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The integration of Terra Preta Sanitation in European nutrient cycles Options for alternative policies and economies

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Abstract

It is hypothesized that with small nutrient cycles in urban farming, including Terra Preta Sanitation, the major part of the biogenic nutrient potential in faeces, urine, grey water and bio-waste could be recycled. And it is further hypothesized that this would be more efficient than to use this potential for the partial replacement of mineral fertilisers in agriculture.

The legal and economic framework for nutrient cycles on the European level is exemplarily illustrated. It is shown that European legislation can provide essential incentives for nutrient recycling on a large scale, but that it failed to establish sustainable structures so far. This conclusion is based on the massive dependence on mineral fertiliser in agriculture. Mineral nitrogen fertiliser is applied 3.5 times more in agriculture than what is contained in the hardly used biogenic potential. The factor for phosphorus is 1.8 and for potassium it is 1.6.

Several legal and economic options for small-scale nutrient cycles are illustrated as well. Many of these options, like Terra Preta Sanitation require more scientific research. But, they definitely represent possible parts of flexible nutrient cycles, which are scalable with only little effort. Therefore, they would fit very well into any changing urban environment, may it be as provisional solution or as part of a complete reorganisation. Although such systems would not completely sustain densely populated cities, they could provide certain foods very efficiently and with less environmental impact, compared to agriculture.

European nutrient stocks and flows

Nearly all agricultural products depend entirely on the growth of plants. Besides solar energy, water and carbon dioxide, certain elements are required for this growth. The six major elements are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S). In addition, there are several more elements which are needed in smaller concentrations.

According to Liebig's Law of the Minimum the scarcest resource controls the growth of the plant. The major elements N, P and K where identified as frequent limiting factors. Industrial production respectively large scale mining of compounds containing these elements could alleviate these limits on a large scale.

Figure 1 illustrates the worldwide consumption of nitrogen (N), phosphate (P_2O_5) and potash (in K_2O equivalent) in the last 40 years. The steady increase, only shortly interrupted by the collapse of the Soviet Union, is of interest when examining the development from a European Union (EU) perspective, which is shown in Figure 2.

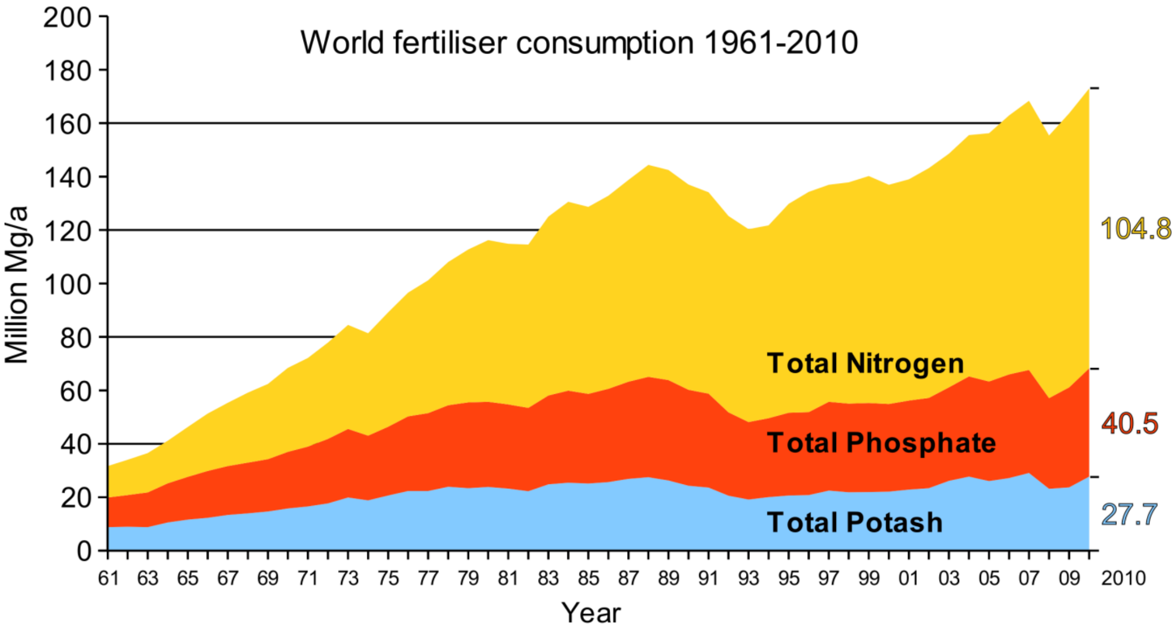

Figure 1: Worldwide mineral fertiliser consumption 1961-2010 (based on IFA (2013))

The fertiliser consumption on the territory of the 27 Member States (EU-27) features a slight decline in the years after 1992. However, fertiliser prices increased quite strong during the same period. One main reason for this is probably the still increasing fertiliser consumption in other world regions, especially in Asia.

The data on fertiliser consumption are not entirely complete for all years depicted. For some smaller countries there is no complete record of every fertiliser type used. However, the data are thorough enough to clearly illustrate trends and to provide rough numbers for comparative calculations.

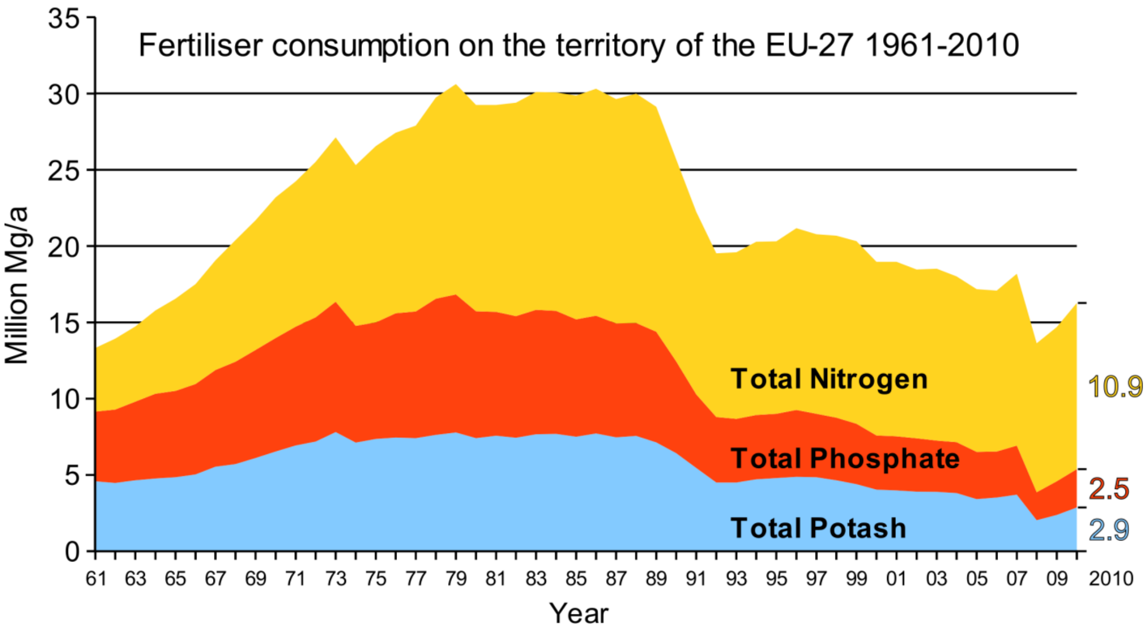

Figure 2: Mineral fertiliser consumption on the territory of the EU-27 1961-2010 (based on IFA (2013))

Regarding the security of supply for all three elements, phosphorus poses the highest threat for the EU. Although the statistical lifetime of the world phosphate reserves might be around 300 years according to the USGS (2013), there are no reserves on EU territory, except for small deposits in Finland and Sweden (Elsner 2008).

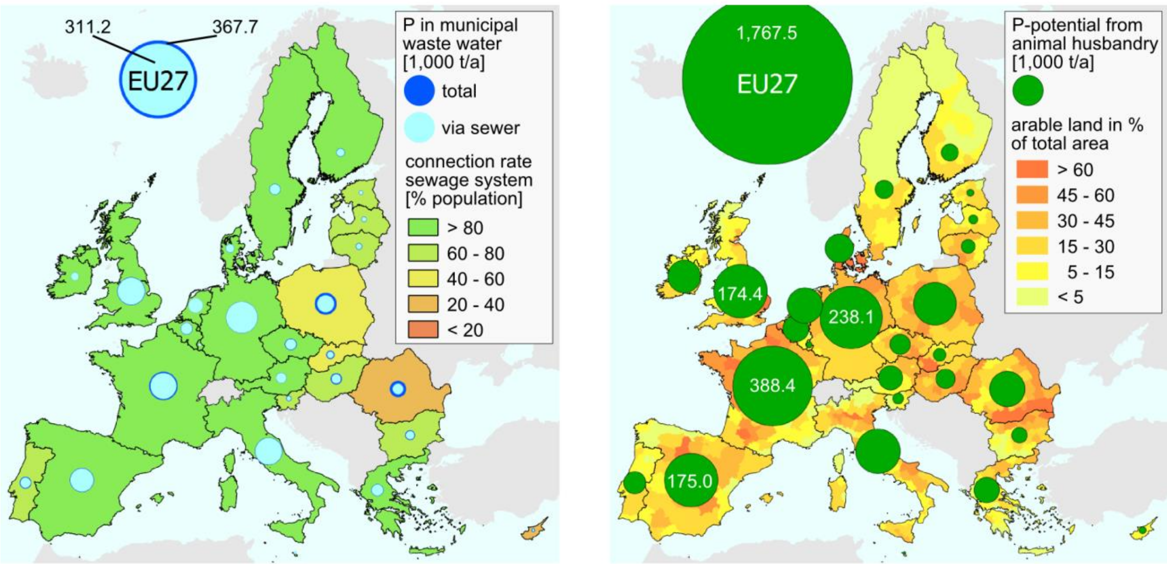

Figure 3: Phosphorus potential from municipal waste water (left) and from animal husbandry (right) in the EU-27 in 2008 (in 1,000 Mg/a) (based on Eurostat (2012))

Figure 3 compares the phosphorus potential from municipal waste water (2 g/inh/d from faeces, urine and grey water) with the potential from animal manure and slurry. The latter represents a higher potential but through the application as organic fertiliser, the corresponding phosphorus flows are used in agriculture to a large degree already (see Figure 4). This is not the case for municipal waste water, although sewage collection and treatment systems are wide-spread on EU territory. This is also visible in Figure 4, where all phosphorus flows in the EU are shown. The phosphorus in waste water is mainly lost in the flow from human consumption to solid and liquid organic wastes. The small flow from human consumption down to crop production represents the utilisation of sewage sludge and bio-waste compost in agriculture. This makes around 45% of the municipal sewage sludge and only around one third of the municipal bio-waste potential.

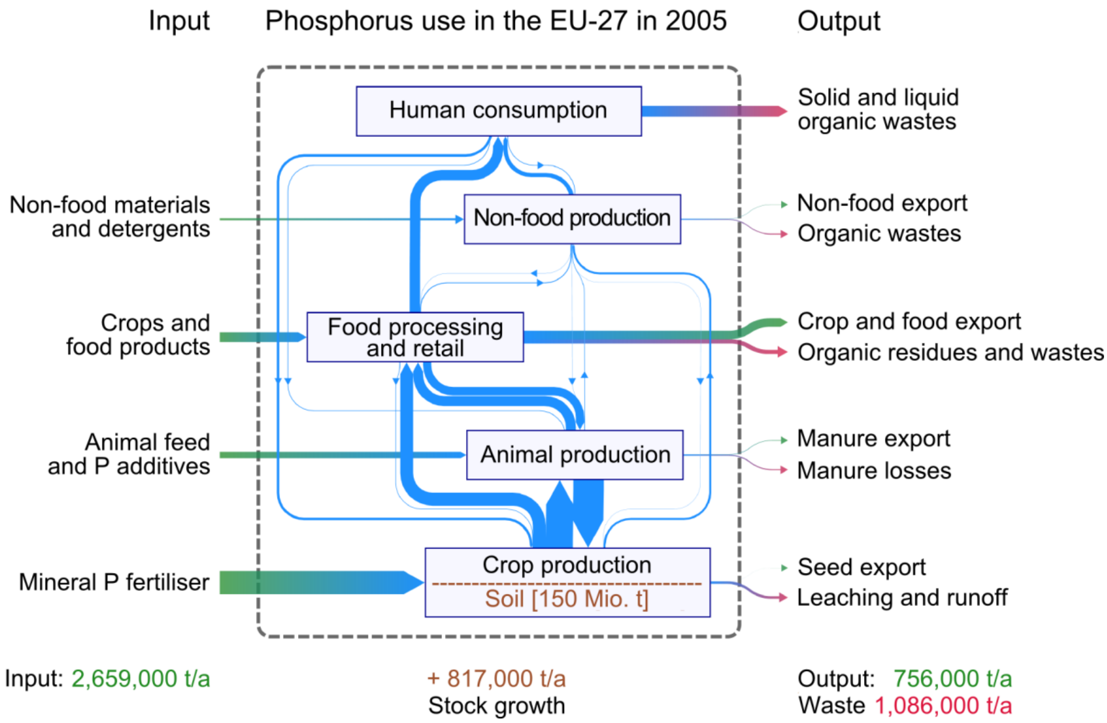

Figure 4: Phosphorus use in the EU-27 in 2005 (in Mg/a) (based on Van Dijk (2013))

Figure 4 illustrates three major aspects of the overall unsustainability of European nutrient flows. First, agriculture is highly dependent on mineral fertilisers, which are based on not renewable and therefore unsustainable resources, like phosphate rock. Second, the stock growth of phosphorus in European soils represents substantial inefficiencies in mineral fertiliser application. And third, through the low recycling rate of organic residues, a large part of valuable nutrients is wasted.

Legislative and economic framework for European nutrient cycles

There are several legal regulations which influence nutrient cycles within the EU. One of the most influential European regulations is probably the Water Framework

Directive (EU 2000) which integrated among others the former Directive on Urban Wastewater Treatment and the former Nitrates Directive into a more coherent and unified approach (DG Environment 2008). The implementation of the Directive on Urban Wastewater Treatment is responsible for the wide-spread existence of wastewater treatment plants throughout the Union. One major result was the alleviation of eutrophication problems through a reduced discharge of nutrients into European waters. But beside the partial application of sewage sludge in agriculture, there were no measures to recycle nutrients; they were just disposed of. The Nitrates Directive required farmers to control the amount of nitrogen fertiliser applied to their land, and therefore should have also reduced the overfertilisation of the environment.

The Waste Framework Directive (EU 2008) and the Landfill Directive (EU 1999) are two of the most important regulations for the nutrient potential in bio-waste. The latter obliges the Member States to reduce the amount of biodegradable municipal waste going to landfill to reduce corresponding methane emissions from them. The reduction goal was set on 35% of 1995 levels by 2016 (for some countries by 2020). Even if that would not be reached in full, the amount of wasted nutrients should have been reduced considerably. The Waste Framework Directive has established a European wide waste hierarchy for waste management options which clearly favours the recycling of nutrients over their disposal. So, one of the favoured treatment options should be the composting of bio-waste.

One Current initiative to improve the recycling of organic nutrients is the revision of the European Fertiliser Regulation (EU 2003) so that it includes also organic fertiliser, e.g. manure and compost. Another is the development of end-of-waste criteria for compost. Both initiatives focus on the free trade of organic fertilisers within the internal EU market. But it remains to be seen if that approach will be successful in the mobilisation of locally dispersed organic nutrients.

The example of Germany provides a case for successful composting through well intended regulations, accompanied by undesirable side effects. Since the Waste Act of 1986 (Federal Republic of Germany 1986), which implemented the hierarchy of waste prevention, recycling, and disposal, composting became a favoured method for the treatment of bio-waste. The Federal German Compost Quality Assurance Organisation (BGK), founded in 1989 provided an important base for a reliable compost market. And the continuously increasing compost production for over 20 years is certainly a success story. However, composting was always regarded as a waste treatment technology and so composting plants are mainly financed by municipal waste fees and only to a minor part by compost sales. This might have discouraged plant operators to increase their product value, may it be through marketing or by further improved composts. However that be, the average price for compost in Germany, which is now at 4 €/Mg (Meyer-Kohlstock et al. 2012) does not even reflect its nutrient content, which is worth around 10 €/Mg, when compared with mineral fertiliser prices (VHE e.V. 2013). At least for such an economic framework there are not many improvements to be expected by any trade related reforms.

Also for the nutrient recovery from waste water, economic barriers may limit the success of current approaches. Gethke-Albinus (2012) compared in her dissertation 13 different recovery processes for phosphorus from municipal and industrial waste water, from slurry and from urine. According to her future scenario of a countrywide phosphorus recovery system, Germany could save 50% of its phosphorus fertiliser imports. Unfortunately, only few processes are already tested at industrial scale. This makes the consideration of the economic viability less certain. But based on currently existing calculations Gethke-Albinus based her scenario on a preference for bigger treatment plants. Because of the high investment costs a direct phosphorus recovery from waste water would not be viable for plants with less than 100,000 population equivalents. For a recovery from sludge water, the treatment plants should not be smaller than 20,000 population equivalents. This would leave many smaller treatment plants and communities with restricted budgets uncovered. Local alternatives to such end-of-pipe solutions may be viable options.

Legal and economic options for individual and local nutrient cycles

The legal framework for potential nutrient cycles on a local level will differ between Member States. The following cases are mainly related to Germany but some refer also to international circumstances. They all can be relevant for the European perspective.

As further up illustrated, the main nutrient potentials from cities are to find in urine, faeces and grey water. The question comes to mind is it allowed to withhold these substances from the sewage system and to treat them differently? While German building codes require flush toilets in homes, offices, and public buildings, it is not mandatory to use them. Therefore, parallel solutions can be implemented.

The composting of human faeces and urine by individuals can be done in a sanitary and comfortable manner. Guidance and experience in this field provide e.g. Jenkins (2006) and Berger and Lorenz-Ladener (2008). Regarding an upscaling, the treatment in composting plants is not strictly forbidden in Germany, it is just not regulated. The current Bio-waste Ordinance (Federal Republic of Germany 2012), which regulates a major part of composting, simply has these matters not included in its definition. Therefore, it could be difficult to convince a plant operator and the public authorities to accept such input. On the other side, the existing technology could provide a safe hygienisation and therefore, such resistance might be overcome.

But since the Bio-waste Ordinance does not apply for household, kitchen, and allotment gardens (§1(3) BioAbfV), there is no legal obstacle to home compost such input. This exclusion of private gardens from the ordinance means also that they are not subject to the agricultural restrictions for compost application, which would restrict them to only 3 kg compost per m² (dry weight) within three years.

Terra Preta Sanitation (TPS) makes it possible to separate the generation point of faeces and urine from the treatment point, e.g. composting, in a spatial as well as in a temporal aspect. The lactic acid fermentation together with the carbonised bio-waste, i.e. biochar, preserves the faeces in a nearly odourless state for weeks up to months. This makes a transport to central treatment points less problematic and allows long collection intervals. Similar benefits could be expected from the lactic acid fermentation of urine. All this could open up new opportunities for service providers, which collect and utilise these substances from individuals who are not able to or do not wish to handle them their self.

In this regard, there are also alternative collection approaches. One example are the “East Side Compost Pedallers” in Austin, Texas (ESCP 2013). For a monthly membership of $16 the personal bio-waste is picked up weekly by cargo bike. The economic viability for the citizen depends on the partial avoidance of the collection fees for mixed waste. The organisation that provides this service on the other hand can generate income from the pick-up fee and from the sale of biomass or compost. But it seems highly likely that such approaches will require a long-lasting community support.

Such support can also come in form of a complementary currency. Ten years ago the first community currencies were issued in Germany. Today, nearly 40 organisations issue these regional and local currencies for their respective regions (Regiogeld e.V. 2013). With this additional medium of exchange the regional economy is supported through customer loyalty, regionally oriented business cycles and interest-free credit. While the current activities are insignificant compared to traditional capital flows, they could strongly support and profit from local nutrient cycles. For once, both subjects are about closed cycles on a local and regional scale. And, while local nutrient cycles may become emerging markets which could support regional currencies, they will remain – by definition – local and will require the main benefits of such currencies, community support and small-scale business connections.

Beside the few mentioned options for local nutrient cycles, their most fundamental requirement should not be forgotten; the places where all the nutrients are transformed to new food. Zoning codes are a basic requirement for long-lasting nets of urban nutrient cycles. Goldstein et al. (2011) provided a policy overview of urban farming legislation in 16 major cities in the US. Beside their different definitions of urban farming, they also address a variety of different issues in their regulations. Among them are lot sizes, the ownership of the land, liability, impact to property values, and runoff and pesticides. Most zoning codes also regulate animal husbandry, like the number of chickens which can be kept per person or property area. The fact that many cities revised their regulations to foster even more urban farming only a few months after the making of the policy overview stands for a continuous development in this area.

But also smaller communities in the US aim at the expansion of urban farming activities with the help of new zoning regulations. Like the City of Wheat Ridge (2011), a former farming community that supported Denver and nearby mining communities before it became a suburb of Colorado’s state capitol. In 2011 the city adopted revisions on zoning codes for urban gardens, farmers' markets and produce stands, which for example allow now urban gardens in all city zones. In addition, hoop houses – greenhouses with a semi-circle shape and plastic covering – are now exempted from building permits when they are smaller than 37 m² (400 sq ft) and are under less strict permit requirements when they are less than 93 m² (1000 sq ft) in size.

Although there are many aspects of local nutrient cycles, which still need a closer examination from science, economy and legislation, the United States illustrate how the creation of legal rights opens up more space for experiments. And this will provide in time also new insights in such matters as the potential nutrient recycling within cities, which would not have been possible without this legal leap of faith.

Potential local nutrient flows

Based on calculations regarding average nutrient potentials in cities, a possible nutrient cycle, including Terra Preta Sanitation, is shown in Figure 5. The data for this figure are provided in detail in Table 1. The estimations for bio-waste are based on the EU population of around 500 Million in 2008 (Eurostat 2012), on the municipal bio-waste potential of around 88 Tg FM (fresh matter) in 2008 (Arcadis Belgium nv and Eunomia 2010) and on its average N/P/K contents (5/1/3 kg/Mg FM), which were extrapolated from the medians of 2,795 German compost samples from 2012 (BGK 2012). The values for faeces, urine and grey water are based on a compilation of several studies (WBBau and DWA 2009). The consumption of mineral fertiliser is based on data for 2008 (IFA 2013) with applied conversion factors for phosphate to phosphorus (0.437) and for K_2O-equivalent to potassium (0.830).

Table 1: EU-27 potential of NPK per inhabitant and year compared to use of mineral fertiliser

kg/inh/a	bio-waste	faeces	urine	grey water	biogenic sum	fertiliser
N	0.878	0.548	3.796	0.365	5.586	19.528
P	0.176	0.183	0.365	0.183	0.906	1.601
K	0.527	0.256	0.913	0.365	2.060	3.371

Figure 5 highlights a possible cycle for the main nutritional elements NPK within urban farming, respectively urban horticulture. Although, the depicted methods are quite individual solutions, they could also be scaled up with the use of respective service providers, e.g. commercial or communal biochar producers (pyrolysis). The question marks indicate research potentials regarding the effectively recycled amount of nutrients. Since TPS and urine collection represent processes which should have negligible nutrient losses, their flows contain all NPK from faeces and urine. This is different for the output of small-scale composting, for the treatment of grey water with biochar, and for the conversion of green waste (part of bio-waste) to biochar. However, the process with the biggest question mark should be the food production via urban horticulture. How much of the nutrients from the compost, the urine, and the grey water loaded biochar can be converted to feed the inhabitants of cities?

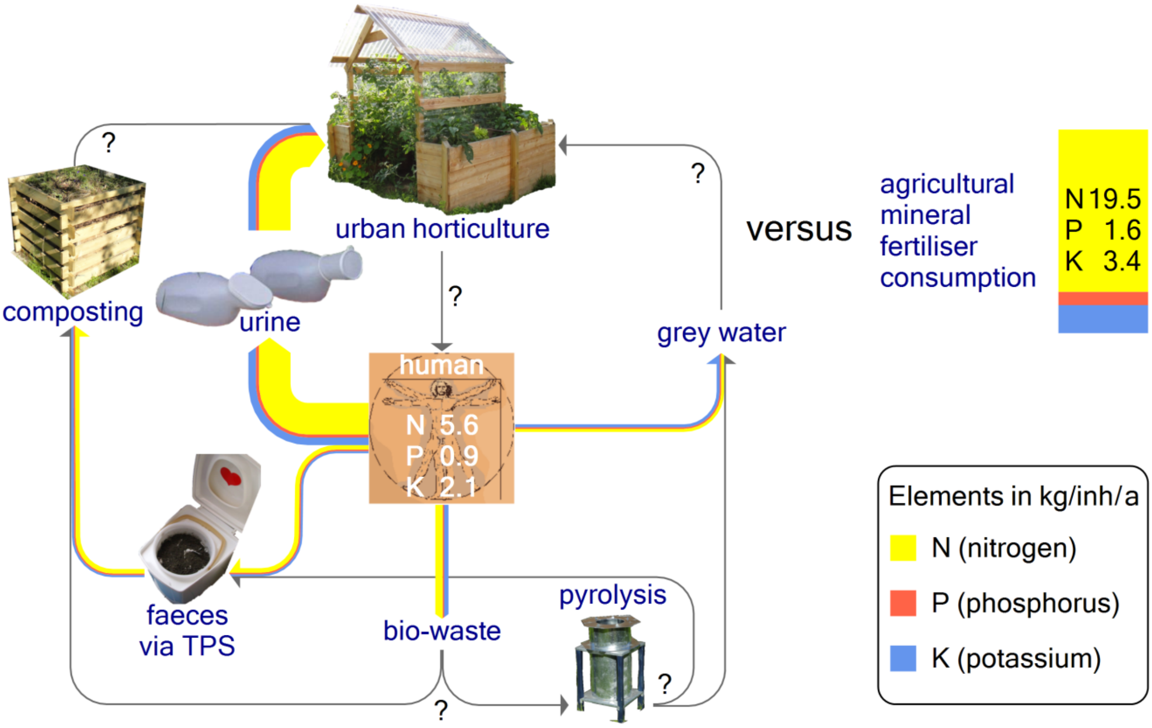

Figure 5: Exemplary local nutrient cycle with indication of various research potentials

Like every individual nutrient flow is different from another, based on gender, size, and dietary habits, so differ the nutrient recycling capacities of cities based on climate, area, and population. When estimating the capacity of urban farming to produce food, then it should be considered that it has several advantages over surrounding agricultural land. First of all, fertiliser is available in abundance at the place where it is needed. Second, there is a constant level of workforce, especially available in form of part time jobs or even in form of recreational activities, e.g. gardening. Third, most cities provide residual energy in form of heat islands or from the heating of buildings. All these advantages could support an intensive horticulture with much higher yields per area compared to the surrounding agriculture.

In 2010 the area of arable land per EU-27 citizen was 2,129 m². The total utilised agricultural area, this includes also pastures, permanent crops and gardens, was 3,533 m²/inh (Eurostat 2012). However, for a sustainable food security, with a diversified diet similar to Western Europe, an area of 5,000 m²/inh should be required. And the absolute minimum of arable land to support one person should still be 700 m², provided that the diet is mainly vegetarian, that there is no land degradation or water shortage and that the land is cultivated by a very skilled farmer (FAO 1993). In contrast, there exist several historical and contemporary examples for food systems which support a person from an area of 400 m² or even less (Jeavons 2006; Smil 2000; Migge 1919). Of course, such food systems are often combined with diets different from the current average. Nonetheless, they illustrate the capacity of intensive horticulture to recycle nutrients very efficiently.

Conclusions

In respect to the mainly unused nutrient potential in urban organic wastes – bio-waste, faeces, urine and grey water - science and legislation should not only focus on using that potential to replace a minor part of the mineral fertilisers used in agriculture. An alternative strategy could be the support of local nutrient cycles within urban farming respectively urban horticulture. There are justified reasons that such an approach could utilise the organic waste potential much more efficiently than agriculture.

Terra Preta Sanitation can play an important role in these local nutrient cycles, since it adds further options for decentralised recycling services. Furthermore, TPS can be used in different scales, which allows flexible and appropriate solutions to various circumstances.

The current agriculture of the European Union is unsustainable in its nutrient flows. In comparison, local nutrient cycles in urban areas have inherent advantages which can make them not only more efficient in food production but also reduce ecological impacts. Therefore, it would be prudent to support such systems not only in economically developing countries, but also in the EU. Provided, that the principles behind these local urban cycles make sense everywhere or nowhere, they should also be researched everywhere equally.

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