Recycling Food System Nutrients in a Circular Economy

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Abstract

Planet Earth already exists for over 5 billion years, while humans have been around for only a million years. The impact of human activity on the natural ecosystem has increased dramatically over the last few hundred years, mainly through agriculture, industry, and urbanisation, resulting in the consumption of natural resources at high rate. Modern agriculture, with the use of fertilizers and agrochemicals, has increased productivity drastically and has loosened the connection between location of food production and location of food consumption. As a result local/regional accumulation of nutrients occurs in terms of waste streams with negative impact on the environment, in combination with regional depletion elsewhere. The circular economy has been generally accepted now by most scientists, policy makers and entrepreneurs, as concept and new paradigm for organizing the food production – consumption cycle. As a consequence any stream of material within that cycle should be considered as an input elsewhere in the cycle. The main question addressed in this paper is ‘how to organize the recycling of food system nutrients effectively and efficiently’? As socio-economic, environmental and cultural conditions differ from one place to the other on the planet there is not one single solution that fits all food systems for organizing a circular economy. Therefore, a mix of several solutions may occur side by side. This diversity will contribute positively to the robustness of the system towards fluctuations due to impacts generated either by nature or by mankind. An important constraints to modifications to food systems is that the modifications and recycling are acceptable by the stakeholders involved. Therefore, initiatives have to be taken to bring together different stakeholders in order to exchange ideas and to explore common grounds for future cooperation. Position papers are written to stimulate partners to move away from their own comfort zone and think about new types of solutions. As the world changes, new techniques become available and new generations prefer to make different choices. What was good in the past might no longer be good enough for the future. Here the first results from this forward-looking and integrated approach are reported.

1. Introduction

Planet Earth already exists for over 5 billion years, while humans have been around for only a few million years. The impact of human activity on the natural ecosystem has increased dramatically over the last few hundred years. As an example, the consumption of fossil energy sources has used up a considerable part of all available fossil fuel resources in less than 100 years. The same tendency is observed for many other natural resources.

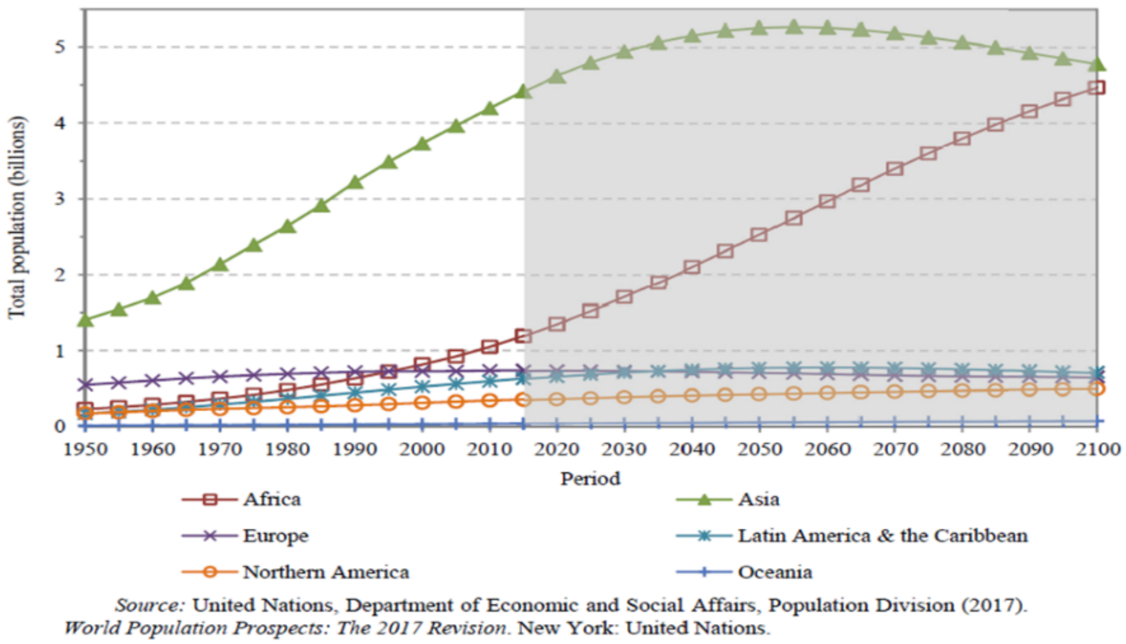

Figure 1. Projected increases in the number of people per continent. Source: United Nations World Population Prospects.

From the early 1970s on people have been worried about this tendency, initiated by a report of the club of Rome (Meadows et al., 1972). Over the years this publication has received a considerable amount of criticism especially on the rather simplified models used to predict future developments. Nevertheless, the awareness among the public for limits to the planet has been increasing. At the beginning of 21th century McDonough and Braungart introduced upcycling way to improve the usability of its constituents by the end of the lifetime of a given product (McDonough and Braungart, 2002). More recently, well accepted models have been published about planetary boundaries which should be respected in order to keep the life on the planet away from major changes and shortages of resources and environmental pollution that might threaten our existence on the long run (Foley et al. 2011, Steffen et al., 2015). For the next decades a steady increase in world population is predicted as shown in figure 1. This increase will result in a population of about 9 billion individuals by 2050. Main increases are foreseen in Asia and Africa.

2. Agro – food production system

Pre-industrial communities have coped with the low input principle for thousands of years. Modern agriculture uses fertilizers and agrochemicals more and more as shown in Figure 2.

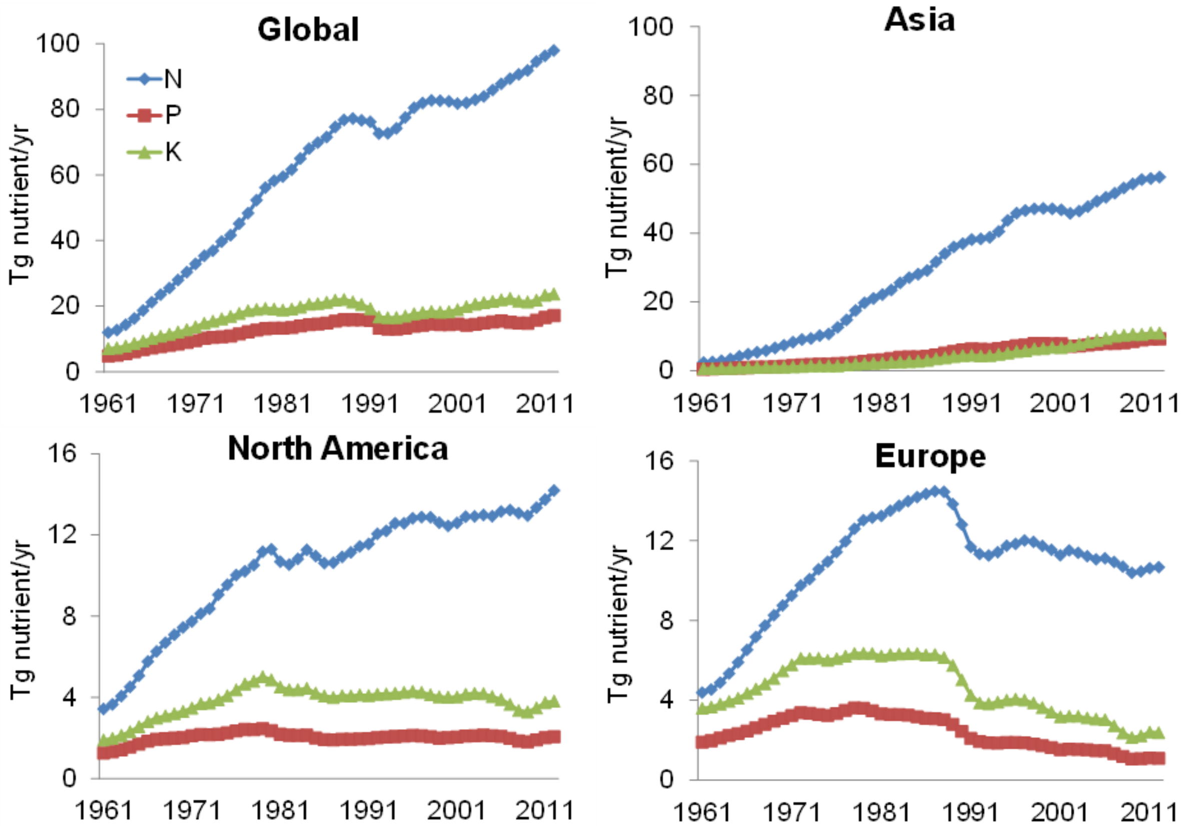

Figure 2. Consumption of synthetic nitrogen (N), phosphorus (P), and potassium (K) fertilizers in the world (upper left panel), Asia, North America and Europe between 1961-2012. Note the differences in Y-axis between the upper two panels and the lower two panels. Data source: FAOSTAT (2015).

About half of the global consumption of fertilizers is situated in Asia. The other half is used in North .America and Europe, with as small additional consumption in Latin America, Oceania and Africa. As a result crop production has increased dramatically in regions with high fertilizer consumption. In addition, and partly as a consequence of the availability of cheap synthetic fertilizers, the connection between the location of food production and the location of food consumption has weakened. The impact of this development is a local/regional accumulation of nutrients in terms of waste streams with negative impact on the environment, in combination with regional depletion elsewhere (Potter et al., 2010). How intensive livestock production will move towards areas where the feed is produced or to regions where the products are consumed is still a topic for many discussions (Poppe et al. 2018).

3. Closing nutrient cycles

The central mission of sustainability is to maintain a liveable planet for the generations to come, and amongst others to keep fulfilling the nutritional needs of the human population. The recycling of all nutrients, maintaining soil quality and fertility and providing clean water on global, regional and local scales are crucial. Making steps on the route towards this situation requires major efforts of all parties involved. Different (economical) interests of the actors generate a complex situation, which requires a new approach to innovate on system level and not only in isolated domains.

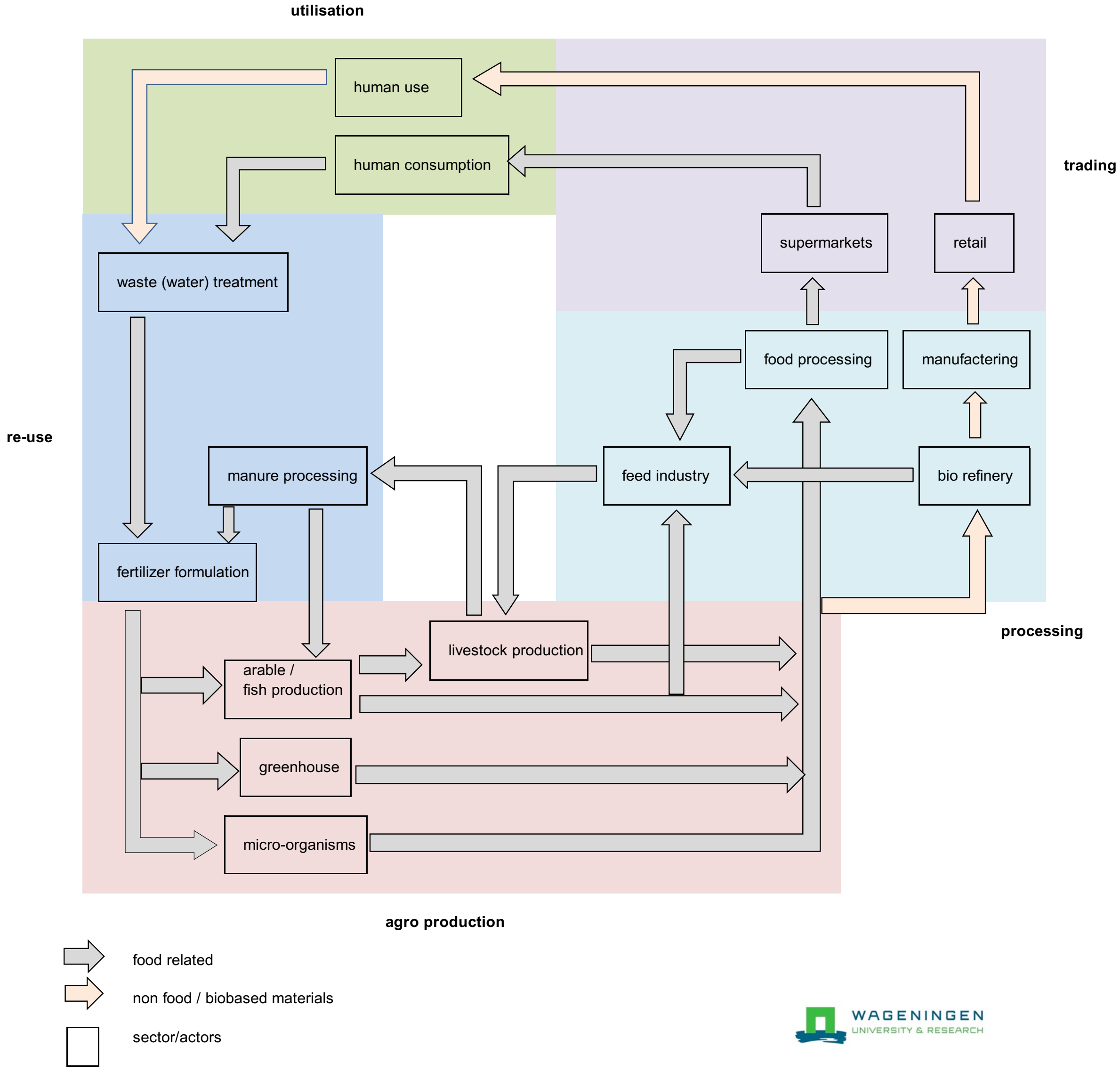

Figure 3. Schematic representation of close nutrient cycles in the Agro-food and Agro-biobased materials production system. Relevant actors and lines of business are shown.

Crucial in the circular economy approach is the awareness that any stream of material considered previously as a waste in the nutrient cycle should be considered as an input for another process in the cycle. In a true circular economy there is no place for the word 'waste'. Organic materials can serve as organic fertilizers and turned into plant nutrients by action of soil micro-organisms. Other side streams, like chemical substances, metals and mineral products can be upcycled to new products or building blocks for new products by the use of clever production processes. Public awareness and political responsible behaviour are currently changing but still have to make additional moves in this aspect. Recent plans to ban single use plastics are promising steps.

As an illustration of how the situation is changing, in The Netherlands 12.000 tons of phosphorus end up in sewage treatment plants originating from household waste water. Slightly over 80 % is recovered into the sewage sludge and incinerated. Ashes are used to stabilize subsoils of high ways rather than being used as a source for plant nutrients Weijma et al, 2018). This implies a loss of nutrients for the agro-food production system and will not be affordable on the long run in terms of a circular system. More recently, both public bodies and private enterprises have been working on the recovery of phosphorous from sewage/sewage sludge. This can be seen as a first step. To recover other valuable plant nutrients from sewage/sewage sludge in an economical way, free from risks for environment, animals and humans is a major challenge. Besides technical issues, social and legal aspects needs to be addressed as well.

As circumstances, socio-economic and cultural aspects differ from one place to the other on the planet there is not one single solution that fits all, which is typical for a wicked problem. Therefore, a mix of several solutions may or should arise side by side to move towards closing the nutrient cycles. This diversity will contribute positively to the robustness of the system towards fluctuations due to impacts generated either by nature or by mankind.

The range of solutions may include among others recycling of nutrients from human waste, re allocating of nutrients back to the location of crop production, and the recovery from scarce nutrients from highly diluted sources. For this a range of actors is required involved in creating solutions. As illustrated in scheme of nutrient cycles, several actors will be involved in every step along the cycle. A solution can only contribute significantly when it is embedded in a system approach, with actors working together, each in its own niche and to its own ability, but sensing a shared responsibility for the whole system.

Wageningen University and Research (WUR) has a worldwide reputation in the field of agricultural research, including studies on nutrients recycling (Henckens et al., 2016; Seyhan et al., 2012). WUR has recognized the need for an integrated systems approach for dealing with nutrients in our agri-food system. Therefore, the taskforce “CirculaResource” with a wide range of expertise has started in 2017. Its ambition is to contribute to sustainable solutions by bringing together actors and stimulate cooperation to develop new knowledge and skills that serve a circular nutrient economy.

Outlook

The taskforce has written a number of position papers (Oenema et al, 2018, Poppe et al, 2018 Weijma et al, 2018) and contributions based on these are presented on both national and international level, either scientific or at stakeholders oriented. This is seen as a first step towards a more practical implementation of the lines of thinking described above. Identifying stakeholders and share their concerns for the future with them is a logical next step which is currently in progress. Round table discussions with stakeholders with different backgrounds are organised. For example fertilizer industry is challenged to take the lead in the debate for future pathways of nutrient management (Oenema et al., 2018) Defining common grounds for future developments and visualizing each contribution to it requires courage of all partners involved as they are challenged to come out of their own comfort zone. Most important for future success is the will to pass a liveable planet to our children and grandchildren.

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