Modelling realized niche of metallophyte species along copper and cobalt gradients on Katangan copper hills

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In South Central Africa were identified more than 650 plant species tolerant to heavy metals, several of which endemic to Katanga and endangered by mining activities. These metallophytes are distributed over a hundred hills containing high copper and cobalt concentrations (20 to 10000 mg/kg for Cu and 2 to 1000 mg/kg for Co). In 1963, Duvigneaud and Denaeyer-De-Smet qualitatively described the realized niche of some of these species. Here, we use a quantitative approach to characterize those species niche (defined as a n -dimensional hypervolume characterising the set of ecological conditions required for development of a species) and test the two following hypotheses.

Hypothesis

- The realized niche of metallophyte are uniformly distributed along the copper-cobalt gradient of katangan hills
- Niche amplitudes increase with niche optima for copper and cobalt factors

The Katangan Copper Belt

Materials and methods

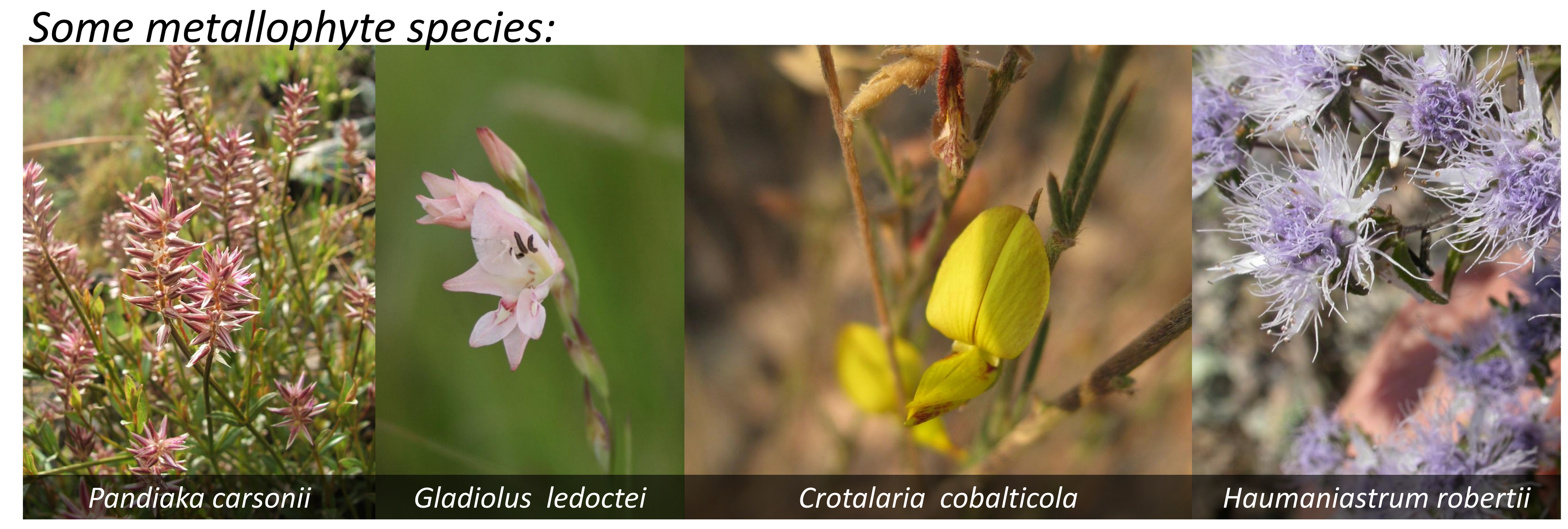
Study area– Data collection

172 vegetation relevés (1m²) were made using a systematc sampling on three hills on the Katangan Copper Belt (Congo D.R.): *Fungurume* V (10°36' S ; 26°17' E), *Kafifwafwaulu* (10°34' S ; 26°9' E.), *Kazinianga* (26° 25' E, 10° 62' S). Species presence/absence was recorded, and topsoil Cu and Co concentrations were measured.

Modelling and statistical methods

Species distribution models were made for Cu and Co concentrations, using generalized additive models (GAM) with 3 df in R interface (JUICE 7.0 - 'mgcv' library). Amplitude limits were determined by extreme values of area under curve (AUC – 80%). Analyses were performed for species present on more than 8 sites.

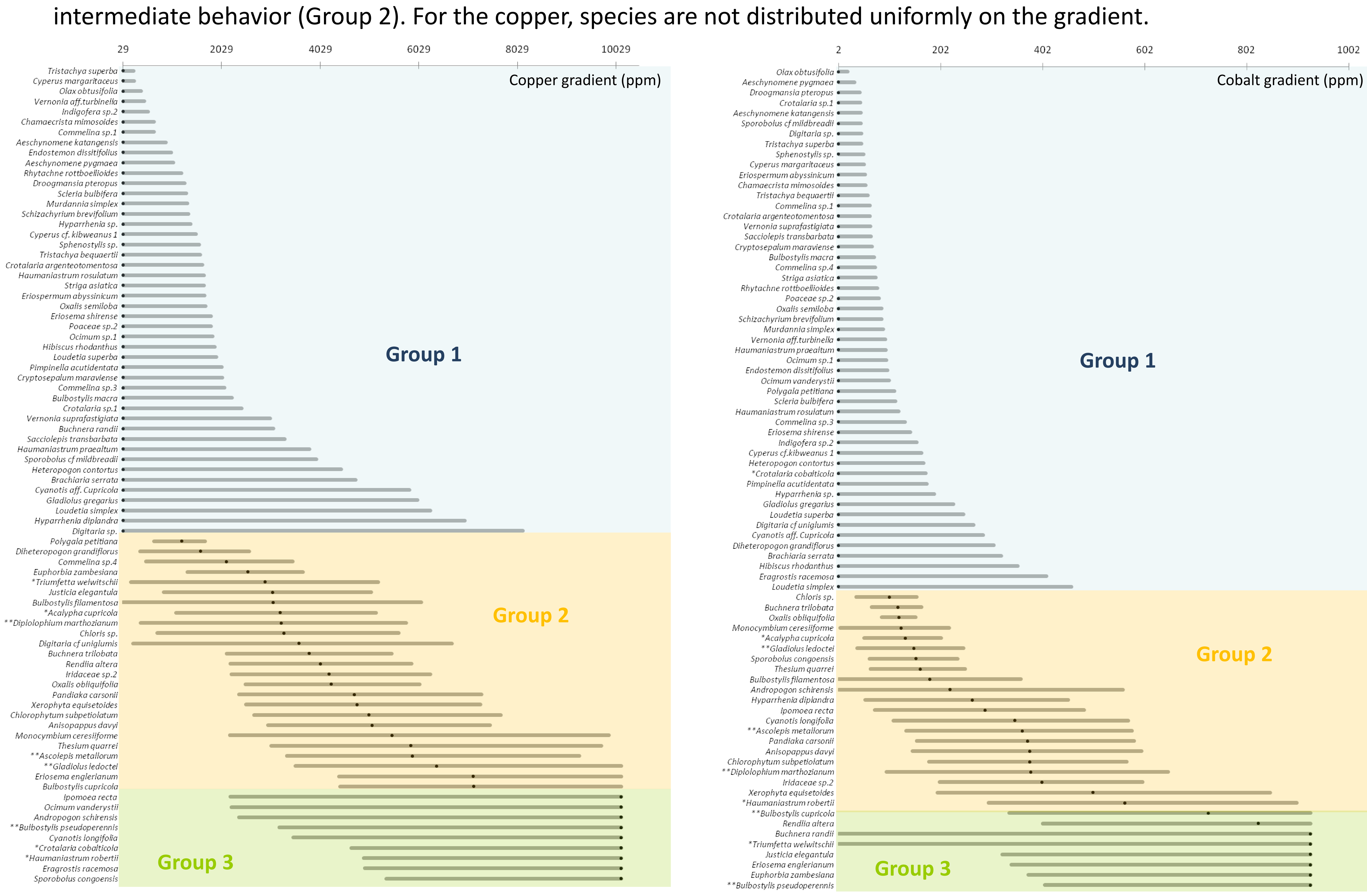
Some metallophyte species:



Pandiaka carsonii *Gladiolus ledoctei* *Crotalaria cobalticola* *Haumaniastrum robertii*

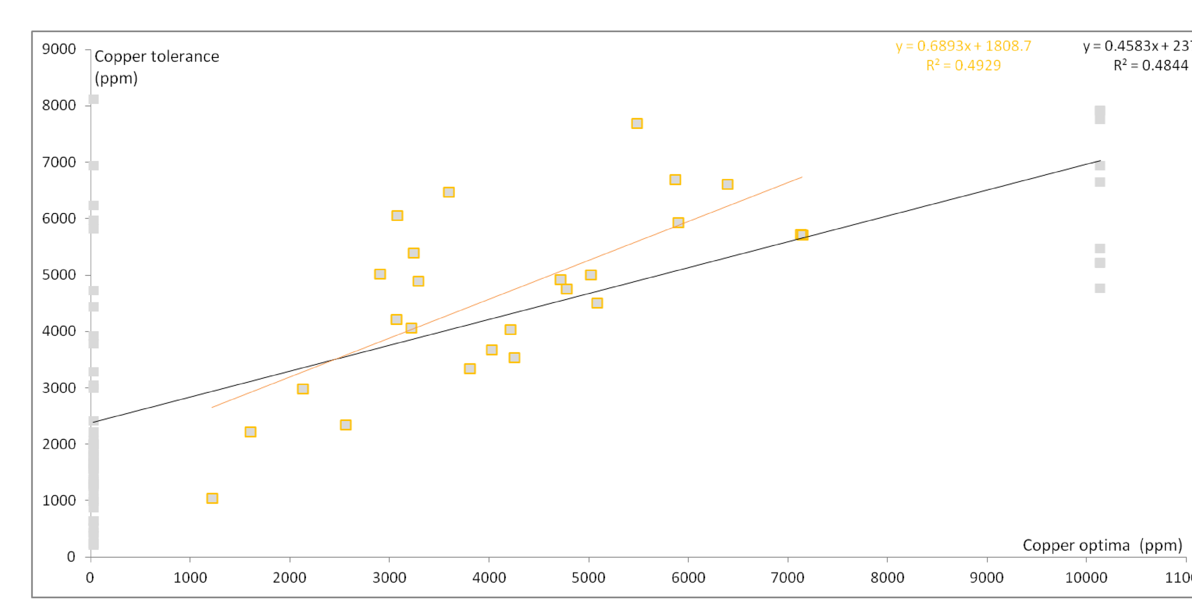
Results

1 - Optima and amplitude of realized niches is estabished for 80 species (9 endemic species) for Cu and Co gradients. In both cases, 3 groups of species can be identified : one for which the minimum is equal to the lowest values of the gradient (Group 1), one for which the maximum is equal to the highest values of the gradient (Group 3) and one group with a intermediate behavior (Group 2). For the copper, species are not distributed uniformly on the gradient.

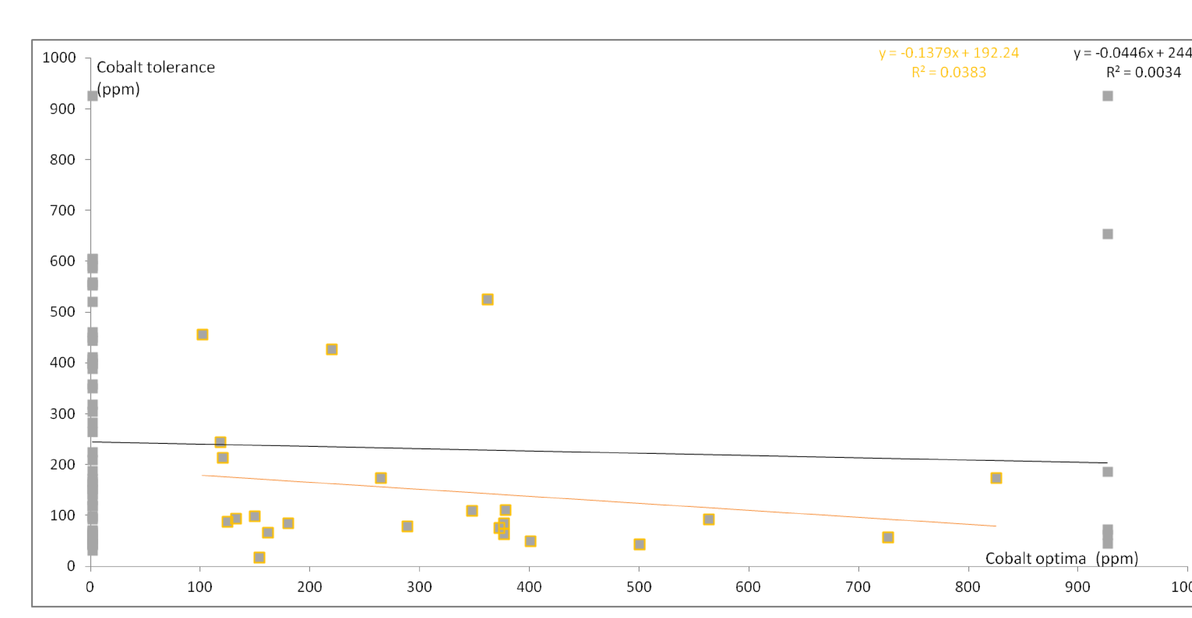


*Representation of the ecological realized niches for copper (left) and cobalt factors (right) of 80 metallophyte species. Classification has been performed according to the optimum positions along the metal gradient. * strict endemic, ** broad endemic.*

2 – The two regressions show different results : For copper, a proportional relationship can be identified between tolerance and optima along gradient. For cobalt, no relationship are highlighted.



Linear regression between tolerance (amplitude) and optima along copper gradient for all species (grey) and group 2 (orange). Regressions are significant (P<0.001).



Linear regression between tolerance (amplitude) and optima along cobalt gradient for all species (grey) and group 2 (orange). Regressions are not significant (P>0.05).

Conclusion

The optima of Katangan metallophytes are distributed over the whole Co gradient. Along the Cu gradient, there is a gap of 4000 ppm between group 2 and 3.

The same groups for Cu and Co gradient do not necessarily contain the same species.

The large amplitude of species typical of highest Cu concentrations (Group 3) indicates that their optimal position on the hill is not related to a physiological requirement. These species have most probably their optima in areas with low competition.