**Integrating untapped resources from cooking and sanitation into farm-scale nutrient management: a system analysis combining material flow analysis and soil nutrient balancing for farming households in Karagwe, Tanzania**

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**Abstract**

Food is a human right and food production requires access to land and sustainable soil management. To sufficiently replenish nutrients and counteract soil degradation, many smallholders in Sub-Saharan Africa lack available resources. However, residues from bioenergy and ecological sanitation (EcoSan) are locally available for integrated nutrient management (INM).

Employing a material flow analysis (MFA), we compared local cooking and sanitation technologies and evaluated (i) the effects on natural resources (atmosphere, aquifers, and forests) and (ii) the availability of by-products, which can be used for INM. Through soil nutrient balancing (SNB), we assessed (i) the current soil nutrient status and (ii) changes that occur when applying biogas slurry, standard compost or CaSa-compost (containing biochar and sanitized excreta) as organic inputs and urine as mineral input. The system analysis refers to a six-member household in Karagwe, Tanzania, and is adapted to local conditions, focusing on an intercropping system of relevant temporary crops (i.e. maize, beans, cabbage, and onion).

Within the energy-system, using improved cooking stoves (ICS) or biogas reduced the pressure on forest resources; using charcoal did not. Greenhouse gas (GHG) emissions were reduced with ICS, but not with the biogas system, due to biogas leakages and emissions from slurry storage.

Within the sanitation-system, latrine or septic facilities emitted 80-90 % of total N and 70-75 % of P to the ecosystem, which EcoSan-systems avoided. EcoSan also reduced GHG-emissions. Changing from pit latrines to a water-based system would highly press scarcely available water resources in farming households.

Results of the SNB show that currently, N and P are depleted by -47±9 and -7±3 kg ha-1yr-1, respectively. The analysed INM-strategies mitigated depletion of N and reversed that of P.

We concluded that consequent recycling of residues from household and farming to agricultural land is a promising path (i) to avoid emissions to the environment and (ii) to leave the vicious circle of insufficient production of food crops and residual matter caused by prevailing P-scarcity.

Further research could regard the different utilization paths of urine and biogas slurry, e.g. direct application versus pre-composting with/without biochar and socio-economic aspects for smallholders.

**Keywords**: integrated nutrient management, soil nutrient depletion, micro energy systems, biochar, biogas slurry, ecological sanitation, micro perspective, carbon recovery, nutrient recycling, natural resource management, closing open cycles, vegan organic farming