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NUTRIENT BUDGETS AND THEIR IMPLICATION ON SOIL FERTILITY IN ORGANIC FARMING ACROSS EUROPE

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Abstract: Knowledge of nutrient budgets of organic farms and their effect on soil nutrient contents across Europe is relatively limited. Therefore, a meta-analysis was conducted to investigate the nutrient supply of organic farms as affected by budgeting method, farm type and studied country. Further, an assessment was performed relating nutrient budgets with soil nutrient contents across five countries. We found an average surplus of N, an almost balanced budget for P and a deficit for K. Yet, nutrient budgets varied over a wide range. Farm type, more than the studied country or budgeting method, was able to explain some of the variations, with vegetable farms having higher surpluses, especially for N, than dairy farms, followed by mixed or stockless farms. Soil nutrient contents showed also considerable differences among farms and countries. A relationship between soil nutrient content and budget was found only for P, which indicates negative P budgets as a real risk for soil P depletion.

Introduction: Low availability of nutrients is a critical limitation for crop yields on organic farms in Europe. However, only limited work has been undertaken investigating nutrient budgets of organic farms and their influencing factors. Many nutrient budget studies do not take into account the soil nutrient status, although it can be used to evaluate the implications of nutrient budgets on the sustainability of soil management (Watson et al. 2002). This study aimed to investigate: i) the nutrient budgets of organic farms across Europe with respect to differences between budgeting method (soil surface field of farm gate budgets), farming type (vegetable, cattle/dairy or stockless farms) and country ii) the status of selected soil fertility parameters on organic farms throughout Europe and iii) the relation between nutrient budgets and soil nutrient contents.

Material and methods: Meta-analysis

A survey of CAB-listed literature, published between 1990 and 2019, was conducted to identify papers concerning nutrient budget studies of organic farms in Europe. The following search terms were used in various combinations: farm gate /

farm / nutrient, budget / balance / flows, organic / bio-dynamic / ecological, and Europe. Additional papers were found by searching the reference lists of already selected papers and by recommendations of experts. The search resulted in 1827 studies being identified. Following this, data was scrutinized according to criteria of thematic fit and availability of means and standard deviations, which resulted in the identification of 50 different studies from 16 different countries concerning nutrient budgets of N, P, or K in organic farming. A meta-analysis using the *metaphor* package in *R* as described by Viechtbauer (2010) was performed on the whole data set and subsets of data based on farm type (arable, dairy / cattle, mixed or vegetable farms), method used for nutrient budget analysis (soil surface, field, or farm-gate budgets) or the different countries.

Soil analysis

Organic farms in five European countries (Germany (DEU): 22, Estonia (EST): 9, Southern Italy (ITA): 17, Switzerland (CHE): 10, and Denmark (DNK): 7 farms) were investigated. On each farm, three fields were sampled and soils were analysed for total contents of N, C, organic C, P, Cu, Ni, and Zn, extractable amounts of Mg, P (extr. P) and K, as well as pH.

Descriptive statistics were used to summarize the data. Linear regression models were used to determine the relationship between soil nutrient contents and years of organic management and farm gate nutrient budgets (country was set as a random effect) for N, P, K of farms with sufficient data (DEU: 22, EST: 9, ITA: 5, CHE: 10, and DNK: 7 farms), derived from Oelofse et al. (unpublished). Before statistical analysis, all data was checked for variance homogeneity and normal distribution. All statistical analysis and plotting were done in *R*.

Results: Proclaimer

Only preliminary results are presented in this section. Regarding the meta-analysis, new studies might be published and will be considered until August 2020. For the soil study, some sampling soil type analysis are not yet finished.

Meta-analysis

The meta-analysis showed an average surplus for N of 46 kg ha^{-1} [95%>confidence interval (CI) 29, 62] over 38 studies (674 farms), a balanced P budget of 0 kg ha^{-1} [CI -2, 3] over 31 studies (533 farms), and a K deficit of -12 kg ha^{-1} [CI -21, -3] over 27 studies (497 farms). However, the range was quite large and studies reporting deficits and surpluses for all nutrients were found. Distinguishing data by farm type resulted in a smaller CI, with similar patterns for N and P: greatest surpluses were found for vegetable farms (131 kg N ha^{-1}, 18 kg P ha^{-1}), followed by dairy or beef farms (78 kg N ha^{-1}, 1 kg P ha^{-1}), and lowest surpluses (N) or deficits (P) were found for arable or mixed farms (21 kg N ha^{-1}, -4 kg P ha^{-1}, or 19 kg N ha^{-1}, -2 kg P ha^{-1}). In contrast to N and P, vegetable farms had the largest K deficit but also the largest CI (-57 kg K ha^{-1} [CI -224, 110]). Arable farms also showed a substantial K deficit (-32 kg K ha^{-1}), while mixed or dairy / beef farms had small deficits (dairy / beef: -2 kg K ha^{-1}, mixed: -8 kg K ha^{-1}). The method used to calculate the nutrient budgets (farm gate, field or soil surface budget) did not result in distinct budgets. Nevertheless, farm gate budgets (60 kg N ha^{-1}, 2 kg P ha^{-1}, -5 kg K ha^{-1}) tended to show higher surpluses than field (5 kg N ha^{-1}, -5 kg P ha^{-1}, -26 kg K ha^{-1}) or soil surface budgets (14 kg N ha^{-1}, 3 kg P ha^{-1}, -14 kg K ha^{-1}), especially for N. Differences between countries were also detected (Figure 1: Meta-analysis of annual nutrient budgets for N, P, and K (in kg ha^{-1}) of organic farms divided by countries. Dots represent means and lines the 95%>confidence interval.), although the variation between studies from the same country was generally high, especially for N budgets in CHE (CI -287, 169 kg ha^{-1}).

Soil samples

Generally, soils seem to be well supplied with the major plant nutrients, but the variation between fields, farms, and countries was very high, showing both under- and oversupplied soils (Figure 2: Soil properties divided by countries. Dots

represent means and error bars indicate the 25 to 75% quarter. Letters show significant differences between countries (alpha level 0.05). (Av.=Average over all soils, extr. P=extractable P)). Significant differences between countries were detected for all soil parameters (lettering Figure 2). A positive relationship between soil nutrient content and farm gate nutrient budget over all countries was only found between extr. P and P budget (p-value = 0.01, R^2=0.04). No such relation was found for total nitrogen to N budget, total soil P to P budget or K to K budget.

Discussion: Our study revealed a surplus of N, an almost balanced budget for P and a deficit of K across the organic farming sector. Therefore, it seems likely that K supply is the major challenge in organic farming, followed by P supply. However, the wide range of reported results show the diversity of approaches and challenges to nutrient management in organic farming across Europe. The type of farm, more than country or balancing method, seems to explain the majority of the variation between farms. Yet, most of the studies do not use soil nutrient contents to interpret the results. Our study has shown that only soil extr. P is affected by nutrient budgets, possibly due to high soil content or a high mineral weathering for K and remineralisation potential N. In combination with a large proportion of soils being undersupplied with P (23% after VDLUFA (2018) classification), this makes negative P budgets a threat to crop production due to soil P depletion.

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Figure 1:

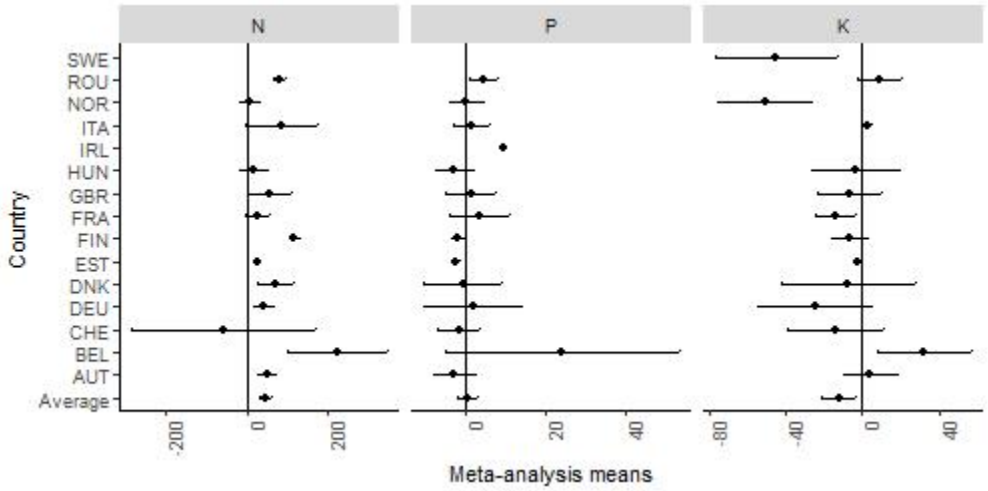
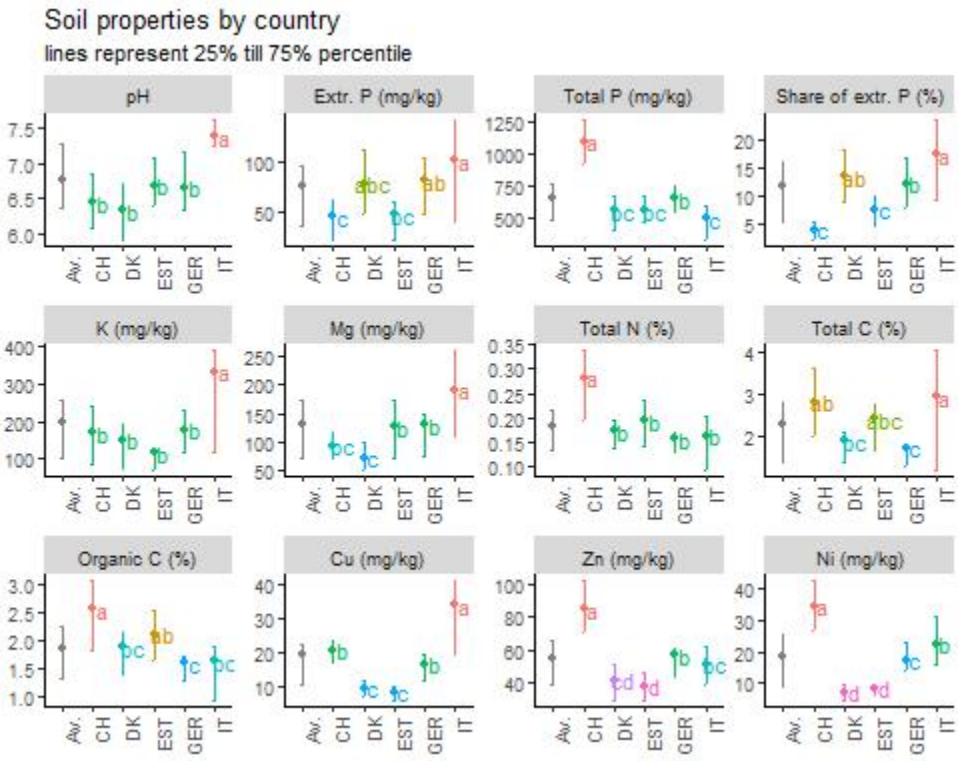


Figure 2:



Disclosure of Interest: None Declared

Keywords: Europe, meta-analysis, nutrient management, soil depletion, soil nutrients, Sustainability