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HISTORICAL ANALYSIS OF PHOSPHORUS FLOWS IN AUSTRIA

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The construction of multi-year MFAs

Based on the analysis of the Austrian phosphorus budget by Egle et al. (2014) this analysis was repeated for the years 1990 to 2013 forming a time series for this system (Zoboli et al. 2015). The analysis was carried out applying material flow analysis according to Brunner and Rechberger (2004) and using the MFA software STAN, a product by Technische Universität Wien (free download under www.stan2web.net). The application of STAN allows for the consideration of data reconciliation and error propagation (Fellner et al. 2011). For this purpose data uncertainty was determined by the approach of Laner et al. (2015). The goal of this analysis was to find out how the system changed over time (small or large changes; steadily or abruptly) and how such a multi-year time series enhances the system understanding compared to classical MFA, where usually a single year budget is analysed and interpreted.

Methodological approach to analyse the time series

The Austrian phosphorus budget consists of 56 processes, 8 stocks, and 122 flows. As almost all flows are determined by data sources the system is overdetermined and data reconciliation is performed. The extent of the reconciliation step indicates if the database is plausible. In a next step all flows were analysed with respect to changes over the years. This was done in two ways: First, each single flow of the budgets for 1991 to 2013 was compared to the initial year 1990. Second, flows of neighbouring years were compared. The first comparisons gives some indication about the overall evolution of the system while the second one provides information if changes appeared more steadily or even abruptly. For the flow comparisons different tolerance levels were applied ($\pm 0\%$, $\pm 5\%$, $\pm 10\%$, $\pm 15\%$, $\pm 20\%$, $\pm \sigma$, $\pm 2\sigma$). A flow is considered constant if the ranges of two years, given by their mean values and tolerance levels, do not overlap. An extreme change is given when the flow more than doubled or halved, all other changes in between are considered as moderate, see Figure 1.

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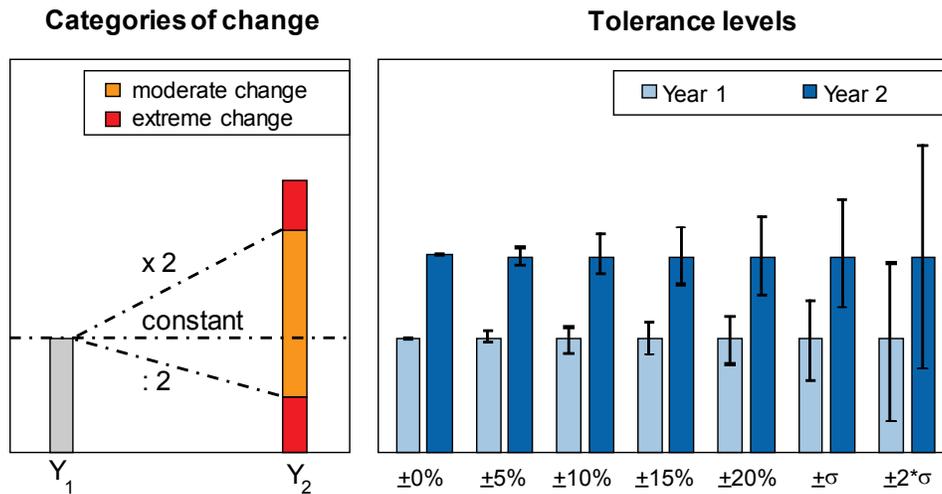


Figure 1 Classification of flow changes (Zoboli et al. 2015)

Results

Figure 2 left side shows that more than 50% of all flows (122) and net stock changes (8) experienced extreme changes since 1990. This is in so far considerable as results of MFAs are often taken as actual and as a basis for decision-making for times spans up to 10-15 years. At least for the example of phosphorus and Austria this would not be justifiable. The right side shows that even some 30% of all flows change extremely within one year, therefore steadiness of the system is rather low, which has to be kept in mind if extrapolations into the future are performed. Analysing the total system by focusing on the development of single flows is a straight forward approach to detect areas of required political action. For example, Figure 3 displays the trends for phosphorus flows into the waste management subsystem (left) and the recovered phosphorus amounts (right).

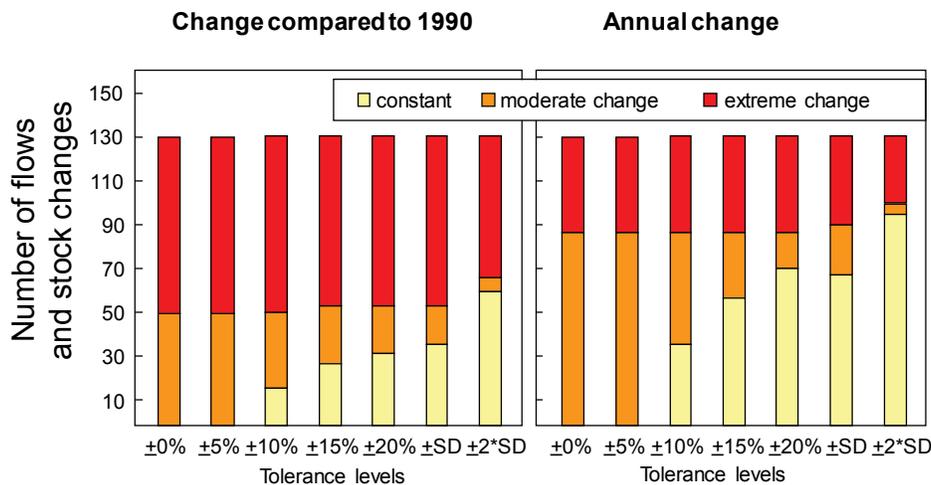


Figure 2 Result of the classification process for flow changes (Zoboli et al. 2015)

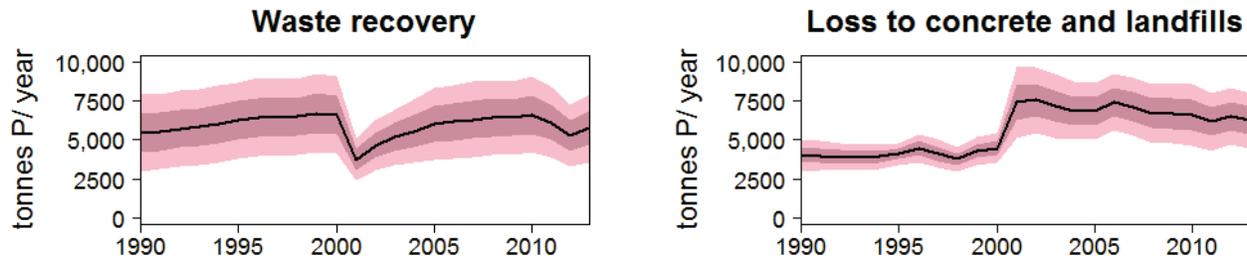


Figure 3 Time series 1990 to 2013 for the input of phosphorus to the waste management system (left) and the recovered phosphorus amounts (right).

It becomes clear that the “responsibility” of waste management has increased since 1990 but the recovered amount stayed rather constant resulting in an overall decline of the recycling rate: a clear indication for the need to take counter measures. Figure 4 shows the development of the three relevant net stock additions in the system. It can be seen that the extent of over-fertilization with phosphorus could be significantly reduced over the years. The high prices for phosphate rock in 2008/09 even made a balanced phosphorus soil budget possible. The largest loss in today’s (2013) system occurs to landfills (disposal of sewage sludge ashes) and concrete (combustion of sewage sludge and meat and bone meal in cement kilns). Again a clear indication for required policy action. Another loss happens in the process private households, which comprises also private and public gardens. There, a rather constant amount of 2,200 t/yr are “potted”. The number is a result of the input/output balance of this process.

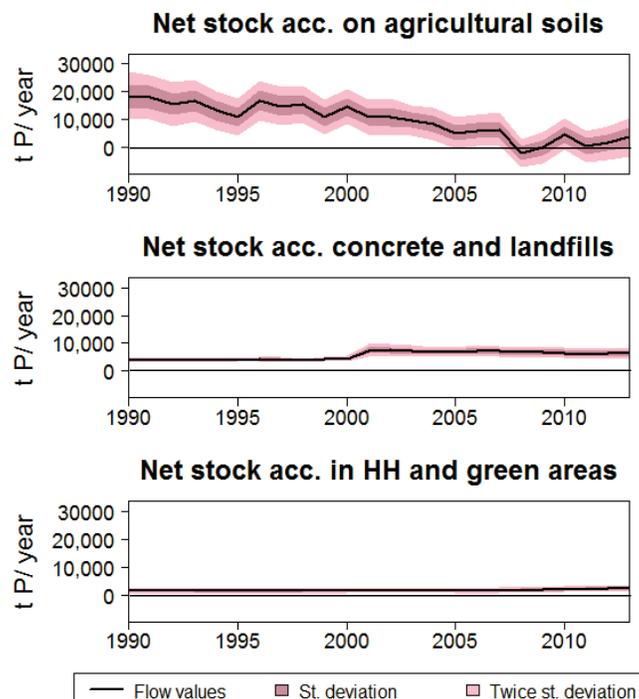


Figure 4 Time series 1990 to 2013 of the three major stock changes in the Austrian phosphorus budget.

To date it is not quite clear where this loss stems from. However, the miss-balance appears fairly constant through all the years making data imperfections rather implausible. This is a typical case where the time series approach points to further and deeper investigation.

Conclusions and outlook

MFA time series increase the system understanding considerably as system dynamics become visible. The results are beneficial with regard to

- Detection of points where the system could be optimized (support in decision-making)
- Monitoring of flows and control of success of policy actions
- Control of data and detection of data imperfections (conflicting data)
- Optimization of data generation with regard to quantity and quality

In our next steps, we want to identify measures of optimization and construct a hypothetical optimized system. Then we want to apply statistical entropy analysis to the time series and test it for its usefulness as a quality indicator. If this is successful, the identified measures will then be monetarised and ranked with respect to efficiency.

Phosphorus here also serves as a role model as we think that national MFA time series should be produced on a routinely basis by national authorities, e.g. the EPAs. The required tools are available now to establish sound time series, which are a necessary requirement for efficient resource management and the establishment of a high-level operating circular economy.

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