Heathlands in the Cantabrian Mountains as a scenario to analyse the effects of atmospheric nitrogen deposition

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Convention on Long-range Transboundary Air Pollution
Working Group on Effects
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Madrid-Spain

1.- The Cantabrian Mountains as a study scenario

1.1-Why do we heathlands on the Cantabrian Mountains?

1.2.- What are the main threats of this community in these mountains?

2.- Research questions: What are the main effects of Nitrogen deposition?

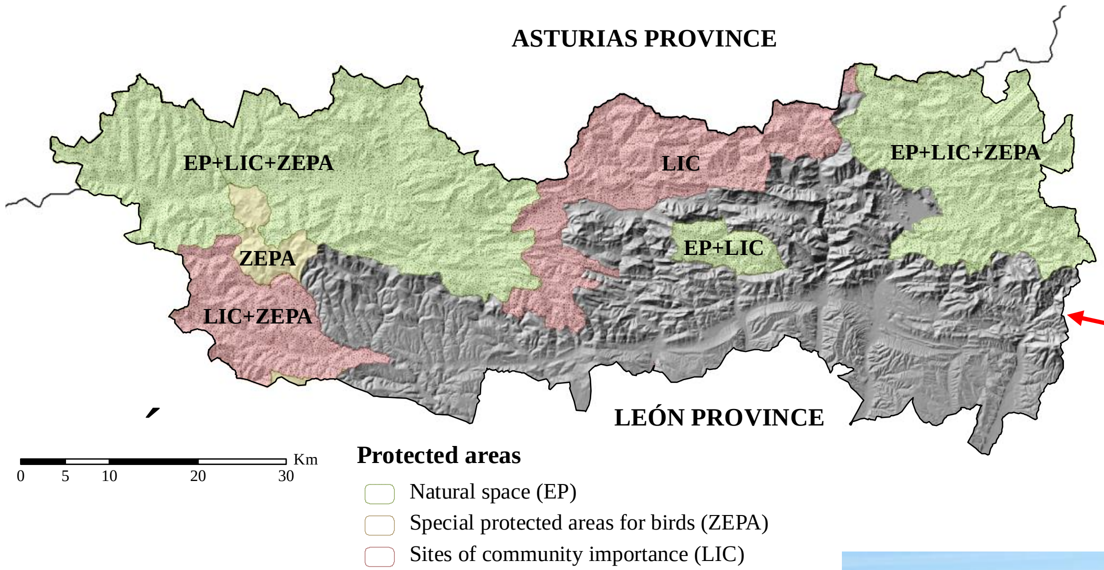
2.1.-How much nitrogen deposition do we have?

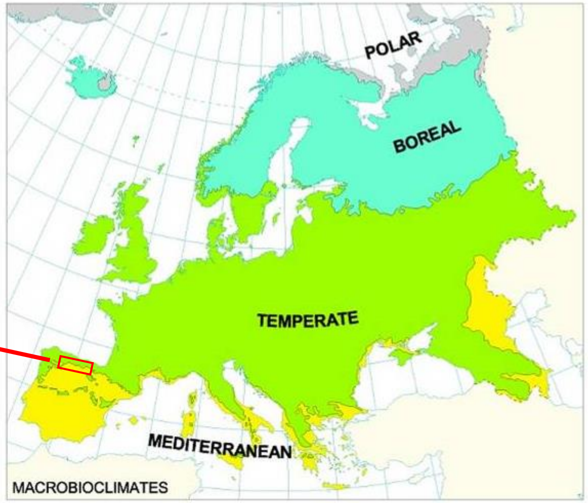
2.2.- Where is N allocated in the ecosystems?

2.3.- Are the effects of nitrogen in heathlands mediated by a time- scale of N inputs and the age of *Calluna*?

3.- Critical Loads

1.1.- Why do we study heathlands in the Cantabrian Mountains?





1. Ecotone Atlantic-Mediterranean
2. Uneven topography
3. Human management

↓

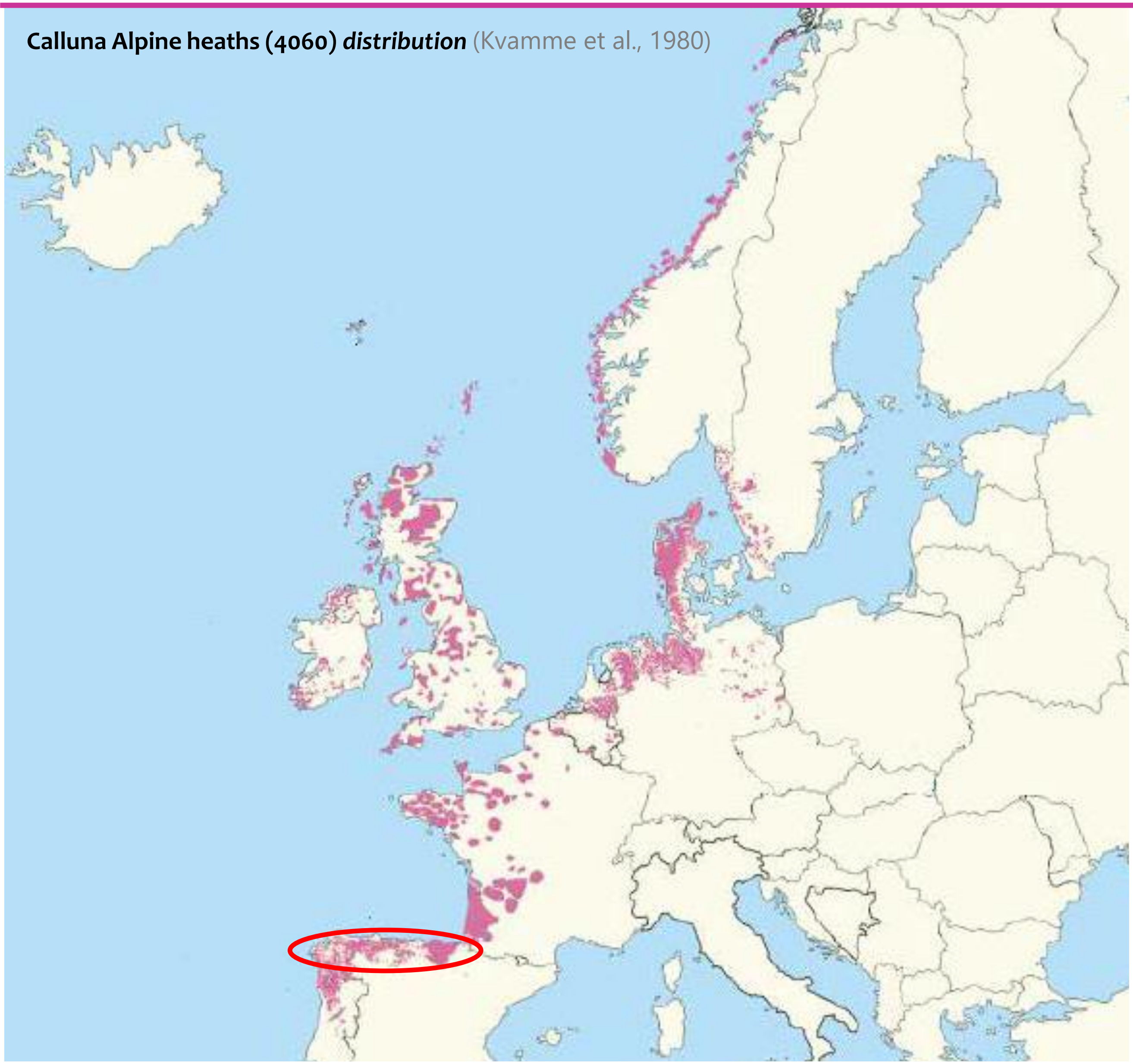
Biodiversity hotspot

Worboys et al. 2010

1.1.- Why do we study heathlands in the Cantabrian Mountains?

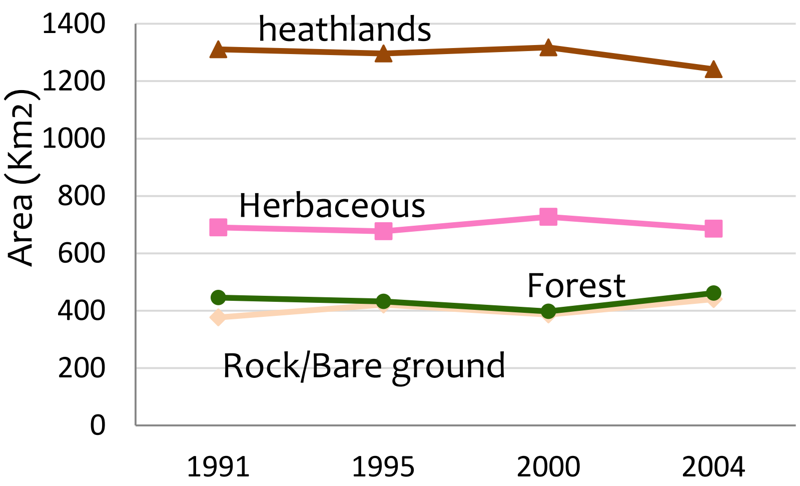
1.- Sandy acidic soils
2.- Poor in nutrients- N
3.- Reflect a long history of human activity and use (Diemont et al., 2014)

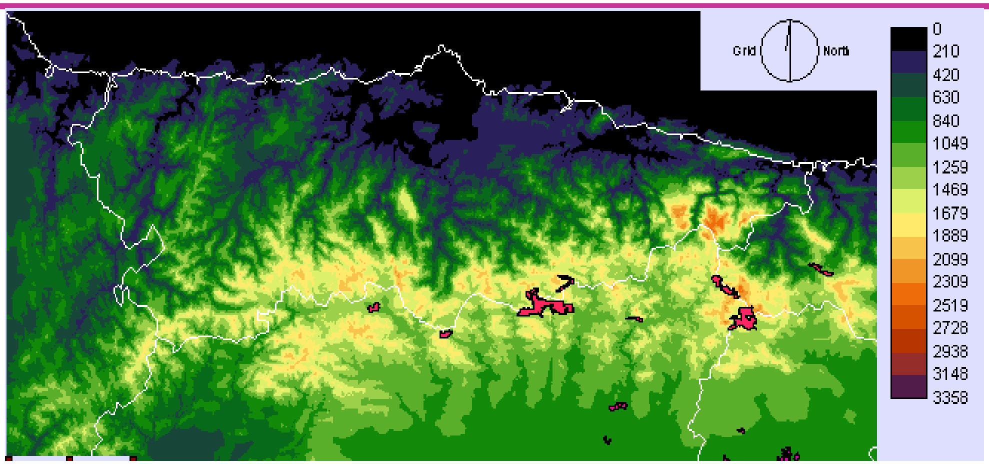
1.1.- Why do we study heathlands in the Cantabrian Mountains?



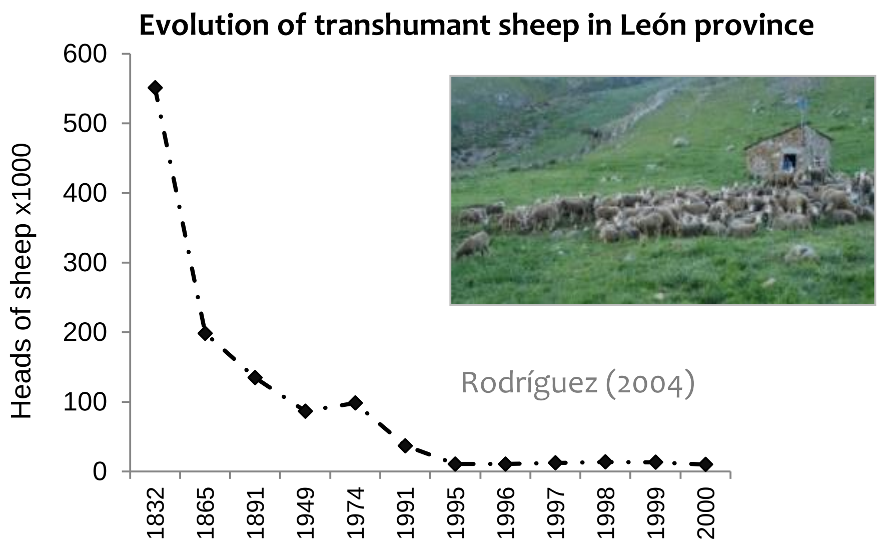
"Heathlands in the Cantabrian mountain range" The most southern distribution limit Hampe and Petit 2005

1.2.- What are the main threats of this community in these mountains?





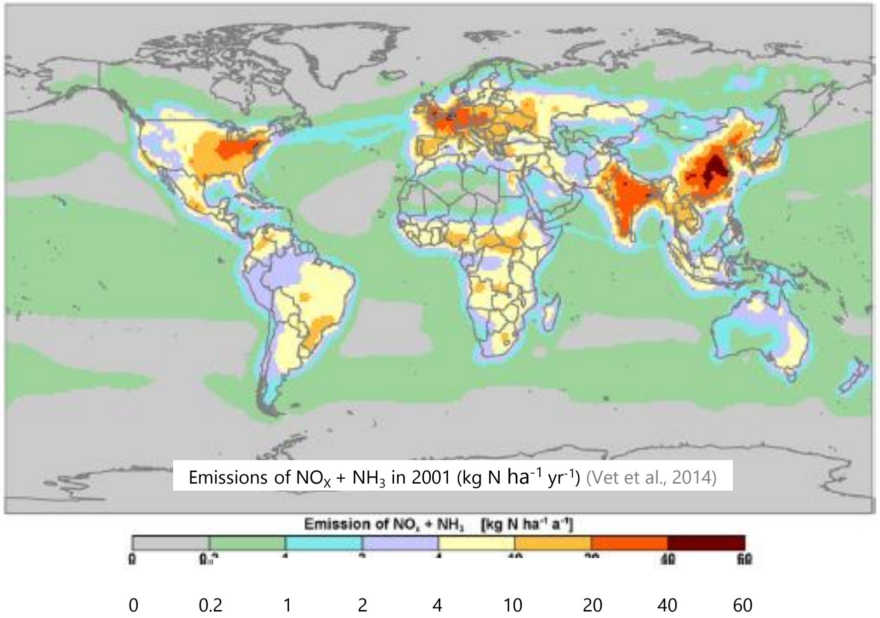
Heathland dominated by *Calluna vulgaris* in the Cantabrian Mountain (Red colour). Source: Cartography Habitat Directive 92/43/CEE (1:50000) Ministerio de Medio Ambiente



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

1.3.- What are the main threats of this community in these mountains?

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



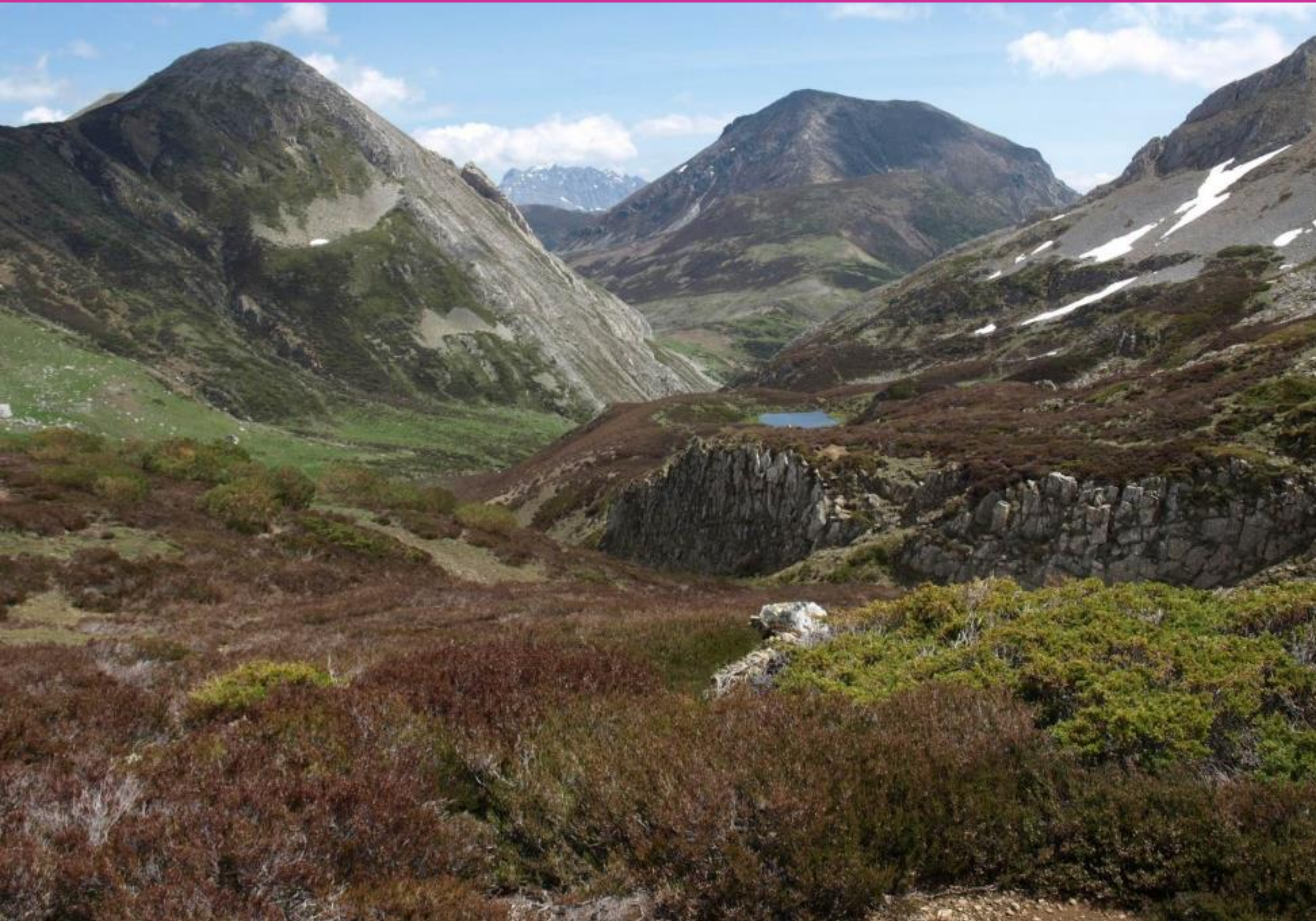
1) Poor in nutrients-----**particularly sensitive to additional atmospheric nitrogen inputs**.

2) Mountain heaths-- received **higher levels of N wet deposition**

⇩

Changes in heathland functioning, structure and composition

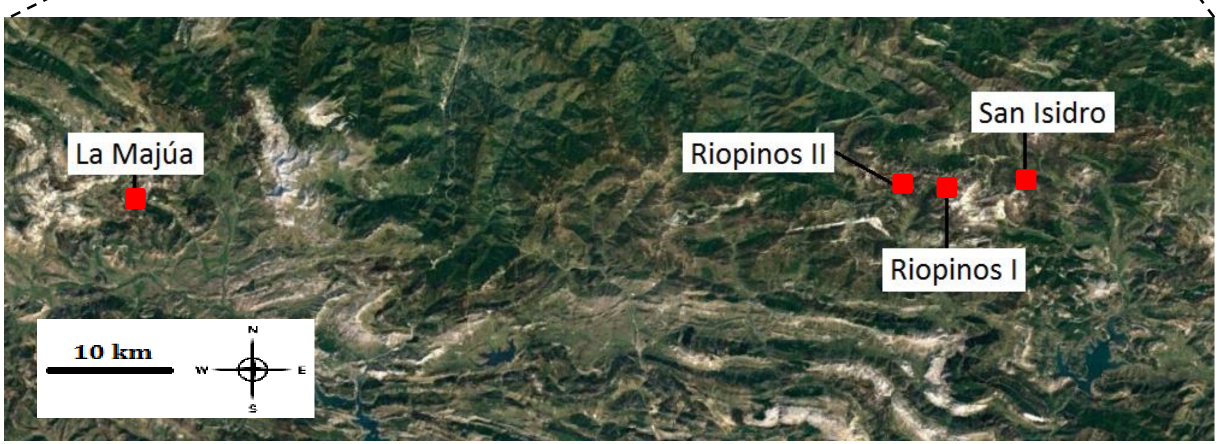
2.- What are the main effects of nitrogen deposition on our heathlands?



Experimental study areas

1998--- 2005---2011

Cantabrian Mountains (NW Spain)



CALVO, L., TÁRREGA, R. & LUIS, E. 2002. Regeneration Patterns in a *Calluna vulgaris* heathland in the Cantabrian mountains (NW Spain): effects of burning, cutting and ploughing. **Acta Oecologica** 23 (2): 81-90

MARCOS, E., CALVO, L. & LUIS-CALABUIG, E. 2003. Effect of fertilization and cutting on the chemical composition of vegetation and soils of mountain heathlands in Spain. **Journal of Vegetation Science,** 14: 417-424

CALVO, L., ALONSO, I; FERNÁNDEZ, A.J., & De LUIS, E. 2005. Short term study of effects of fertilisation and cutting treatments on the vegetation dynamics of mountain heathlands in Spain. **Plant Ecology**, 179: 181-191

CALVO, L., ALONSO, I., MARCOS, E. & LUIS-CALABUIG, E. 2007 Effects of cutting and atmospheric nitrogen deposition on biodiversity in Cantabrian heathlands (**Applied Vegetation Science**, 10: 43-52

MARCOS, E., VILLALÓN, C., CALVO, L., LUIS, E. 2009. Short-term effects of experimental burning on soil nutrients in the Cantabrian heathlands. **Ecological Engineering** 35:820-828

(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

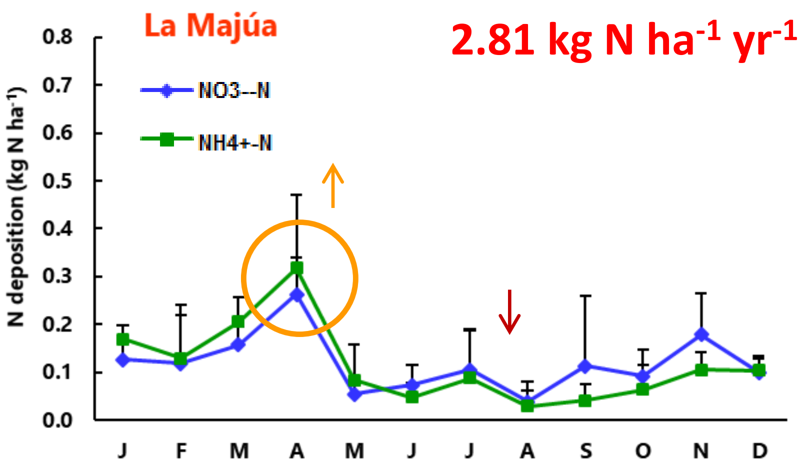
Ammonium (NH_4^+) concentration (Reardon et al., 1966)

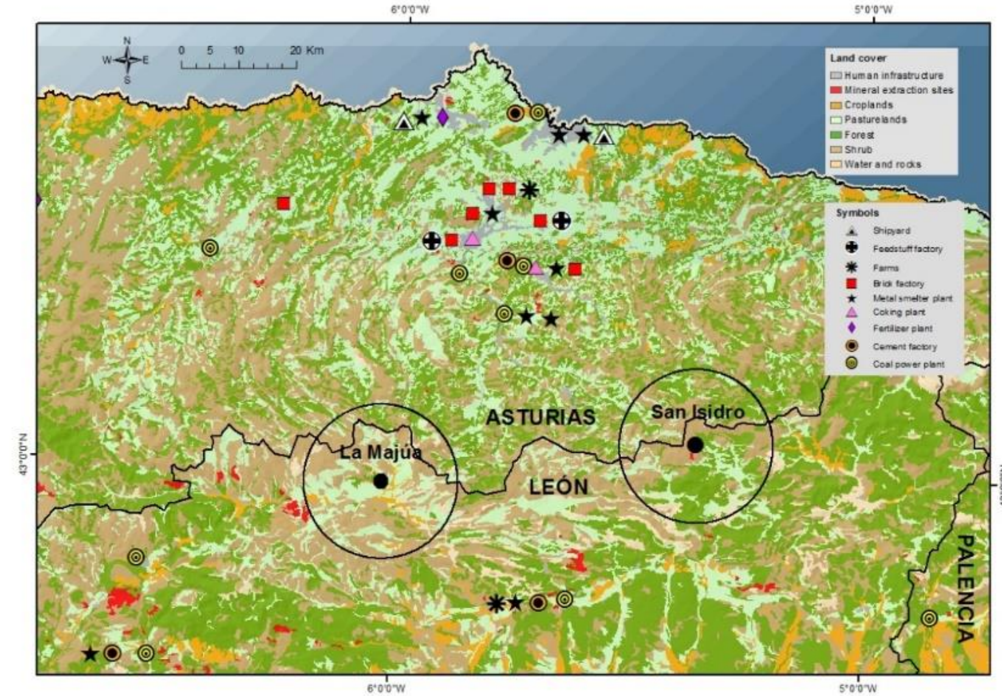
Nitrate (NO_3^-) concentration (Tabatabai and Dick, 1983)

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.

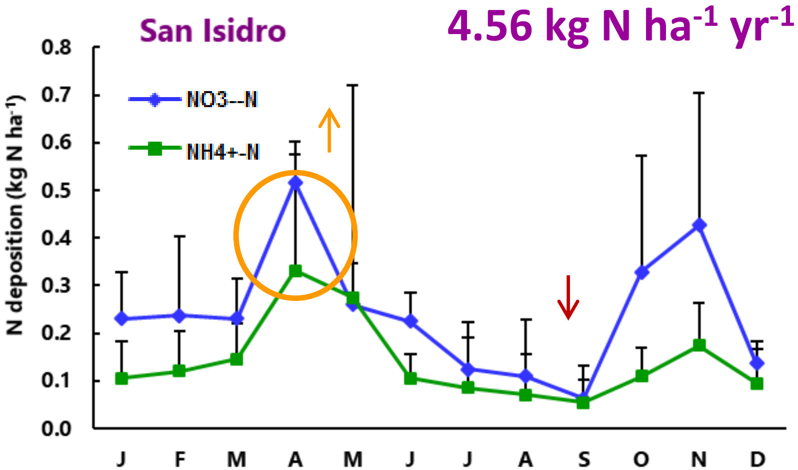
Bulk NO_3^--N and NH_4^+-N depositions

Mean annual rainfall was 858 mm





Mean annual rainfall was 1645 mm

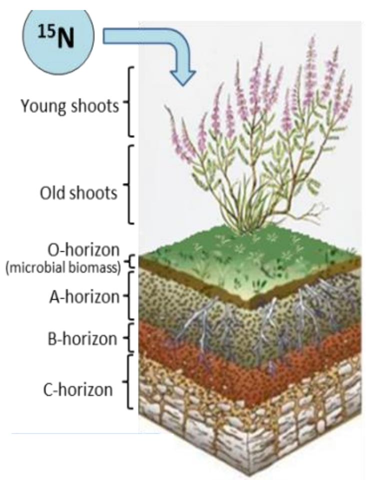


La Majúa: NH_4^+-N / NO_3^--N = **0.98: Agricultural**

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

3. 2.- Where is N allocated?

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 ^{15}Nrec (mg N m^{-2})		November 2011 % ^{15}Nrec		November 2012 ^{15}Nrec (mg N m^{-2})		November 2012 % ^{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**	

2. Soil organic horizon: compartment with the greatest retention capacity

3. Negligible N leaching losses

1. Heathlands in the Cantabrian Mountains retain 72% of atmospheric N depositions in the short term

In summary: Heathland are still not N saturated under current N deposition loads

3.3.- Are the effects of nitrogen in heathlands mediated by a time- scale of N inputs and the age of *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	N 20	N 50	N 56
	Low	Medium	High	High

Mature >40 years old

0	N 10	N 20	N 50	N 56
	Low	Medium	High	High

Short term N inputs
2 years

Long term N inputs
10 years

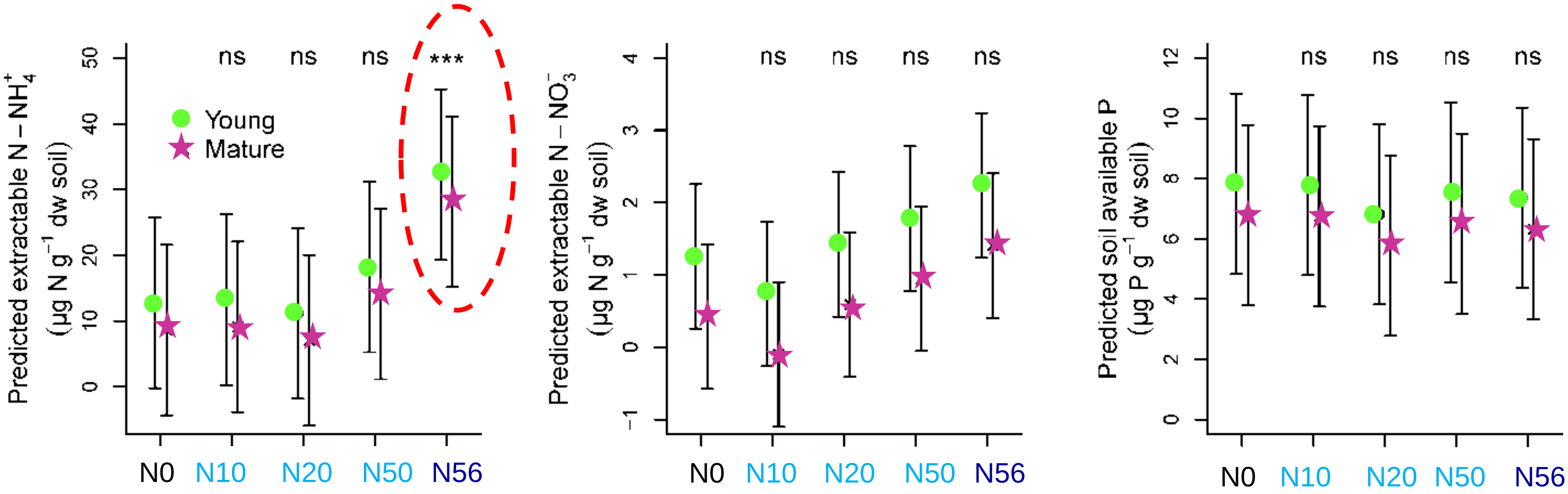
3.3.- Are the effects of nitrogen in heathlands mediated by a time- scale of N inputs and the age of *Calluna*?

Vegetation

(1) Plant Community composition
(2) Plant species richness
(3) Vascular and non-vascular life forms cover
(4) Calluna vital rates (shoot growth / flowering)

Soil

(1) Plant-litter-soil N and P contents
(2) Enzymatic activities
(3) Soil microbial biomass C and N contents
(4) Root mycorrhizal colonization



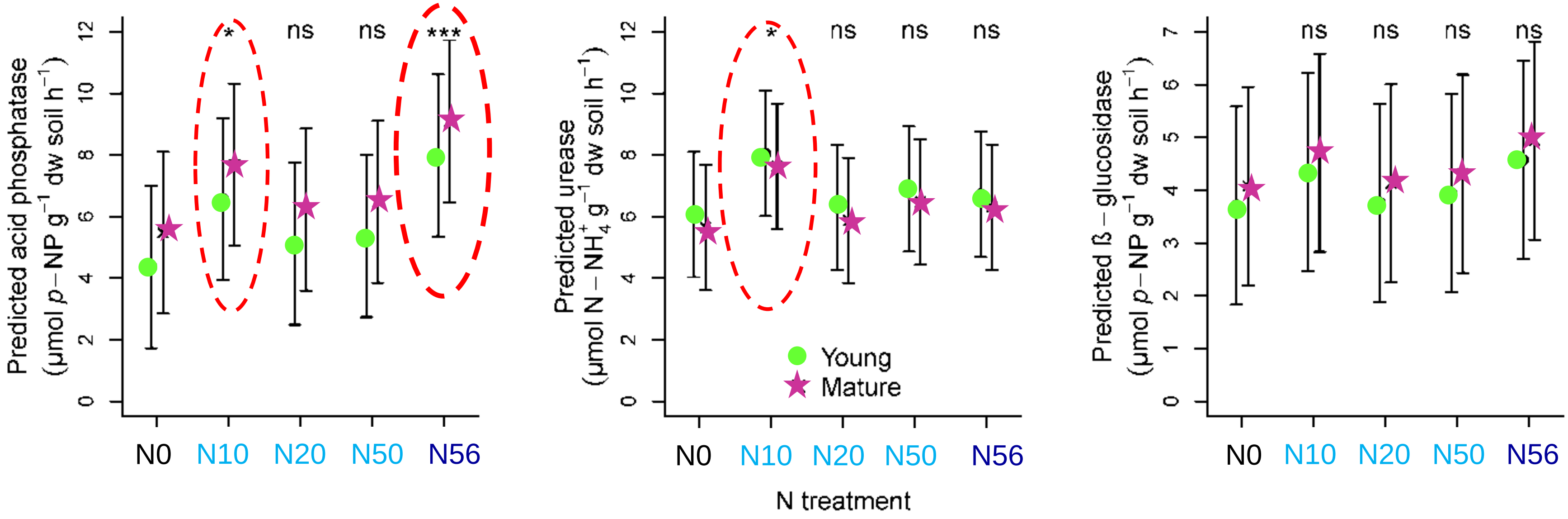
(1) **Soil extractable N-NH_4^+** increased in response to N addition-***long-term high N input (N56)***

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

NO3 and **Available Phosphorous** **young**

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

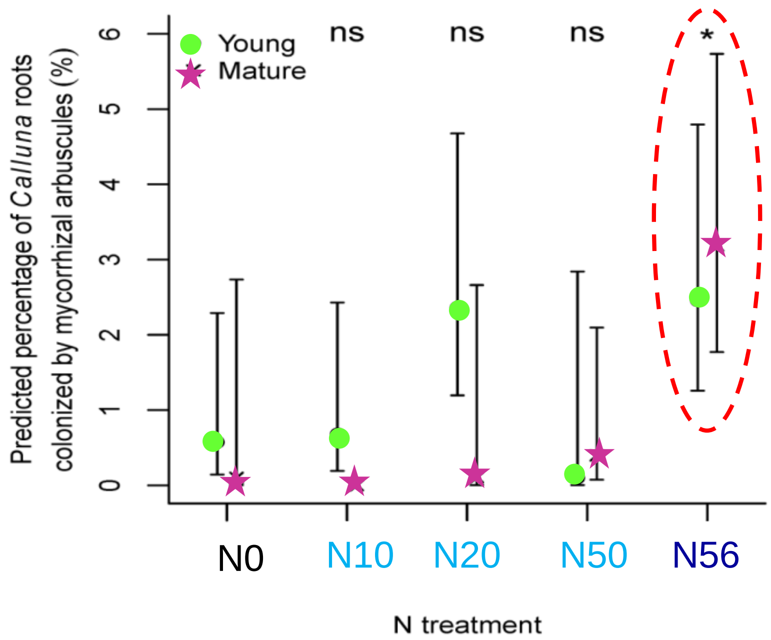


(1) **Acid phosphatase** and **urease** increased in response to N addition, particularly, the first one in the **long term high N inputs** (N56), and to a lesser extent both in the low N input (N10)

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

No significant differences

Calluna root mycorrhizal colonization

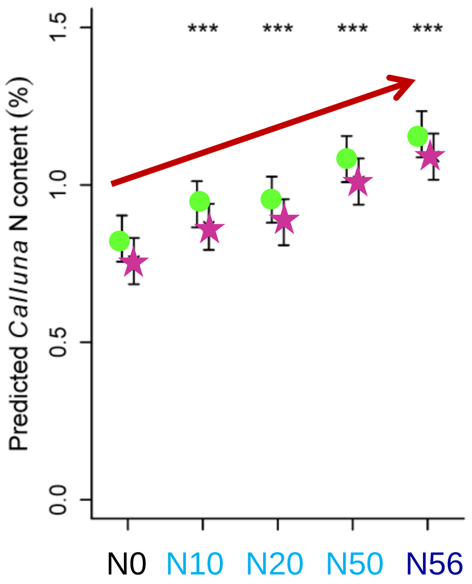


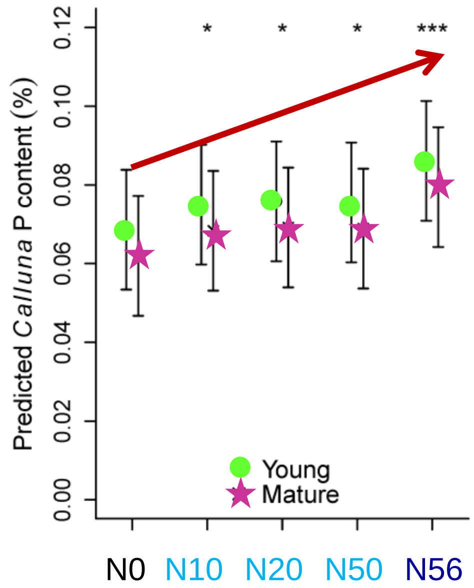
(1) There was a significant **increase** in the *Calluna* **roots colonization by mycorrhizae** under **long term high N loads** (N56).

(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

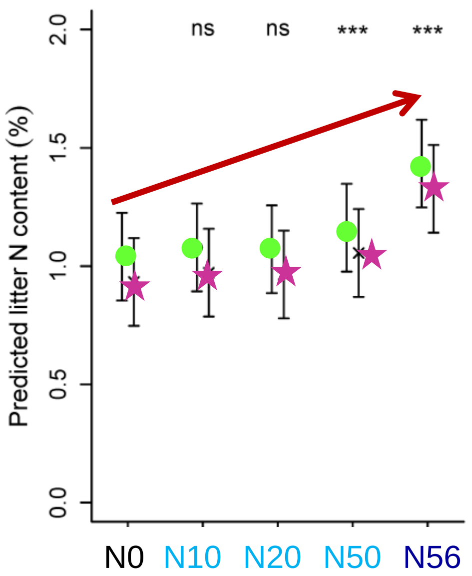




N inputs

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

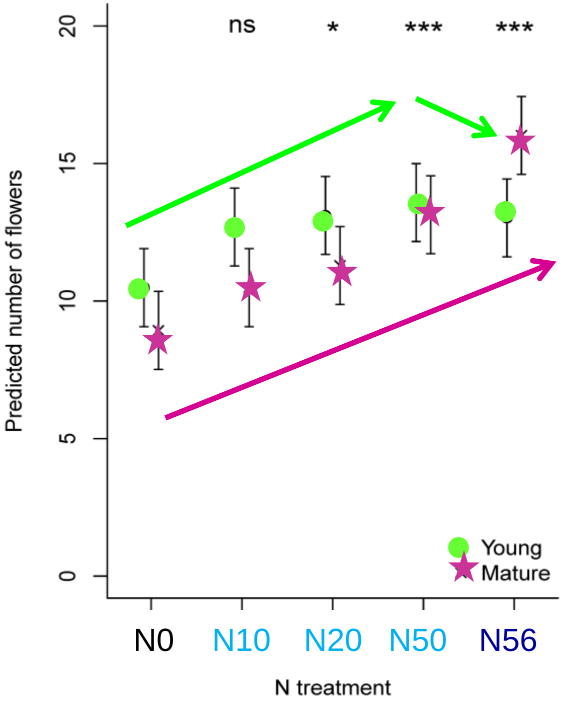
Litter **N**, P content

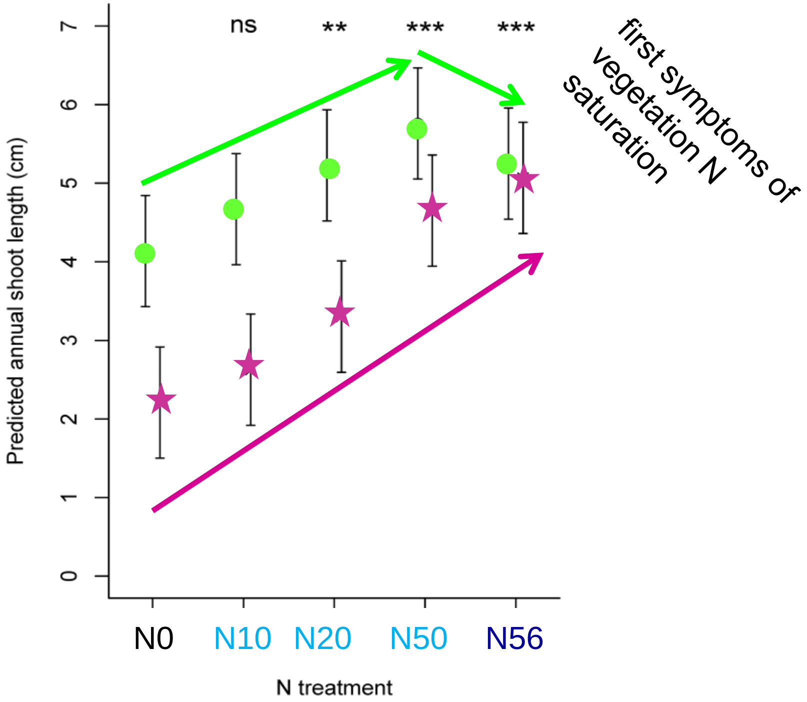


Age-related effects:

Young - Higher N and P content

***Calluna vulgaris* vital rates**





***(1)* <u>*Calluna* flowering</u>**

- Progressive increase

***(2)* <u>*Calluna* shoot length:</u>**

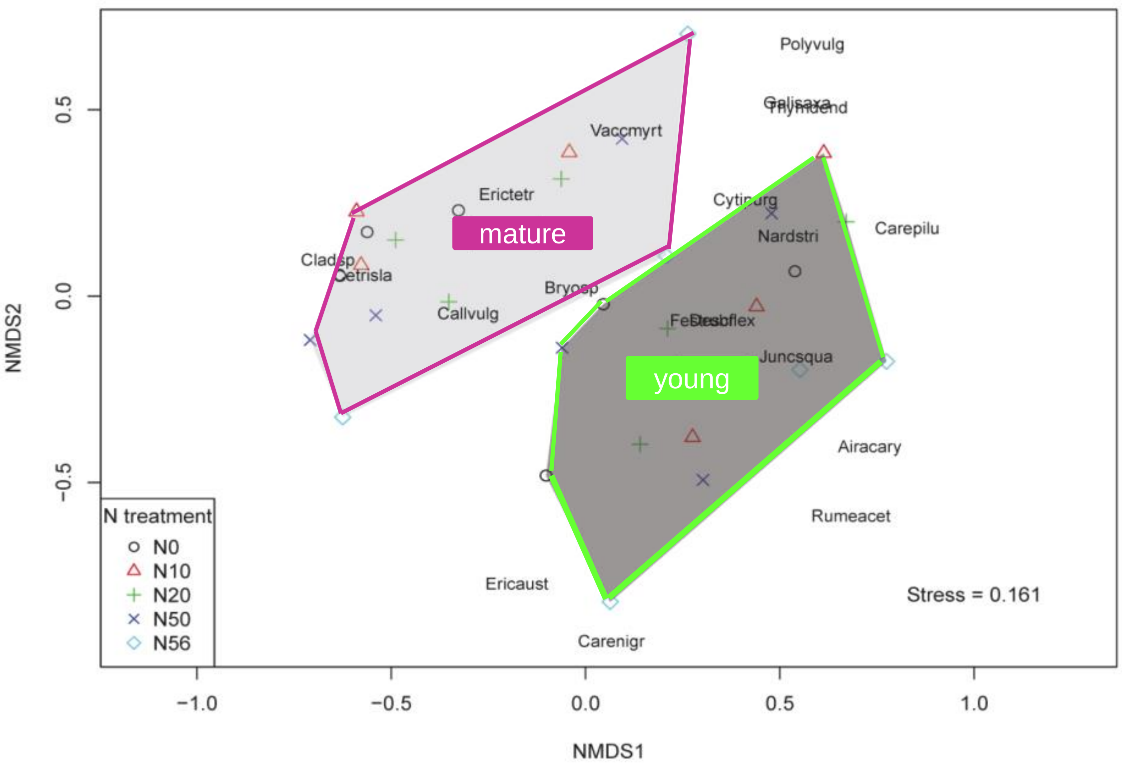
- Progressive increase

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

Young= Higher flowering and shoot length

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

Plant species composition



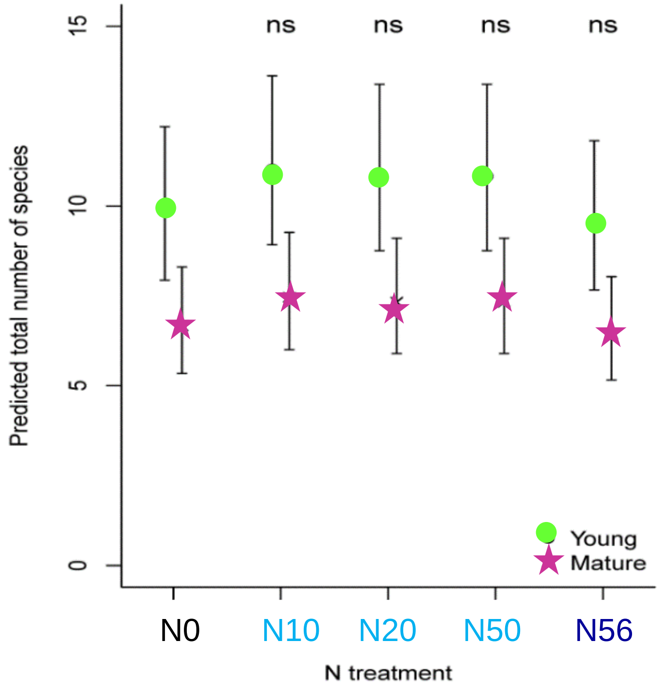
(1) N loads had **<u>no effect</u>** on plant **<u>species composition</u>**

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

- **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



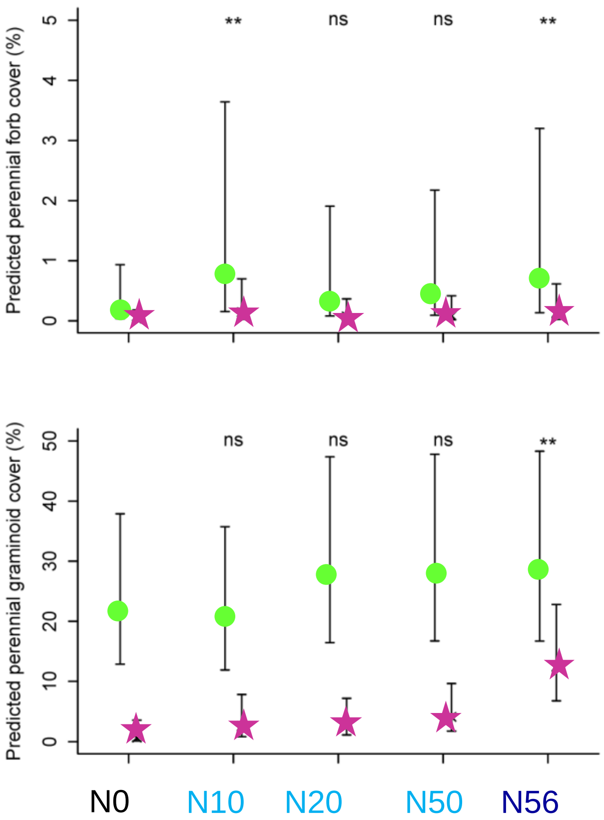
(1) Increasing N loads had **no effect** on **species richness**

(2) Age-related effects:

Young= higher plant species richness

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

Vascular life-forms cover



(1) Increasing N loads:

↑perennial forbs/ graminoids cover

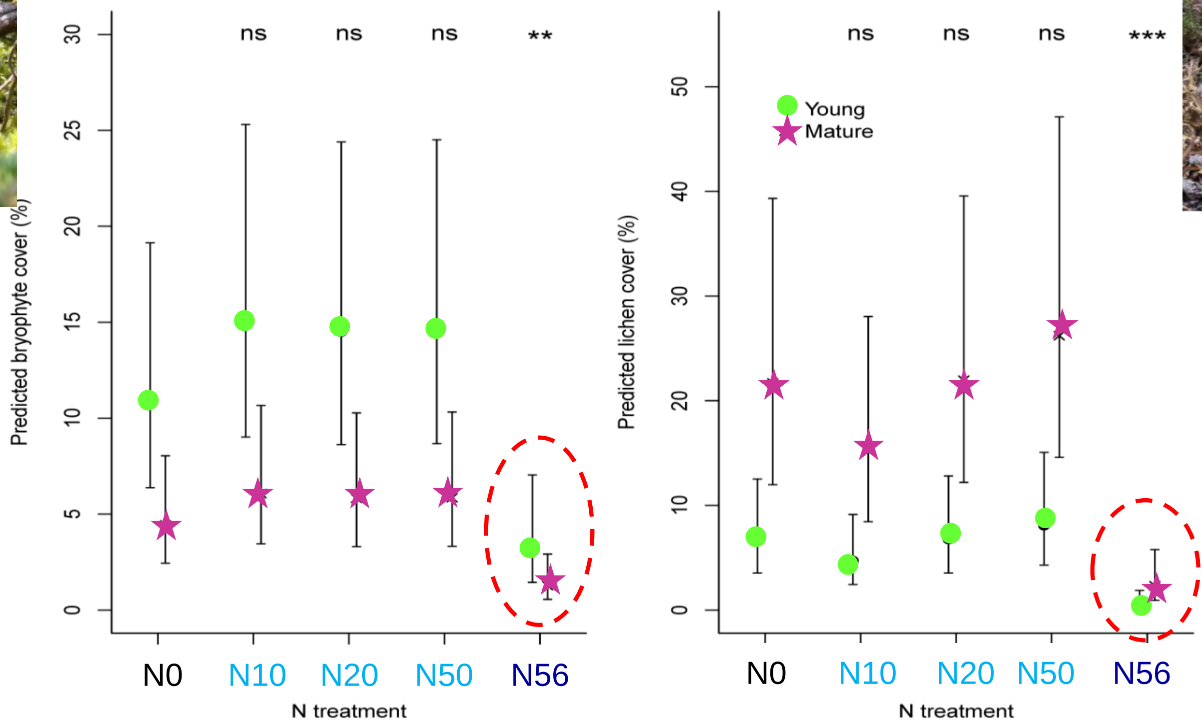
↑annual forbs/ graminoids cover

(2) <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>**

In summary

1.- Increase N 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**

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

3.- Critical loads

Short term N inputs
2 years

0 | N 10 | N 20 | N 50

Low | Medium | High

0 | N 10 | N 20 | N 50

Low | Medium | High

Short term N inputs
2 years

Calluna ages

Young=8 years old

Mature >40 years old

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)

Mature heathlands

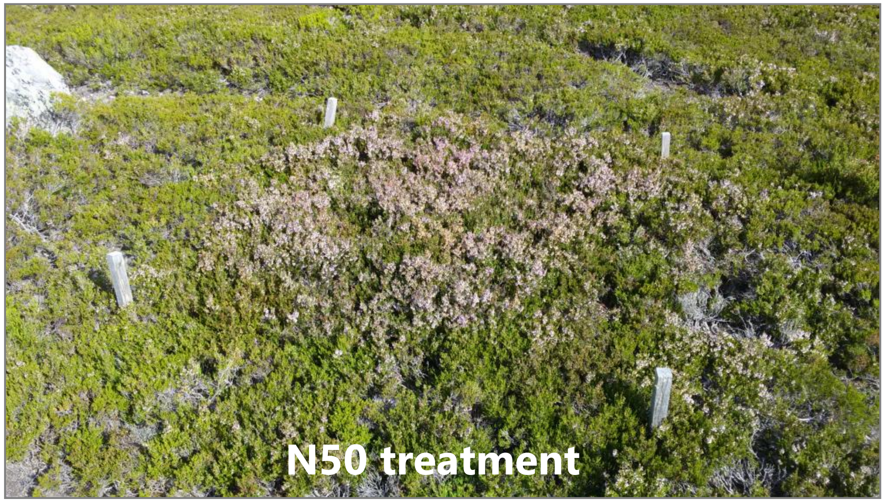
N10 treatment (14.6 kg N ha^{-1} yr^{-1})

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

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

	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

Mature stands



Annual shoot growth

-Number
-Size
-Phenology

Lochmaea suturalis

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**

Thank you

Unidad de Investigación Consolidada

<u>"Ecología Aplicada y Teledetección"</u>

<u>Universidad de León</u>

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