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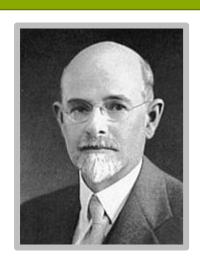








- Place occupied by an organism in ecosystem (Grinnell, 1917)
  - Sum of conditions that allow an organism to occur in environment

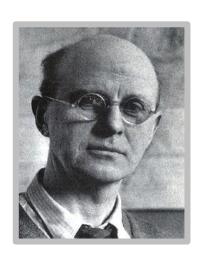


Introduction Methods Results Conclusion Application

### **Ecological niche**

- Place occupied by an organism in ecosystem (Grinnell, 1917)
  - Sum of conditions that allow an organism to occur in environment

- Role of an organism in ecosystem (Elton, 1927)
  - Influence a an organism on his environment



Introduction Methods Results Application

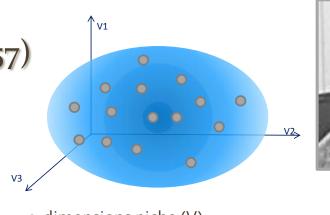
### **Ecological niche**

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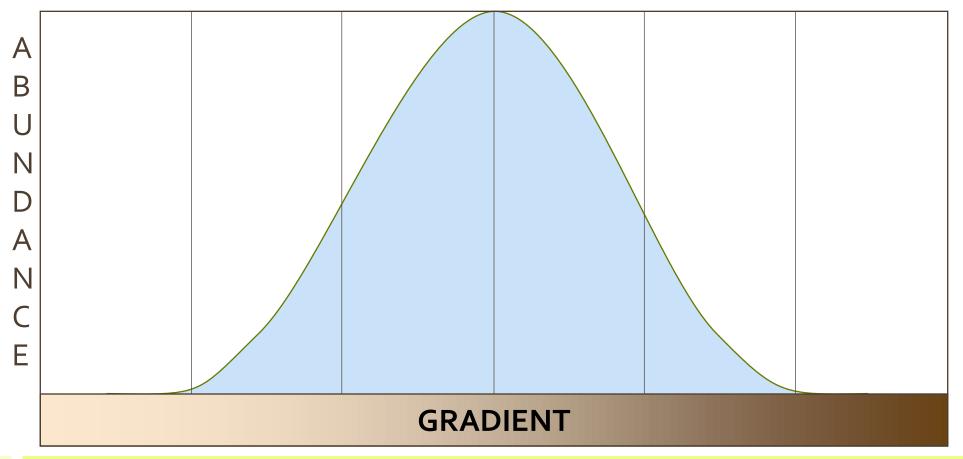
• n-dimensional hypervolume (Hutchinson, 1957)

Dimensions = conditions and resources

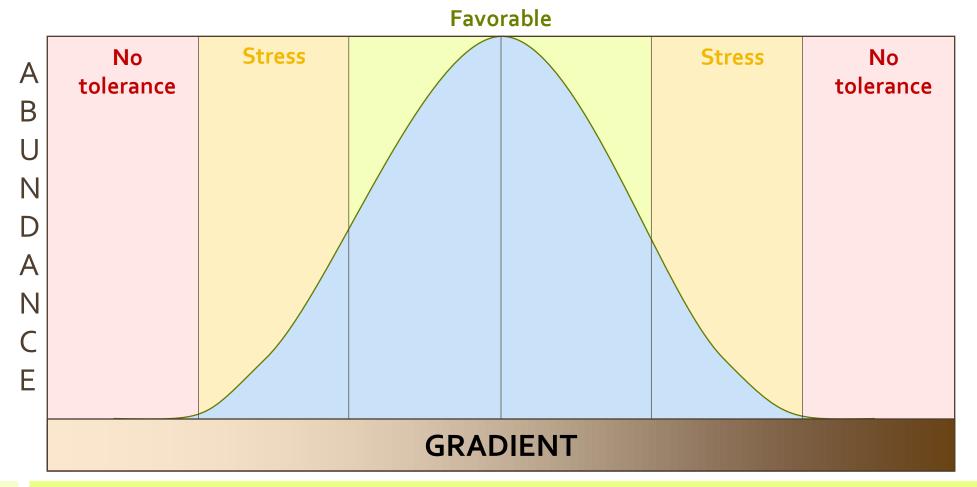




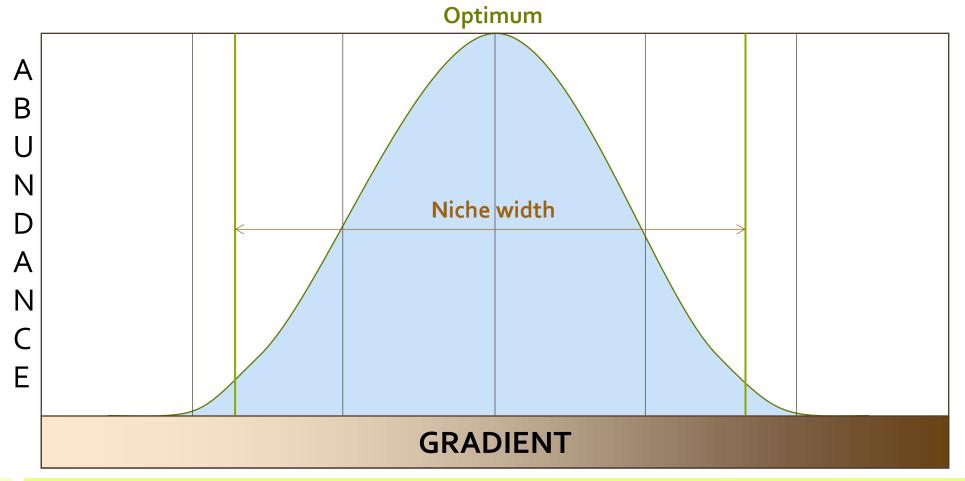
• For one environmental factor



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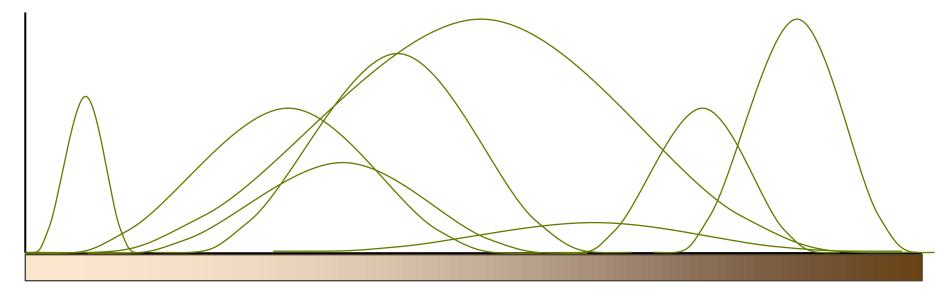
• For one environmental factor



• Individualistic continuum concept (Gleason, 1926)

Species response assemblages are random in community

Abundance

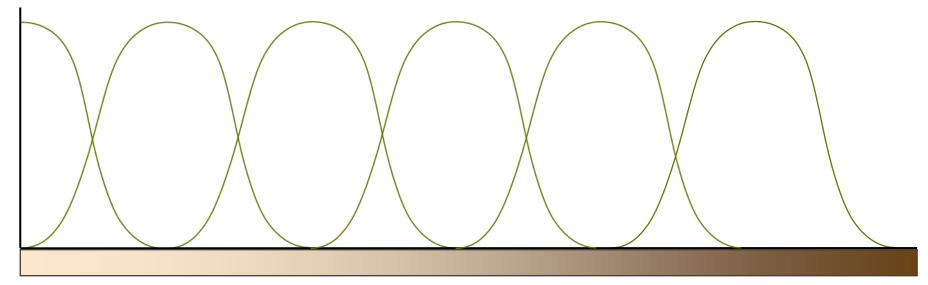


Resource gradient

• Resource partitioned continuum (Austin, 1985)

Resource partitioning and competition lead to uniform distribution along gradient

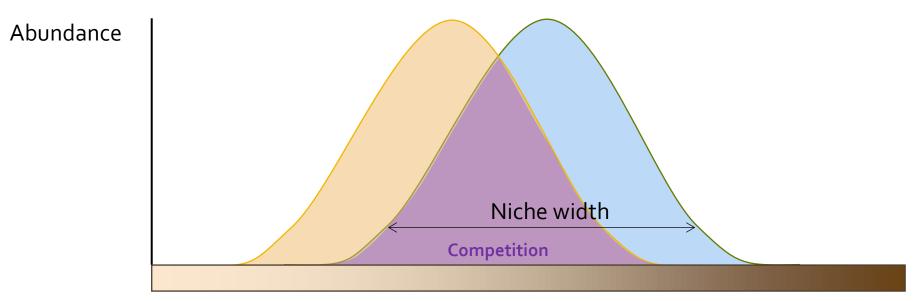
Abundance



Resource gradient

• Competitive exclusion principle (Gause, 1934)

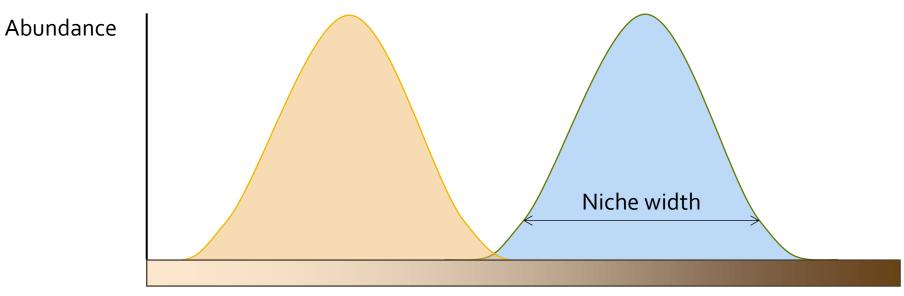
Two species competing for the same resources (niche) cannot coexist if other ecological factors are constant



Resource gradient

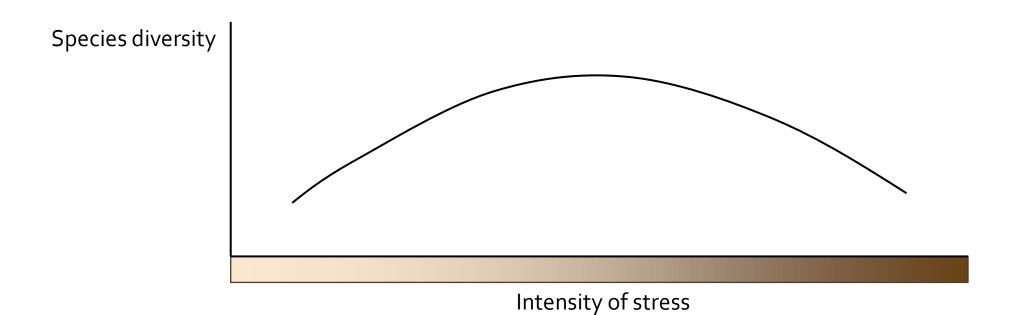
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Two species competing for the same resources (niche) cannot coexist if other ecological factors are constant



Resource gradient

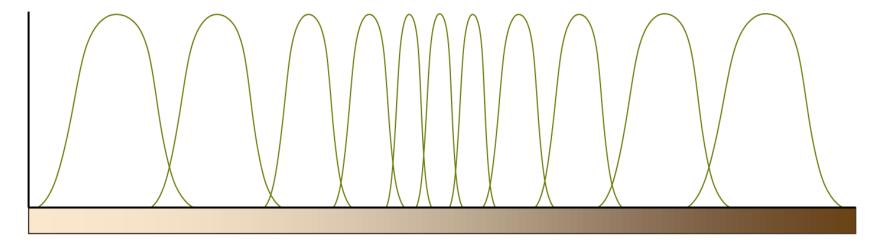
• Competitive exclusion in herbaceous vegetation (Grime, 1973) Species diversity is higher at intermediate intensity of stress



- Resource partitioned continuum (Austin, 1985)
- Competitive exclusion principle (Gause, 1934)
- Competitive exclusion in herbaceous vegetation (Grime, 1973)

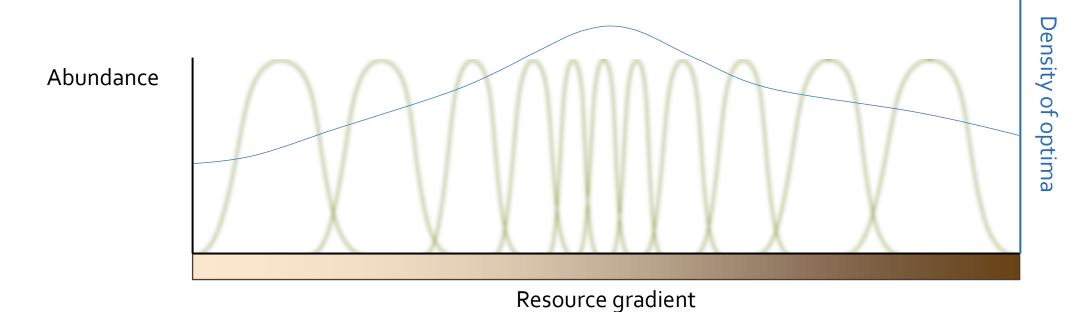
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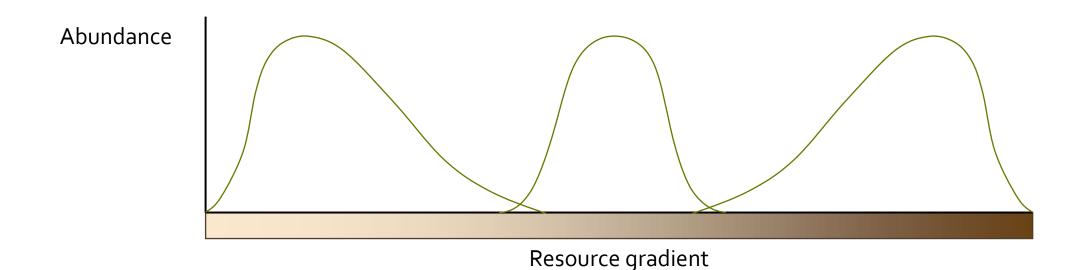


Resource gradient

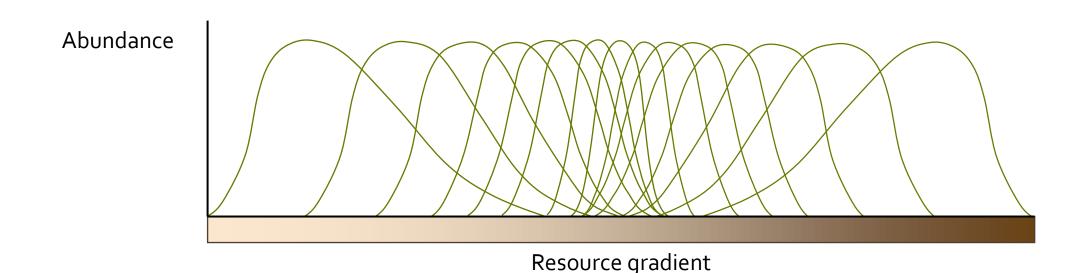
- Plant species are packed on mesic position of environmental gradient;
- Niche widths are narrower when optima of species are packed (Lawesson & Oksanen 2002)



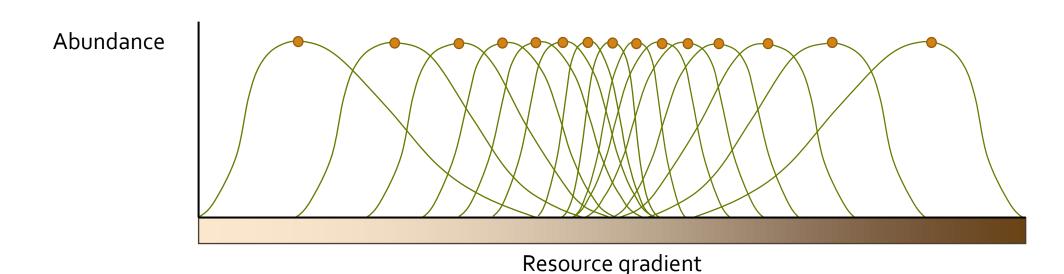
- Ecological response curves are often skewed ...
- ...with a 'longer tail' towards mesic position (Austin & Gaywood, 1994)



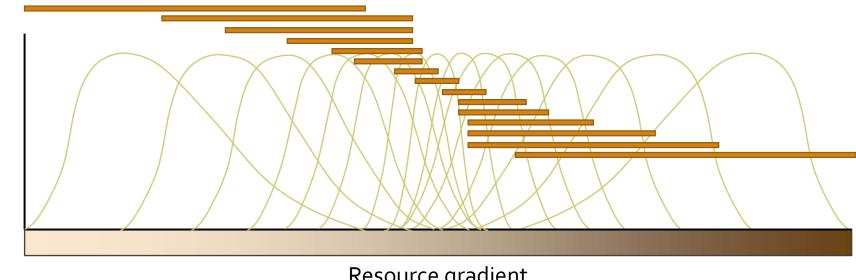
- Species optima are packed on mesic position
- Species tolerances are narrower in mesic conditions
- Response curves are more skewed at the extremities of gradients



- Species optima are packed on mesic position
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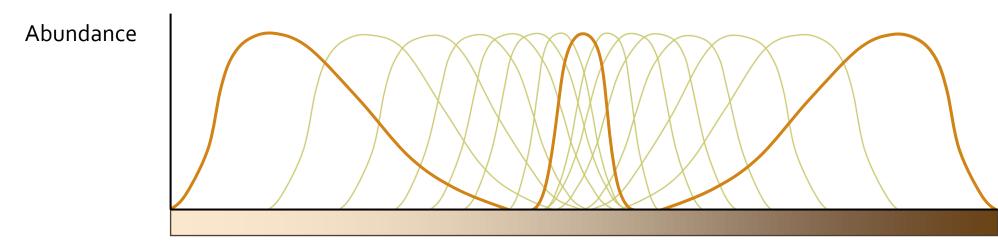


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**Abundance** 

- Species optima are packed on mesic position
- Species tolerances are narrower in mesic conditions
- Response curves are more skewed at the extremities of gradients



- Species optima are packed on mesic position
- Species tolerances are narrower in mesic conditions
- In this study, we tested these assumptions on response curves along a metal toxicity gradient



Resource gradient

#### Resource gradient vs metal toxicity gradient

#### Resource gradient vs metal toxicity gradient

Most studies focus on macronutrients = low toxicity

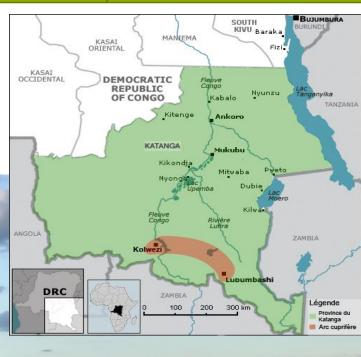
#### Resource gradient vs metal toxicity gradient

Species distribution on Cu, Co, Pb, etc.?

Metals are toxic at lower concentrations

# Study site

- Katangan copperbelt, Katanga (D.R. Congo)
- Copper and cobalt outcrops → contaminated soils

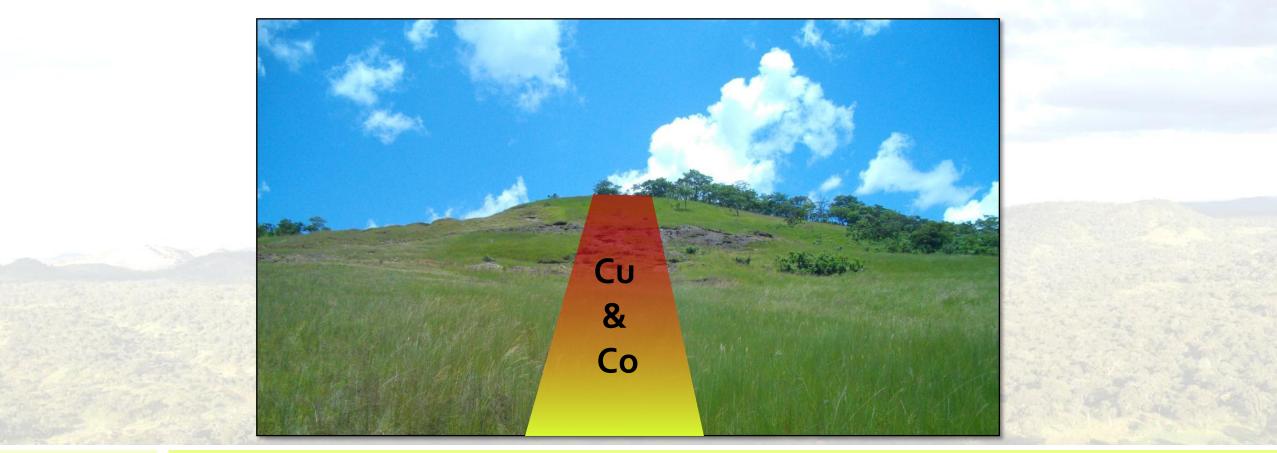




Introduction Methods Results Conclusion Application

### Original flora

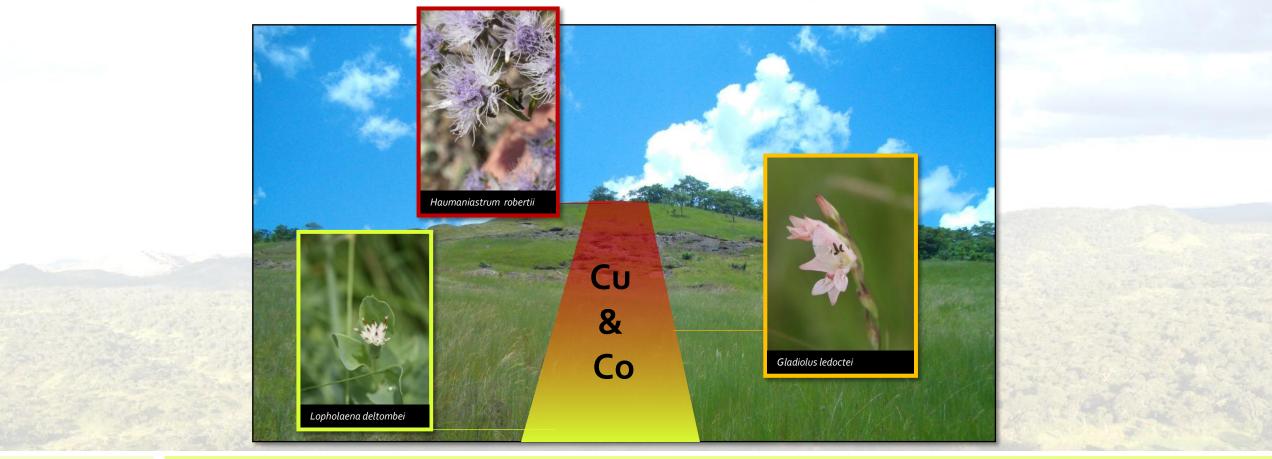
• More than 650 plant species, 9 % endemics



Introduction Methods Results Conclusion Application

### Original flora

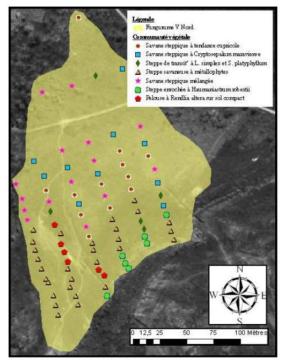
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### Sampling

- Vegetation
  - 184 taxa
  - 172 quadrats (1m²) on 3 hills
    - Presence/absence

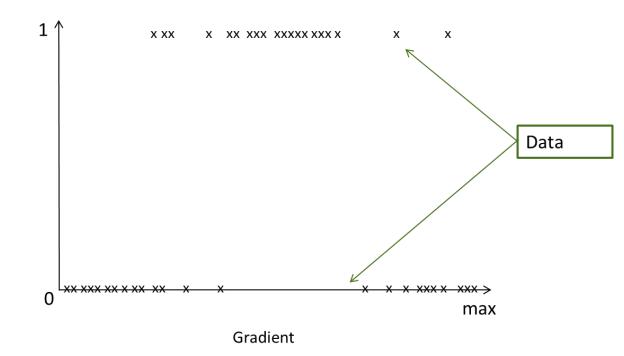
- Soils
  - 10-15 cm depth
  - Cu and Co extracted by EDTA 4.65 (atomic absorption spectroscopy)



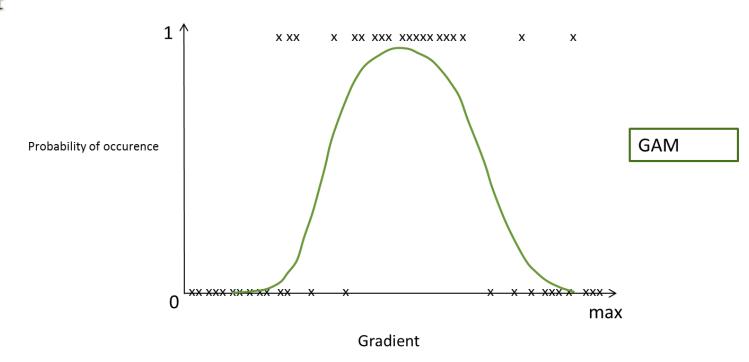
Example on one hill

• Select taxa with occurrence ≥ 8 in dataset (=80 taxa)

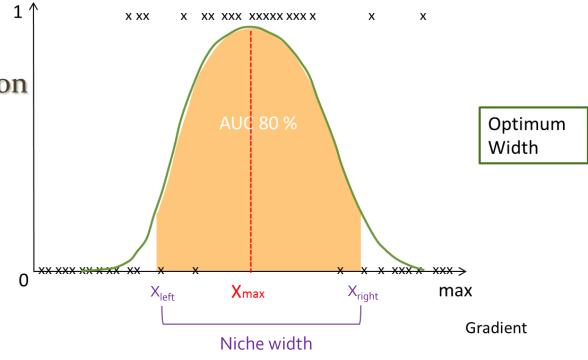
- Select taxa with occurrence ≥ 8 in dataset (=80 taxa)
- Generalized additive model (Cu and Co) (Hastie & Tibshirani, 1990)
  - Non parametric method, robust
  - Logistic approach (o/1)



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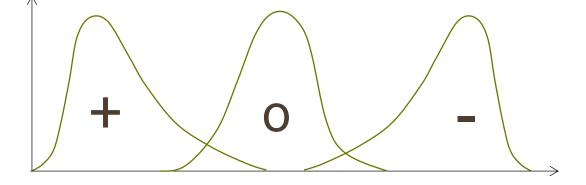
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  - Non parametric method, robust
  - Logistic approach (o/1)
- Niche optima and niche width calculation
  - Optimum : X location for Y-max
  - Width: extremities of AUC 80 %



• Skewness coefficient (Fisher, 1930)

$$\mu_3/\sigma^3$$

- μ<sub>3</sub>, central moment of order 3
- $\sigma$ , standard deviation ( $\mu 2^{1/2}$ )

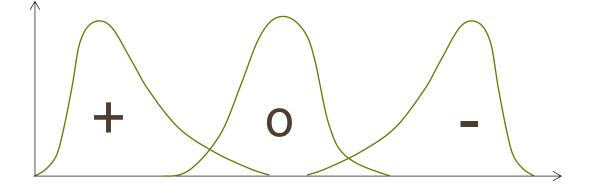


33

• Skewness coefficient (Fisher, 1930)

$$\mu_3/\sigma^3$$

- μ3, central moment of order 3
- $\sigma$ , standard deviation ( $\mu 2^{1/2}$ )



- Density curve
  - Kernel density

Overview

### Taxa distribution

Along copper gradient

Methods Results Introduction

Overview

### Taxa distribution

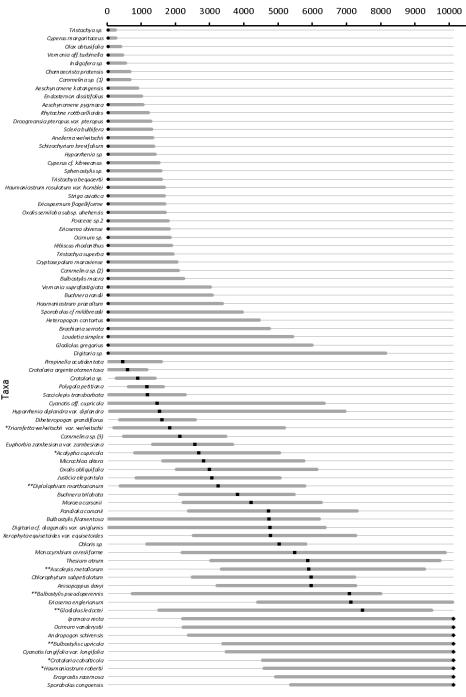
Along copper gradient

• Range: 29 – 10 000 mg Cu.kg soil -1

• = niche optima

= niche width

#### EDTA-extractable copper (mg kg-1)



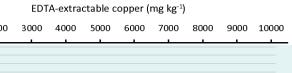
Overview

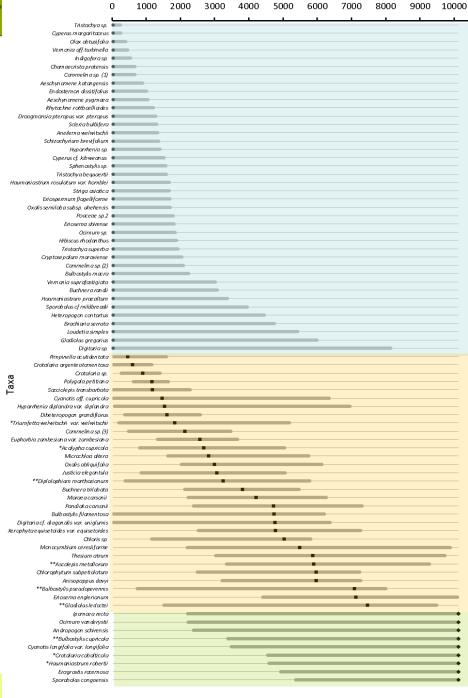
### Taxa distribution

Along copper gradient

• Range: 29 – 10 000 mg Cu.kg soil -1

• = niche optima = niche width





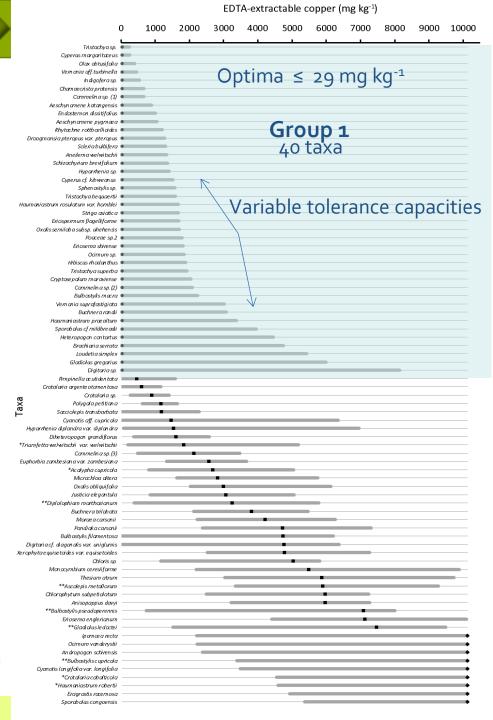
Overview

## Taxa distribution

### Along copper gradient

- Range : 29 10 000 mg Cu.kg soil -1
- Group 1: 40 taxa

• = niche optima



Overview

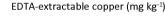
### Taxa distribution

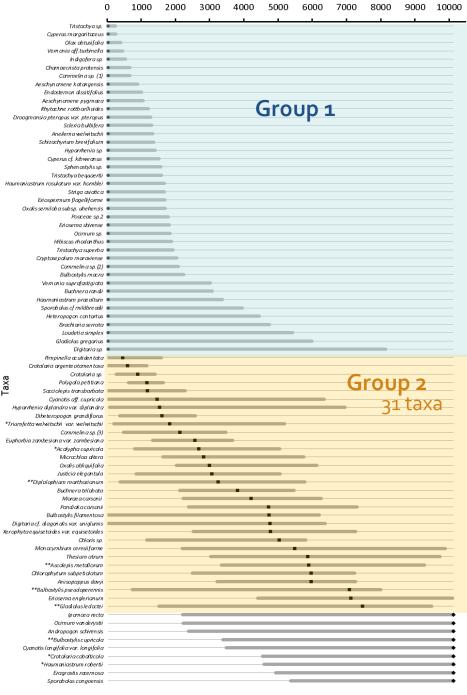
### Along copper gradient

- Range : 29 10 000 mg Cu.kg soil -1
- Group 1: 40 taxa
- Group 2 : 31 taxa

Well defined and uniformly distributed optima

= niche optima





Overview

## Taxa distribution

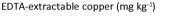
### Along copper gradient

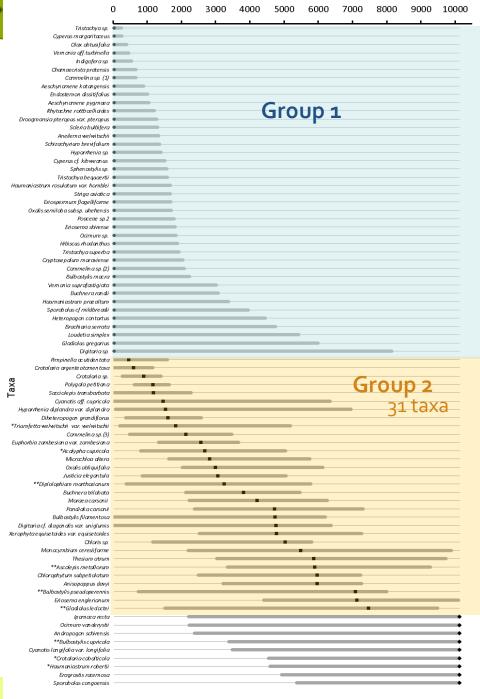
- Range : 29 10 000 mg Cu.kg soil -1
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- Group 2 : 31 taxa

Well defined and uniformly distributed optima

Variable tolerance

= niche optima





Overview

### Taxa distribution

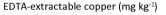
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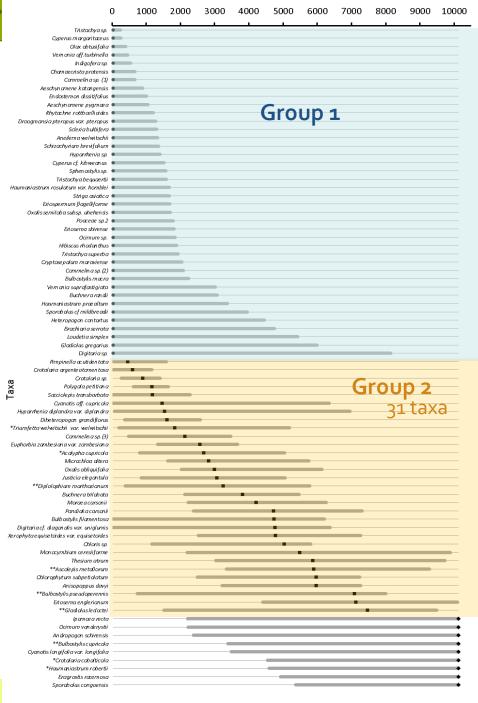
- Range : 29 10 000 mg Cu.kg soil -1
- Group 1 : 40 taxa
- Group 2 : 31 taxa

Well defined and uniformly distributed optima

- Variable tolerance
- Competition

= niche optima





Overview

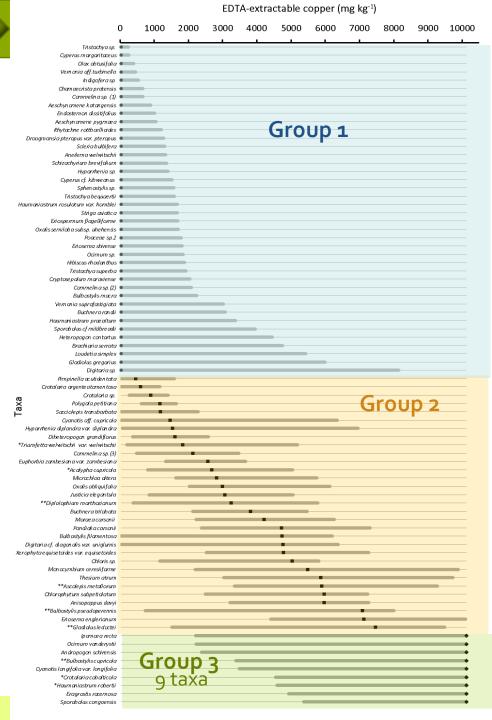
### Taxa distribution

### Along copper gradient

- Range : 29 10 000 mg Cu.kg soil <sup>-1</sup>
- Group 1 : 40 taxa
- Group 2 : 31 taxa
- Group 3: 9 taxa

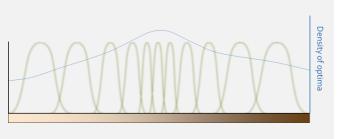
Optima ≥ 10 000 mg kg-1 Highly toxic conditions (Cu) Large niche widths

= niche optima

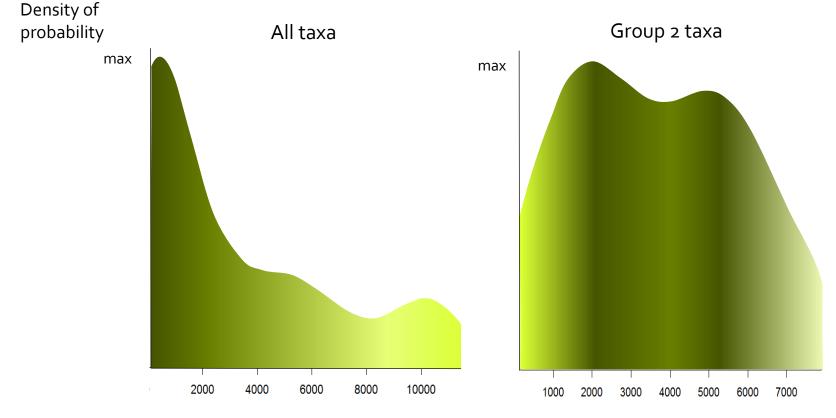


# Hypothesis 1 Optima are packed on mesic position

Along resource gradient

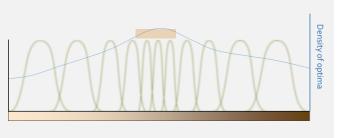


Along copper gradient

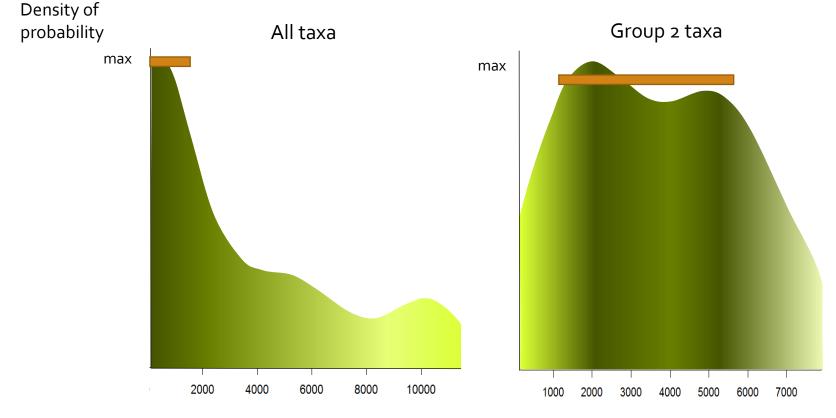


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Along copper gradient

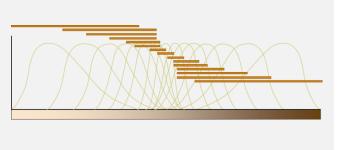


# Hypothesis 2 Niche wid

### Hypothesis test

# Niche width are narrower on mesic positions

Along resource gradient

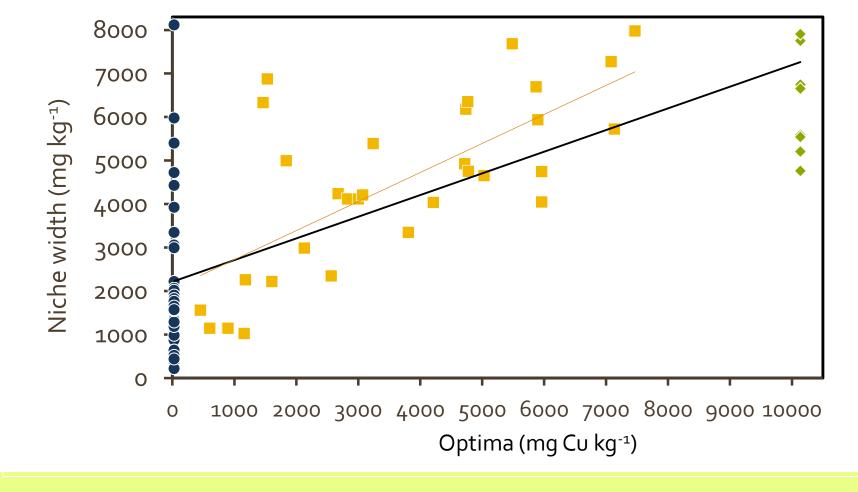


All taxa:

$$R^2 = 0.54$$
 p-value < 0.001

Group 2 only  $R^2 = 0.50$ p-value < 0.001

Along copper gradient



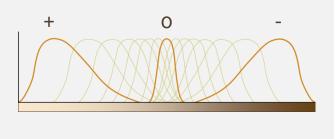
# Hypothesis 3

Hypothesis test

# Skewness is higher at the extremities of gradient

Along resource gradient

Along copper gradient

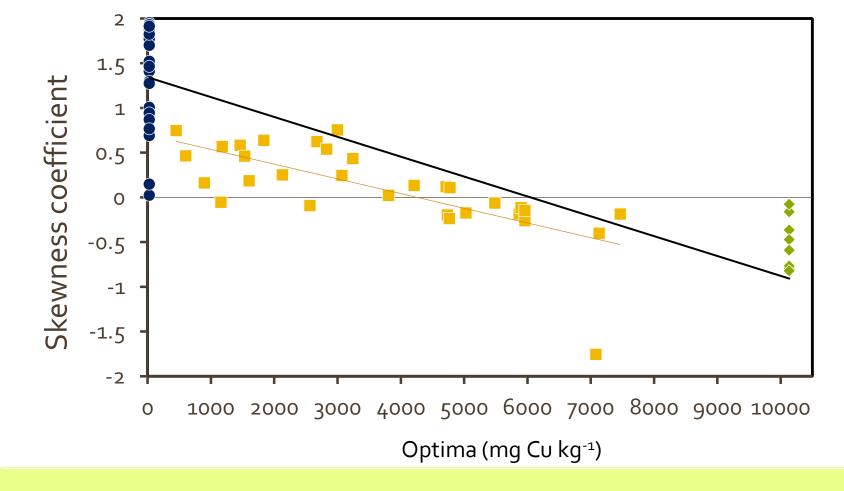


Group 2 only:

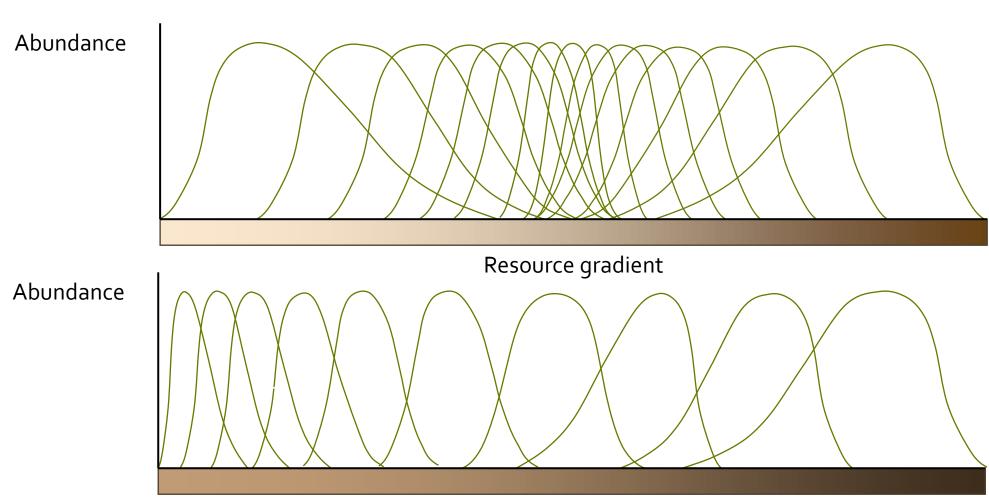
 $R^2 = 0.52$ p-value < 0.001

All taxa:

 $R^2 = 0.66$ p-value < 0.001



# **Comparison** of theoritical niche distributions



Metal toxicity gradient

# Implication for conservation







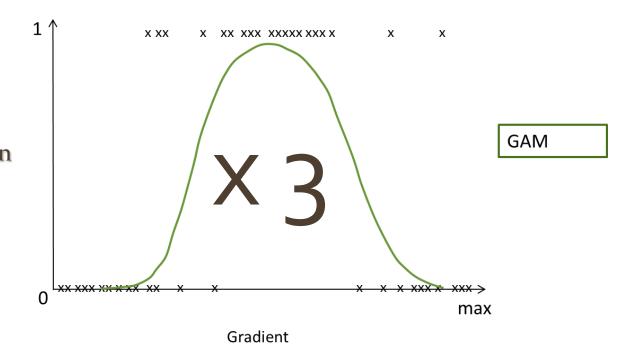
# Copperflora

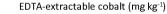
Mining

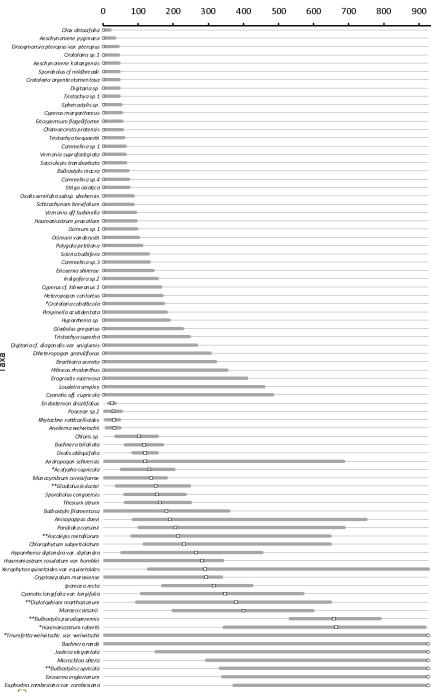


# **Modeling & analysis**

- Select taxa with occurrence ≥ 8 in dataset (=80 taxa)
- Generalized additive model (Cu and Co) (Hastie & Tibshirani, 1990)
  - Non parametric method, robust
  - Logistic approach (o/1)
- 3 degrees of smoothing by taxon
  - Selection with Akkaike Information Criterion







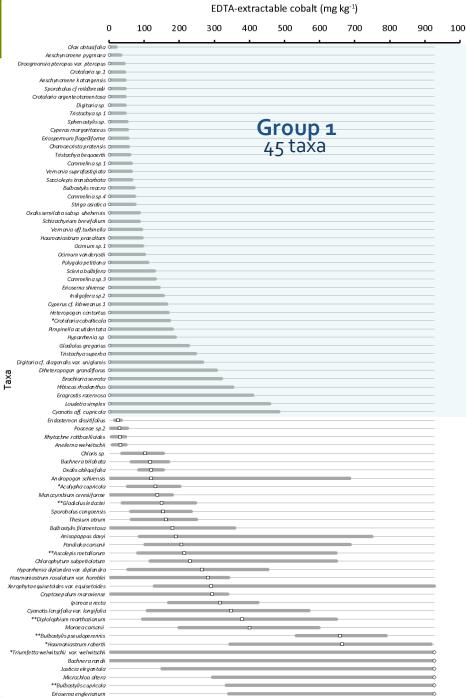
Results Discussion Conclusion

## Taxa distribution

Along cobalt gradient

• Range: 2 – 900 mg kg<sup>-1</sup>

- = niche optima
- = niche width



Results Discussion Conclusion

Optima  $\leq$  2 mg kg<sup>-1</sup>

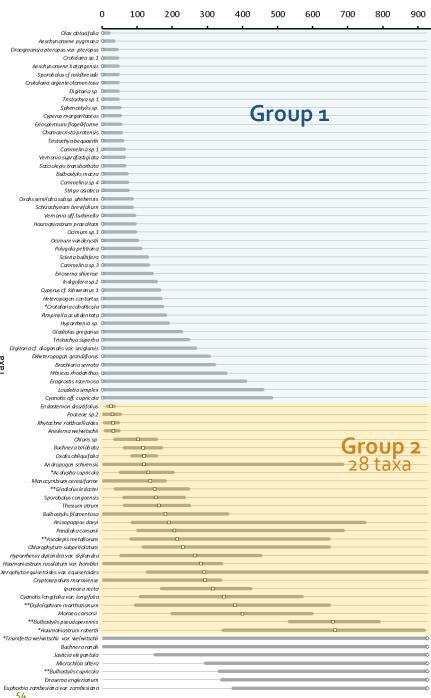
### Taxa distribution

Along cobalt gradient

- Range: 2 900 mg kg<sup>-1</sup>
- Group 1: 45 taxa

- = niche optima
- = niche width

EDTA-extractable cobalt (mg kg<sup>-1</sup>)



Results Discussion

## Taxa distribution

Along cobalt gradient

- Range: 2 900 mg kg<sup>-1</sup>
- Group 1: 45 taxa
- Group 2: 28 taxa

- = niche optima
- = niche width

EDTA-extractable cobalt (mg kg-1) 800 900 Olax abtusifalia a Aeschyn amene pygmaea 🗆 🗆 Droogmansia pteropus var. pteropus O Crotalaria sp.1 Aeschyn omene katangensis O Sporabalus of mildhre adii Crotalaria argente otamentosa 💷 Digitaria sp. O Tristachya sp. 1 Sphen ostylis sp. O Group 1 Cyperus margaritaceus 💷 Eriospermum flagelliforme Chamaecrista pratensis O Tristachva be quaertii O Commelin a sp. 1 Vem onia suprafastigiata 🔾 Sacciole pis transbarbata O Bulbostviis macra O Cammelin a sp. 4 O Striga asiatica O Oxalis semilaba subsp. uhehensis O Schizachyrium brevifalium a Vem onia off.turbinella Haumani astrum præaltum 🗆 📉 Ocimum sp. 1 Cammelin a sp. 3 💷 in digofera sp.2 💷 Cyperus cf. kibwe an us 1 Heteropogon contortus \*Crotalaria cabalticola C Tristachya sune rha C Dibeteropogan grandiflorus O Hibiscus rhodanthus O Loudetia simplex Cvanotis aff. cupricala a En dostern on dissitif di us -Pogrege sp.2 Rhytachne rottbaelliaides Aneilema welwitschii Group 2 Buchnera trilahata Oxalis obliquifalia An dropopon schiren sis \*Acalypha cupricala Mon ocumbium ceresiiforme \*\*Gladidusledcctei Sporabalus congoensis Thesium atrum Anisopappus davvi Pandiaka carsonii \*\*Ascdepis metallorum Chlorophytum subpeticlatum Hunardienia dinlandra var. dinlandra Haumaniastrum rosulatum var. homblei Xerophyta e qui setci des var. e qui setoides ipamaea recta Cyanotis I an aifalia var. Ionaifolia Morae a carsonii \*\*Bulbostylis pseudoperennis \*Haumaniastrum rabertii \*Triumfetta welwitschii var. welwitschii Buchnera ran di Justicia elegantula Microchloa altera \*\*Bulbostyliscupricala Eri osema englerianum

Euphorbia zambesian a var. zambesian a

Results Discussion

Conclusion

### Taxa distribution

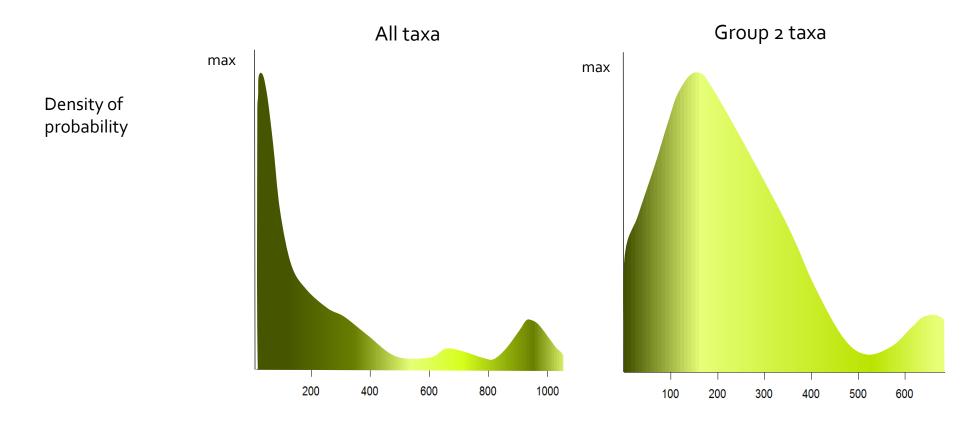
Along cobalt gradient

- Range: 2 900 mg kg<sup>-1</sup>
- Group 1: 45 taxa
- Group 2: 28 taxa
- Group 3:7 taxa

- = niche optima
- = niche width

# Density of optima

Along cobalt gradient



Optima (mg Cu kg soil-1)

56

# Niche width depends on niche optimum

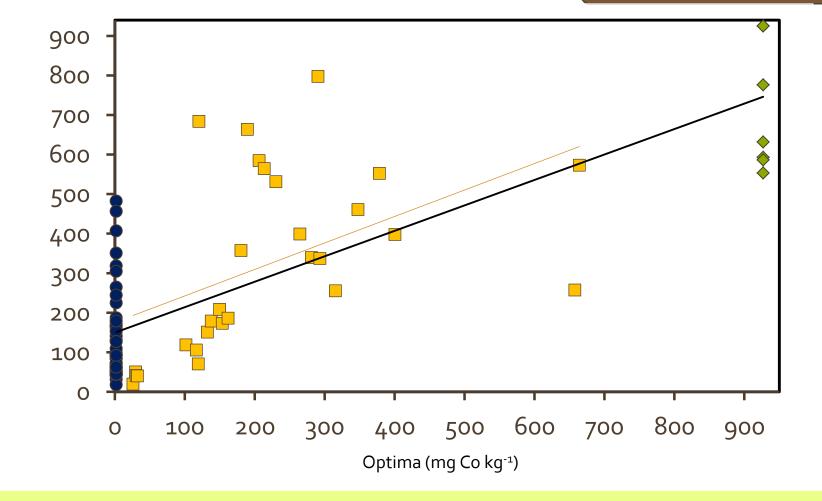
Along cobalt gradient

#### All taxa:

 $R^2 = 0.57$  p-value < 0.01

#### Group 2 only:

 $R^2 = 0.23$  p-value < 0.01



# Skewness depends on niche optimum

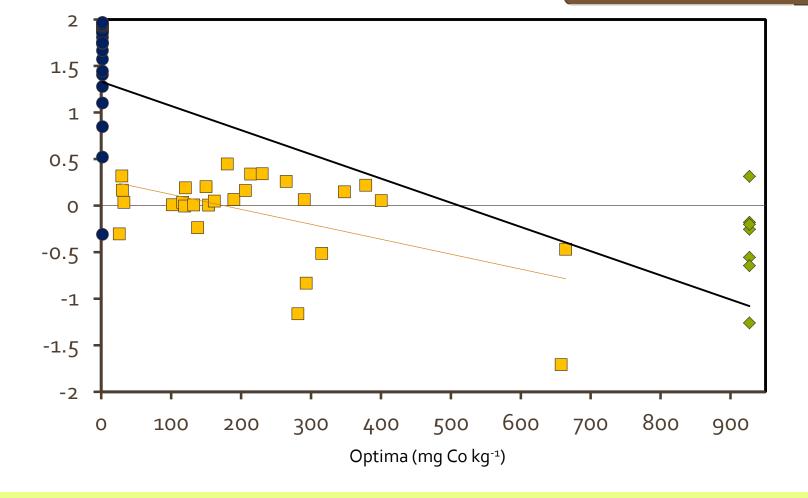
Along cobalt gradient

#### All taxa:

 $R^2 = 0.48$  p-value < 0.001

#### Group 2 only:

 $R^2 = 0.29$  p-value < 0.001



## Niches distribution

### Along copper gradient

Along cobalt gradient

- Gradient : 0 10 000 mg kg<sup>-1</sup>
- 11 % highly tolerant taxa
- For group 2, optima are uniformly distributed along gradient

- Gradient : 0 1000 mg kg<sup>-1</sup>
- 9 % highly tolerant taxa
- For group 2, optima are packed on lowest concentrations

Niche width and niche skewness depend on optimum location on the gradient

Assumptions assumed for resource gradient are verified on metal gradient

! Mesic conditions are found at low metal concentrations

! Copper is an essential element <> Cobalt is a beneficial element

### **Annexes**

**Endemics** 

Cu (mg kg-1)

Co (mg kg-1)

	Médiane	1 <sup>er</sup> Quartile	3 <sup>ème</sup> Quartile	3Q-1Q
B. lobelioides	113	86	243	157
T. coerulea	126	77	172	95
L. deltombei	294	234	560	325
T. likasiensis	211	193	364	170
B. kisimbae	223	200	223	23
H. rosulatum	209	79	464	385
E. cupricola	1286	332	1313	981
S. neptunii	5325	1808	7170	5361
C. zigzag	7571	5320	8603	3283
	Médiane	1 <sup>er</sup> Quartile	3 <sup>ème</sup> Quartile	3Q-1Q
B. lobelioides	Médiane 53	1 <sup>er</sup> Quartile	3 <sup>eme</sup> Quartile	3 <b>Q-1Q</b> 22
B. lobelioides T. coerulea				
	53	43	65	22
T. coerulea	53 15	43 10	65 48	38
T. coerulea L. deltombei	53 15 15	43 10 9	65 48 28	22 38 19
T. coerulea L. deltombei T. likasiensis	53 15 15 15	43 10 9 10	65 48 28 44	22 38 19 33
T. coerulea L. deltombei T. likasiensis B. kisimbae	53 15 15 15 15	43 10 9 10 37	65 48 28 44 51	22 38 19 33 13
T. coerulea L. deltombei T. likasiensis B. kisimbae H. rosulatum	53 15 15 15 15 51 2	43 10 9 10 37 10	65 48 28 44 51 49	22 38 19 33 13 38