Cadmium uptake by vegetables in market gardens : investigating between generic and site-specific effects in a field experiment

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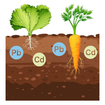
1. Background

Past industrial activities in central Belgium have been responsible for large atmospheric deposition of metallic trace elements (TE) in the environment.



The commercialization of food products such as vegetables is subject to a European directive setting maximum levels for TE.

Food safety has become a prominent public concern due to the transfer of metals, such as Cd and Pb, from soil to vegetables in market gardens.

The research aims to identify remediation strategies allowing a safe production of vegetables in areas impacted by small atmospheric contaminations.

2. Research questions

1. What are the effects of **soil conditioners** (biochar, green waste compost and lime) on soil properties and TE concentrations in plants ?
2. How does **site variability** influence soil–plant interactions ?

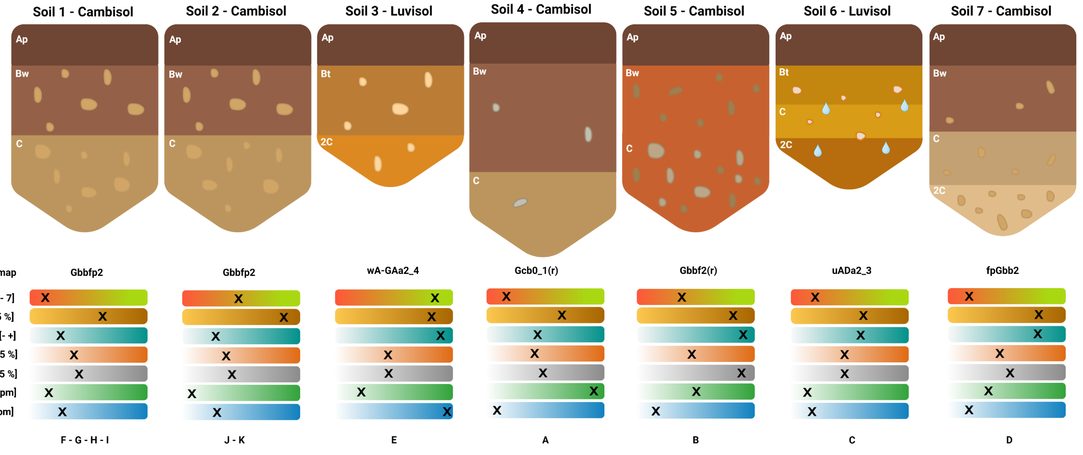
3. Experiment

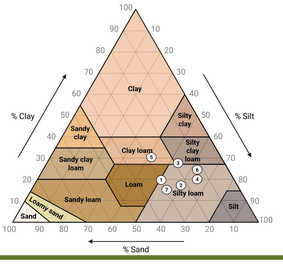
- **Study sites** : 7 market gardens (Province of Liège, Belgium)
- **Experimental design** :
  - 11 blocks – 15 to 20 microplots in each block (1 m²)
  - 3 soil conditioners :
    - Lime : 200 g/m²
    - Biochar : 5 L/m²
    - Green waste compost : 5 kg/m²
    - Control : no amendment
  - 5 replicates per treatment on each block
- **Crops grown** :
  - Lettuce (*Lactuca sativa* L.)
  - Swiss chard (*Beta vulgaris* L. subsp. Vulgaris)

4. Lab analysis

- **TE composition of plant tissues** - HNO_3 + $HClO_4$ digestion
- **Soil analysis monitoring per microplot (3 sampling times)**
  - Soil pH in $CaCl_2$ 0.01M
  - $CaCl_2$-extractable trace elements
    As – Cd – Co – Cr – Cu – Mn – Mo – Ni – Pb - Zn
- **Initial soil characterisation**
  - pH KCl 1N 2:5 w:v
  - Total organic carbon (TOC) - Springer and Klee method
  - Available elements - Lakanen – Erviö method
  - Total element content - *Aqua regia* extraction
  - Cation exchange capacity - Cobaltihexamine chloride method
  - Soil texture – Robinson pipette method

5. Soil characterisation





6. Results 2022

Soil properties

Fig. 1

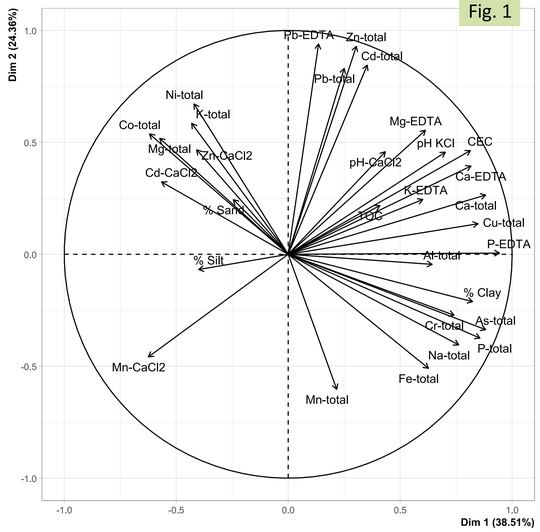
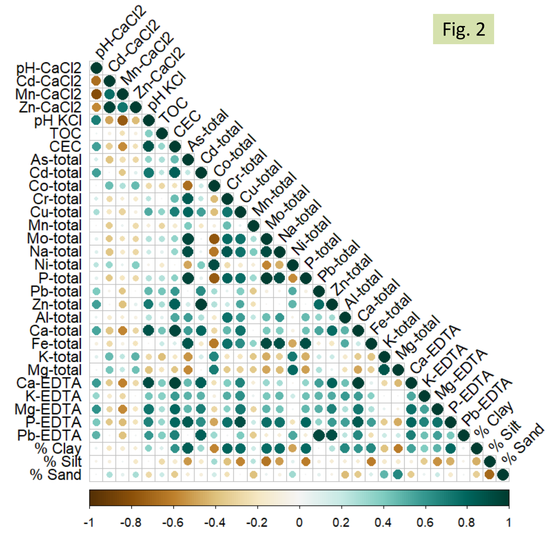


Fig. 2



- The first two axes of the Principal Component Analysis explain **60% of the total variance** in soil properties.
- The distribution of **Zn, Pb, and Cd** reflects the **geochemical signature of regional contamination** in **the Province of Liège** (Belgium).
- **Mobile forms of Zn and Cd** are oriented to the **left side** of the plot and do **not align with total concentrations** — likely due to **pH influence**.

Soil - plant interactions

Fig. 3

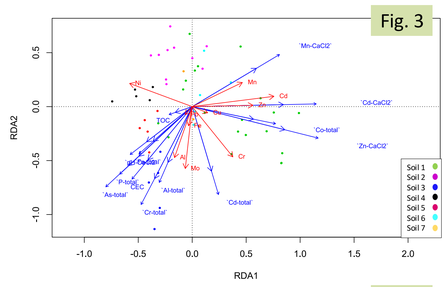
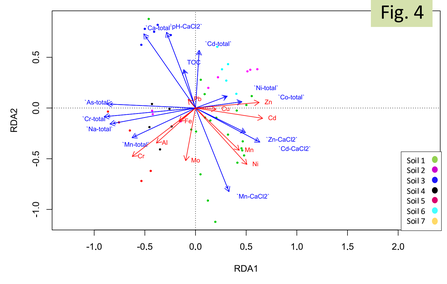


Fig. 4



Redundancy analysis (RDA) were performed on 55 soil–plant pairs to explore the relationships.

Fig. 5

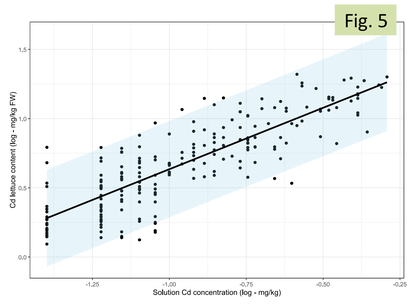
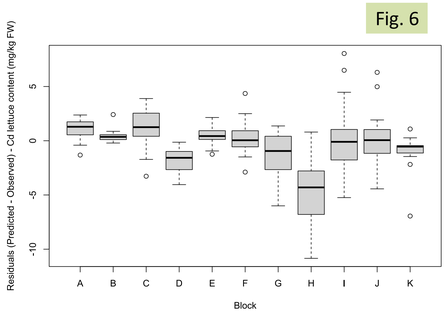


Fig. 6



- The **RDA plots** illustrate the **relationships** between a selection of key **soil properties** and **TE concentrations** in lettuce (Fig. 3) and Swiss chard (Fig. 4).
- **Blue arrows** indicate the **direction** and **strength** of **soil property influence** on plant element composition (**red arrows**).
- The included **soil properties** explain **54%** and **67%** of the **variation** in lettuce and Swiss chard TE content, respectively.
- The **general linear regression model** explains **68% of the variability of Cd content** (Fig. 5).
- Despite variability between blocks, **differences in model slopes are not statistically significant**.
- The model **underestimates Cd concentrations in lettuce** from blocks **G and H**. This **unexplained** pattern suggests that a **more specific model may be required** (Fig. 6).

7. Perspectives

The experiment was repeated over three consecutive years (2022 – 2023 – 2024) on the same microplots.
Future work will aim to :

- Explore multivariate regression and integrate geochemical modelling approaches to improve the estimation of cadmium bioavailability in soils.
- Analyse the results of this three-year field experiment to assess temporal dynamics in TE mobility and plant uptake, as well as the cumulative effects of soil conditioners.