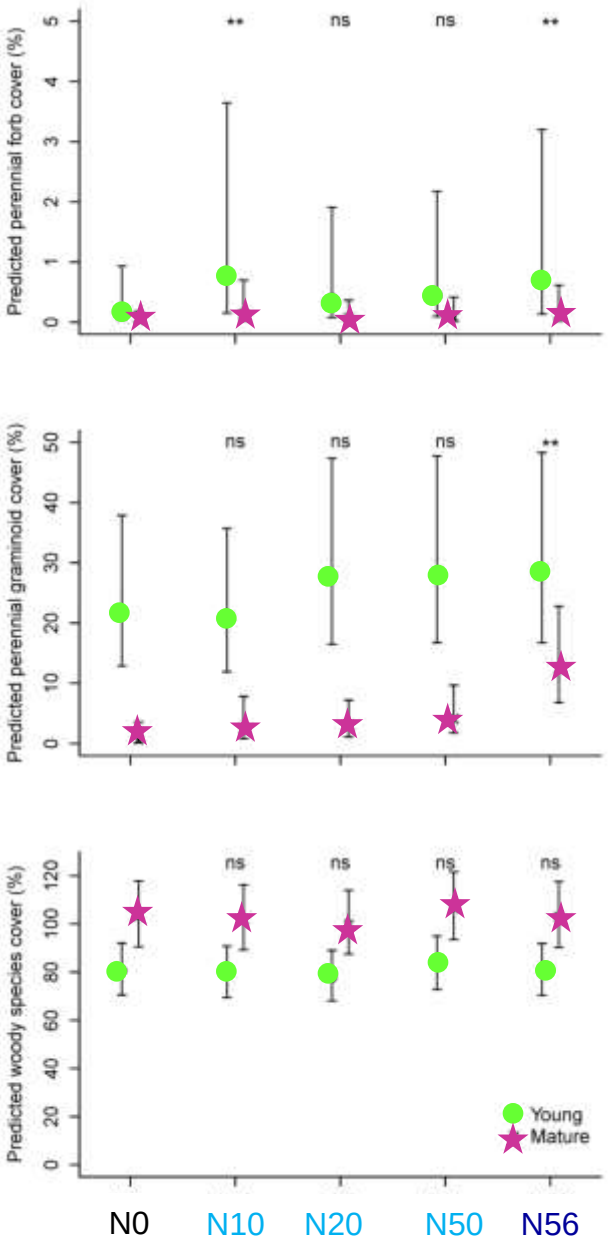


(1) Increasing N loads had **no effect** on **species richness**

(2) Age-related effects:

Young= higher plant species richness

Vascular life-forms cover



(1) Increasing N loads:

↑perennial forbs/ graminoids cover

↑annual forbs/ graminoids cover

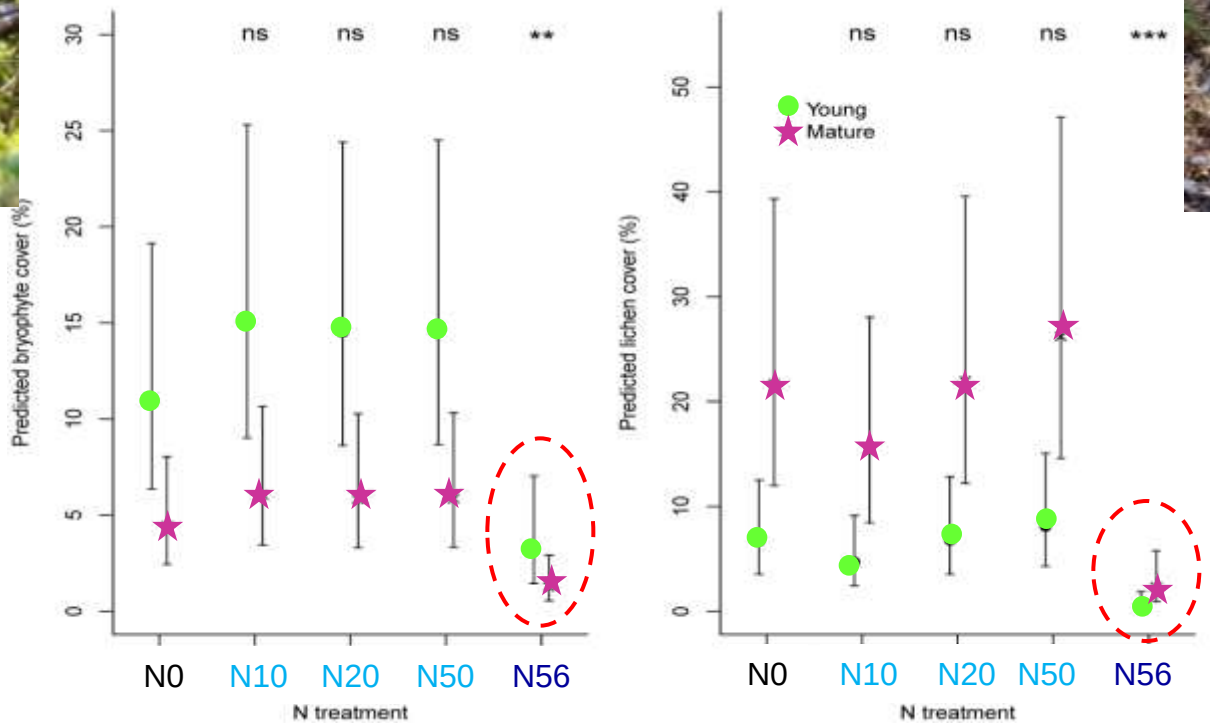
(2) No effects on woody species cover

(3) <u>Age-related effects</u>:

<u>Young=</u> more cover of graminoids

<u>Mature=</u> more cover of woody species

Non-vascular life-forms cover



(1) **Long term high N inputs (N56)** ⬇ **<u>Non-vascular species cover</u>**

(2) **<u>Age related effects</u>**:

- **<u>Young</u>**= Higher cover of **<u>bryophytes</u>**
- **<u>Mature=</u>** Higher cover of **<u>lichens</u>**

Conclusions

1.- Increase nitrogen inputs **mainly at long term N_{56}** affect the structure and functioning of *Calluna* heathlands in the Cantabrian Mountains

by increasing:

1.- Soil available **NH_4^+**

2.- Acid **phosphatase** activity

3.- *Calluna* **shoot N and P content**

4.- **Litter N content**

5.- *Calluna* **root colonization by ericoid mycorrhizae.**

6.- Cover of **annual and perennial graminoids and forbs**

7.- Calluna **shoot growth and flowering**.

by decreasing:

1.- Cover of **bryophytes and lichens**

Conclusions

2.- The responses to N loads are **age-mediated:**

Young heathlands higher:

1.- **NO_3** and available **Phosphorous**

2.- *Calluna* **shoot N and P** content

3.- Litter N content

4.- Calluna **shoot growth and flowering**.

5.- **Graminoid** and **bryophytes** cover

6.- Plant species **richness**

Mature heathlands higher:

1**.- Woody** and **lichens** cover

3.- ¿Carga crítica?

Young heathlands

	N treatment			
	N10	N20	N50	p-value
No. flowers	↑ **	↑ ***	↑ ***	0.000
Calluna shoot length	ns	↑ **	↑ ***	0.000
Calluna shoot N content	↑ ***	↑ ***	↑ ***	0.000
Calluna shoot P content	ns	↑ *	↑ *	0.017
Litter N content	ns	ns	↑ *	0.030

N10 treatment (14.6 kg N ha^{-1} yr^{-1})

N critical load in young montane heathlands: 10-20 kg N ha^{-1} yr^{-1}

(Bobbink and Hettelingh, 2011; Hall et al., 2015)

N10 treatment (14.6 kg N ha^{-1} yr^{-1})

N critical load in mature montane heathlands: 10-20 kg N ha^{-1} yr^{-1}

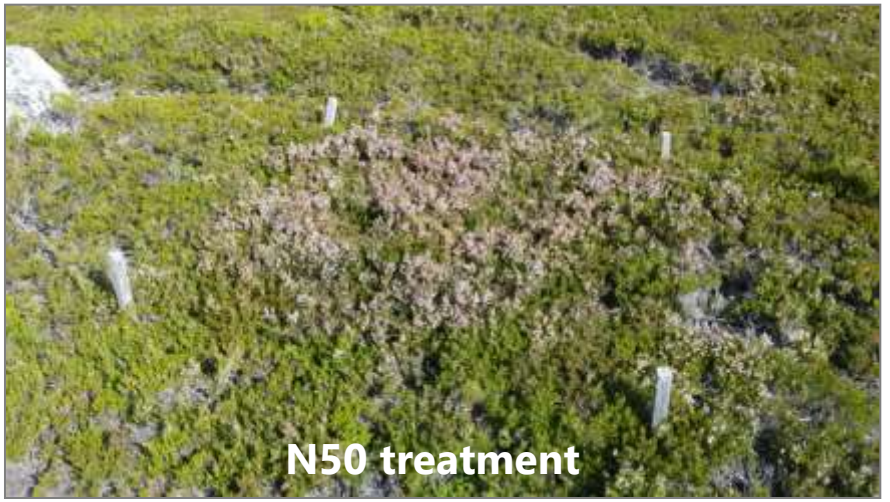
(Bobbink and Hettelingh, 2011; Hall et al., 2015)

Mature heathlands

	N treatment			
	N10	N20	N50	p-value
No. flowers	↑ **	↑ ***	↑ ***	0.000
Calluna shoot length	ns	↑ ***	↑ ***	0.000
Calluna shoot N content	ns	↑ *	↑ ***	0.000
Litter N:P ratio	ns	↑ *	↑ *	0.013

3.- ¿Carga crítica?

Riopinos I: Mature stands



3.- ¿Carga crítica?

Annual shoot growth

-Number
-Size
-Phenology

Lochmaea suturalis

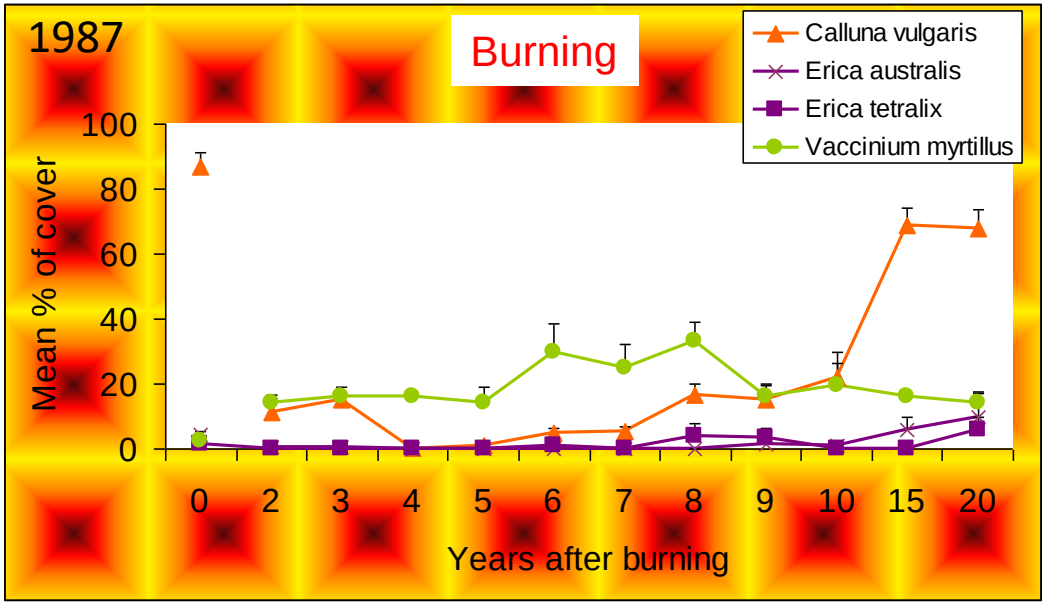
4.- ¿Qué hacer para conservarlos?

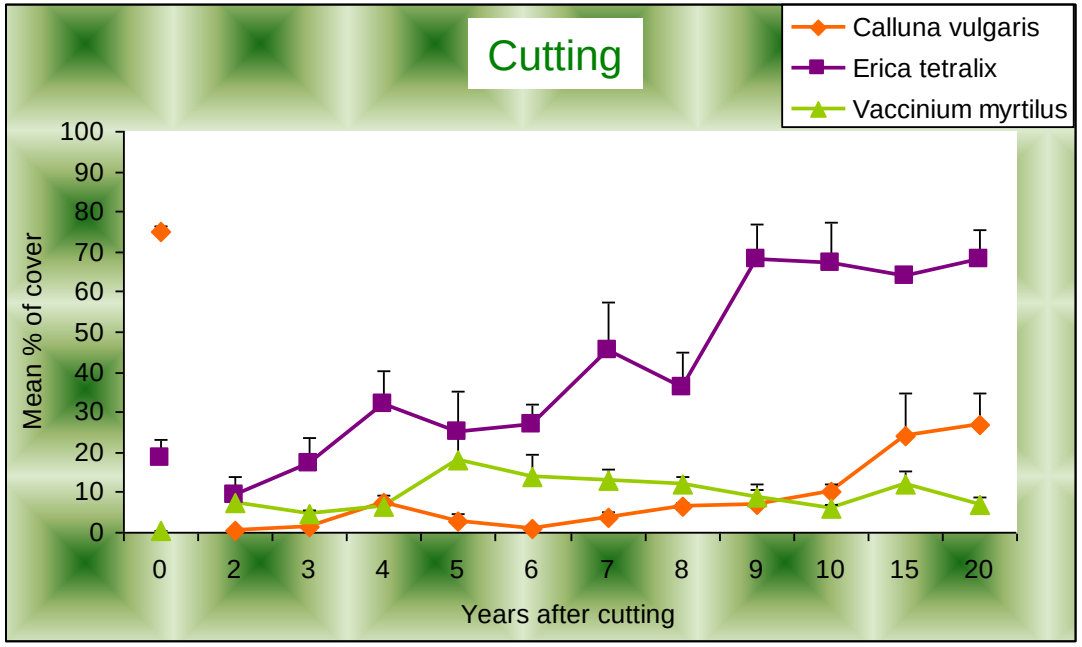
Building/Mature-PHASE

Burning

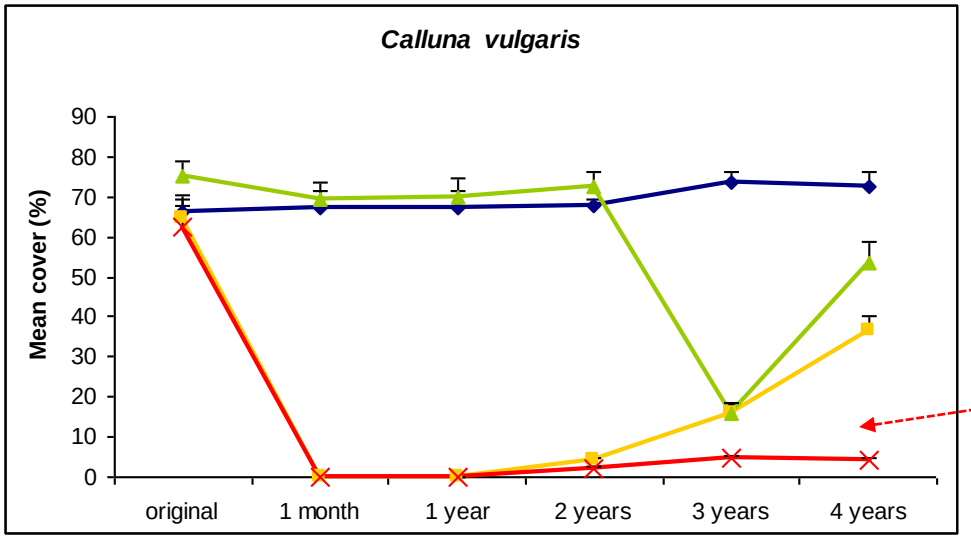
Cutting

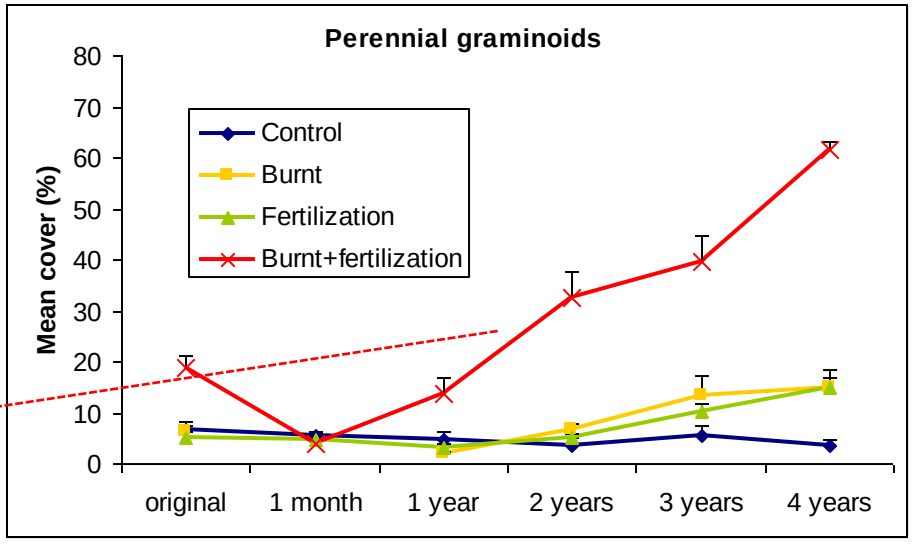
4.- ¿Qué hacer para conservarlos?





5.- ¿Quéma en escenarios de alta deposición de nitrógeno?





4 years after burning

4 years after burning+fertilization

***Calluna* only regenerates by germination after burning**

We propose the use of **burning** as a **management tool** under current conditions of nitrogen deposition, but … in new scenarios of higher N deposition: **Burning+ grazing**

Muchas Gracias

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