Long-term impact of farmyard manure on copper and zinc concentrations in Swiss grassland soils

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Introduction

Farmyard manure (FYM) plays an important role in nutrient cycling and to maintain organic matter contents in the soil. However, FYM contains potential soil contaminants such as copper (Cu) and zinc (Zn) [1,2]. Both trace elements are indispensable micronutrients for plant and animal life, but may also accumulate in the soil [3].

Because accumulation occurs over decades, measured data is needed at that time-scale to detect trends and underlying drivers.

Objectives

This study shows the evolution of Cu and Zn in the topsoil of eleven grassland sites over three decades and addresses the following questions: Can inputs of FYM explain observed trends? How to avoid accumulation?

Conclusions

Intensively managed grassland sites show a slow increase of Zn and on some sites Cu in the topsoil. Substance flow analysis indicated that this was caused by frequently applied FYM. Adapted application rates of FYM and feed additives are needed to avoid further Cu and Zn accumulation in intensively managed grassland soils.

Material and method

This study capitalizes on three decades of soil and agricultural management data collected on eleven independently managed grassland sites of the Swiss Soil Monitoring Network (NABO, Fig. 1).

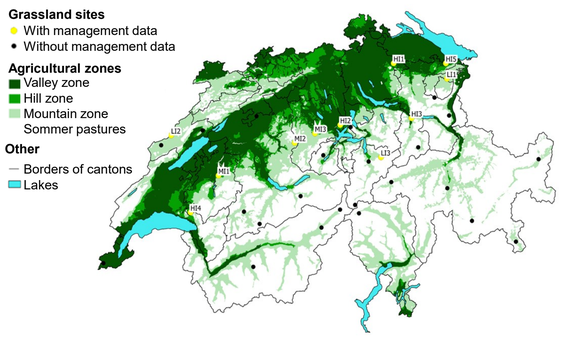

Fig. 1 Grassland sites of the Swiss Soil Monitoring Network (NABO)

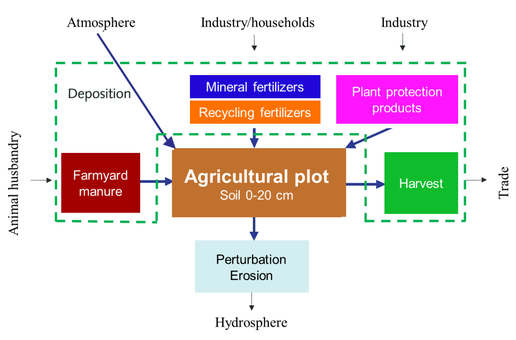

Fig. 2 Elements of the substance flow analysis

We compare measured Cu and Zn concentrations in the topsoil (0-20 cm) against modelled concentrations from substance flow analyses from 1985-2014:

- **Concentrations in the topsoil** sampled every five years at always the same 10 x 10 m sites (Cu and Zn total concentrations, extraction with nitric acid) [4];
- **Agricultural management data** collected annually from farmers for the agricultural plots on which the 10 x 10 m sites are located [5];
- **Substance flow analysis** (surface balances, Fig. 2) with FYM quality sampled on farms [5];
- **Stochastic uncertainty analysis** [5];
- **Grassland management intensity** characterized based on agricultural management and site characteristics (e.g. climatic conditions) [5].

References ***[1]*** *Alloway BJ (2012) Heavy metals in soils: trace metals and metalloids in soils and their bioavailability. Springer Science & Business Media;* ***[2]*** *Spiess E (2011) Nitrogen, phosphorus and potassium balances and cycles of Swiss agriculture from 1975 to 2008. Nutr Cycl Agroecosystems 91:351–365;* ***[3]*** *Keller A, Schulin R (2003) Modelling regional-scale mass balances of phosphorus, cadmium and zinc fluxes on arable and dairy farms. Eur J Agron 20:181–198;* ***[4]*** *Meuli et al. (2014) Nationale Bodenbeobachtung (NABO) 1985−2004, Umwelt-Wissen 1409, Bern;* ***[5]*** *Gross T et al. (2021) Stoffbilanzen für Parzellen der Nationalen Bodenbeobachtung Nährstoffe und Schwermetalle 1985−2017, Agroscope Science 123*

Evolution of Cu and Zn in grasslands is driven by inputs of farmyard manure

Cu and Zn concentrations in the topsoil of Swiss grassland sites slowly increased on sites with a high management intensity (HI) and stayed relatively constant on sites with low and moderate management intensity (Fig. 3).

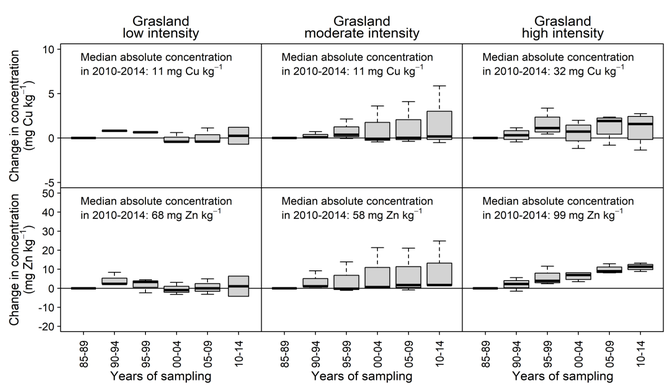

Fig. 3 Change of Cu and Zn concentrations in the topsoil compared to the first sampling period (1985-1989) in grassland sites with low (n = 3), moderate (n = 3) and high intensity (n = 5) of management

Substance flow analysis showed that on HI sites nutrient inputs exceeded nutrient export via harvest (Fig. 4, phosphorus shown). Nutrient inputs were dominated by FYM. Modelled Cu and Zn concentrations in the topsoil were in most sites and years within ±1 standard deviation of the modelled values (Fig. 4, middle and right panels).

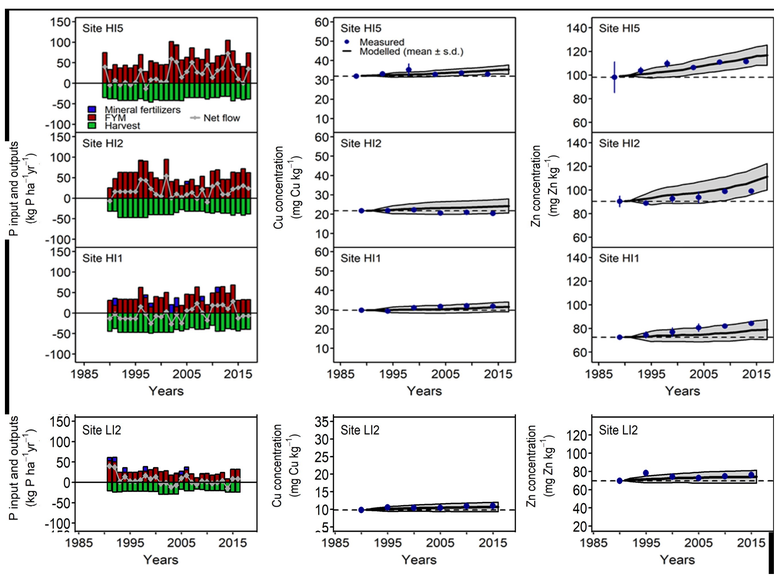

Fig. 4 Phosphorous (P) in- and outputs (left panel) and measured vs. modelled Cu and Zn concentrations in the topsoil of three HI sites and one low intensity site (bottom row)

Plot-level nutrient balancing

Our results suggest that a fertilization that meets but does not exceed nutrient uptake by grass is promising to avoid future accumulation of Cu and Zn in the soil. To obtain reliable substance flow analyses, regular measurements of the FYM quality are indispensable.

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