Linking Urban Agriculture and Environmental Sanitation

Dionys Forster* dionys.forster@eawag.ch
Roland Schertenleib roland.schertenleib@eawag.ch
Hasan Belevi hasan.belevi@eawag.ch
EAWAG/SANDEC
Ueberlandstrasse 133
8600 Duebendorf, Switzerland

Keywords

environmental sanitation, Ghana, Kumasi, material flux analysis, urban agriculture, West Africa

Abstract

In developing countries, demographic and urban growth often results in severe environmental and social problems, including the lack of adequate water supply, environmental sanitation services and food security. Reusing waste products in peri-urban and urban agriculture can contribute to food security and reduce environmental pollution and waste management costs. A comprehensive method is required to assess the potential and limitations of channelling urban waste products to peri-urban and urban agriculture. Material Flux Analysis is a helpful tool to assess material fluxes in a given system. It allows to identify problems and to quantify the impact of potential measures on resource recovery and environmental pollution. The present study analyses the material/nutrient fluxes of the city of Kumasi, Ghana. Import and export of products into or from the given system are recorded. Processes are identified and material fluxes between these processes are determined. The analysis revealed that households are the key process for material and nutrient fluxes. The groundwater and surface waters receive large amounts of waste products from the households. Reusing organic waste products in peri-urban and urban agriculture could significantly improve the organic matter and nutrient situation of agricultural soils and also protect the environment. However, a treatment process (e.g. co-composting) is required to reduce the health hazards related to the use of waste products.

Introduction

Demographic and urban growth is one of the major challenges of the next decade. In 1994, 45% of the world's population lived in cities; by 2025 this figure will have risen to 65% (Nugent, 1997). The most rapid change is occurring in the developing world, where urban populations are growing at 3.5% annually. Historically, cities have been the driving force in the field of economic and social development. However, urbanisation not only provides benefits, but also creates environmental and social problems. These include a lack of adequate water supply, environmental sanitation services and food security.

This challenge should be faced by a holistic approach to environmental sanitation and urban agriculture. Human and municipal solid waste is a cheap fertiliser as it contains significant amounts of nutrients for food and non-food crop production. Reuse of municipal wastewater and solid waste in urban agriculture is usually the most effective way to reduce waste treatment and disposal, provided public health is not impaired. However, it is often difficult to quantify and assess the potential and limitations of nutrient recycling in environmental sanitation systems.

A helpful tool for linking environmental sanitation with urban agricultural production is the "Material Flux Analysis" (MFA). The method studies the fluxes of resources used and transformed as they flow through a region, through a single process or via a combination of various processes. It allows planners and decision-makers to identify key processes, and to suggest appropriate environmental protection and resource recovery measures in a given system. In industrialised countries, material flux analysis proved to be a suitable instrument for early detection and solution of environmental problems. Data from market research can be combined with those from urban waste management to analyse the metabolism of urban regions (Baccini and Brunner, 1991).

In this study, fluxes of organic material are used to describe the present system in Kumasi, Ghana with 982,000 inhabitants spread over 254 km^2, of which 38% is open land (Kumasi Metropolitan Assembly, 1996). The peri-urban districts cover an area with a radius of about 40 km from the city centre beyond the administrative boundaries of the city and with about 740,000 inhabitants (Blake and Kasanga, 1997). Breweries, sawmills and poultry farms are important industries regarding organic material fluxes. Existing sanitation systems such as unsewered public toilets, pit latrines or septic tank systems are recorded. Production and supply of organic material (e.g. agriculture, industries), including production, collection and treatment of urban waste, like human excreta and municipal solid waste, are quantified.

Method

According to Baccini and Brunner (1991), development of a regional material flux analysis starts with an analysis of the overall system: Goods, processes, system borders and time period have to be defined. The term "materials or material mixtures" is used for chemical elements and their compounds such as nitrogen, nitrate, phosphorus, and phosphate. Materials and material mixtures with functions valued by man are defined as "goods". Transport, transformation or storage of materials and goods are called "processes". While in most cases transport does not change the chemical composition of goods, it requires energy and involves other goods and materials. The same applies to storage. Through transformation, goods are converted into new products with new qualities and usually different chemical composition. In system analysis, goods and processes are linked. Each good has one origin and one destination process. Consequently, each process is linked to other processes by means of goods. A particular good, which flows from process A to process B is called an output good for process A, and an input good for process B. An import good is defined as a good entering the system, and an export good a good leaving the system. The same terminology applies to material fluxes. A flux analysis of selected materials comprises:

- Identification of goods and processes.
- Determination of the mass fluxes of all the goods per unit of time.
- Determination of the concentrations of the selected materials (elements) in these goods.
- Calculation of the material fluxes from the mass fluxes of goods and element concentrations in these goods (these fluxes can either be assessed by literature data, determined by field measurements, calculated by mass balances over a process or process chains or through a combination of all these methods).
- Interpretation and presentation of the results.

The system of organic material fluxes in the city of Kumasi, Ghana, is characterised by 7 processes within the system border, by the fluxes between these processes and by the import and export fluxes to and from the system. The administrative boundary of the city of Kumasi is chosen as the system border. Since peri-urban and urban agriculture have different characteristics, they are regarded as separate processes in the system. The environmental compartments “atmosphere”, “groundwater and surface waters”, and “soil” are sinks for the residual fluxes. They are placed outside the system border and have not been investigated here. The processes themselves are viewed as black boxes. In the case of Kumasi, material fluxes were assessed through a combination of field measurements, calculations of mass balances and literature data.

Results and Discussion

According to Leitzinger (2000), an average person in the city of Kumasi consumes about 770 kg of food per year. This value is estimated with an error margin of about 20% and does not include food consumed from own production. While peri-urban agriculture covers about 66% of the household food requirements in Kumasi, urban agriculture contributes to only 14%. About 20% of the household food demand is met by import into the system. The local industry has a high turnover of organic material; i.e., sawmills, breweries and poultry farms. The raw material is imported into the system and an important part of the products is re-exported. Industry is responsible for a major nitrogen flux import of 3.2 kg · capita^{-1} · year^{-1} (Figure 1). About 54% of the nitrogen is exported and only 9% is transported to the households from industry. The remaining nitrogen is either landfilled or transferred to the air, water or soil. The industrial contribution to the phosphorus flux is low.

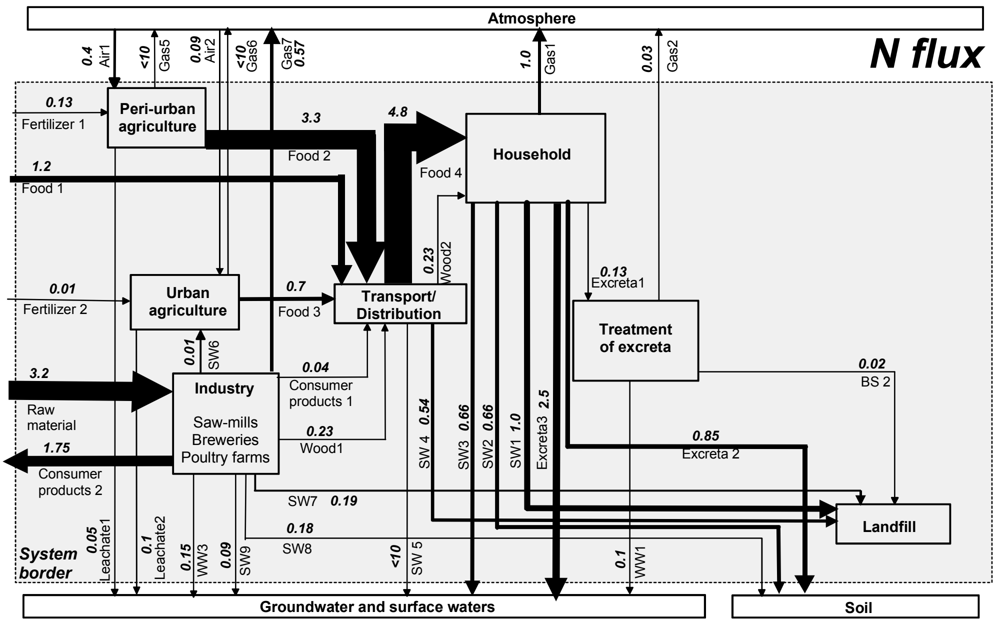

Figure 1: Estimated annual nitrogen fluxes (error margin 20-50%) of Kumasi, Ghana in kg · capita $^{-1}$ · year $^{-1}$.

Households are the most significant transformation process with regard to nitrogen and phosphorus. In the analysed system, about 80% of total nitrogen and about 90% of total phosphorus, which is transferred to air, water, soil, and landfill, flow through the households. Households are responsible for 87% of the nitrogen and 82% of the phosphorus emissions to groundwater and surface waters, as well as for 90% of the nitrogen and 97% of the phosphorus emissions to the soil. About 58% of the nitrogen and 34% of the phosphorus fluxes to the landfill also originate from the households (Leitzinger, 2000). Consequently, households can be regarded as the key process. Measures should be implemented at household level, as they would contribute to saving resources and to protect the environment.

Groundwater and surface waters receive 47% of the total nitrogen and 54% of the total phosphorus from the households (Leitzinger, 2000). About 22% of the nitrogen and 29% of the phosphorus from the households reach the soil. About 15% of the nitrogen and 16% of the phosphorus from the households are landfilled. The faecal sludge treatment plant receives less than 2% of the nitrogen and phosphorus. The nitrogen transferred to the atmosphere is estimated at 15%.

The total system fluxes can be calculated by multiplying the fluxes per capita and year with the number of inhabitants of Kumasi. Hence, the nutrient deficiencies in agriculture are obtained by calculating the differences between output and input fluxes. According to Leitzinger (2000), the annual nitrogen and phosphorus deficiencies in urban agriculture are estimated at 690 t and 160 t, respectively. In peri-urban agriculture, the soil lacks 2700 t of nitrogen and 720 t of phosphorus every year.

About 1700 t of nitrogen and 500 t of phosphorus originating from different types of waste are disposed of annually in landfills. Additionally, about 3600 t of nitrogen and 690 t of phosphorus are discharged into surface waters, and about 1700 t of nitrogen and 310 t of phosphorus reach the soil (Leitzinger, 2000). From a nutrient balance perspective, part of these nitrogen and phosphorus fluxes could be recycled for instance by co-composting faecal sludge and municipal solid waste, and by using the finished compost as fertiliser and soil conditioner. This could also reduce soil, groundwater and surface waters pollution and save landfill space. However, technical and socio-economic aspects must be taken into consideration in order to determine the feasibility of this recycling option.

Conclusions

Material flux analysis allows to quantify material (nutrient) fluxes moving through a defined system. It is a suitable tool to assess the emissions to air, water and soil and, thus, appropriate for early detection of possible hazards. Since it can be used to determine the impact of different waste management options on nutrient recycling and environmental pollution, it can assist in the choice of effective measures and strategies towards an integrated management of resources. Mass fluxes from and towards peri-urban and urban agriculture can thus be optimised.

In the city of Kumasi, private households are the key process for nutrient fluxes. Groundwater and surface water receive large amounts of waste products mainly in the form of faecal sludge from households. Channelling these material/nutrient fluxes towards peri-urban and urban agriculture could significantly improve the organic matter and nutrient situation of agricultural soils and also protect the environment. However, a treatment process (e.g. co-composting) is necessary to reduce the health hazards related to the use of waste products.

References

Baccini, P. and Brunner, P. (1991) Metabolism of the Anthroposphere, Springer-Verlag, Berlin.

Blake, B. and Kasanga, K. (1997) Kumasi Natural Resource Management Research Project, Inception Report, Natural Resources Institute (NRI), The University of Greenwich, UK and University of Science and Technology, Kumasi, Ghana.

Kumasi Metropolitan Assembly (1996) Development Plan for Kumasi 1996 – 2000, Part II, District Profile.

Leitzinger, Ch. (2000) Ist eine Co-compostierung aus stofflicher Sicht in Kumasi/Ghana sinnvoll?, Diploma Thesis, ETH Zurich.

Nugent, R.A. (1997) The Significance of Urban Agriculture, City Farmer, City Farmer home page, Sept. 19, 2000 [on-line]. Available on internet: http://www.cityfarmer.org/racheldraft.html.